

NEW MODEL FOR AGGLUTINITIC GLASS FORMATION FROM LSCC DATA C. M. Pieters¹ and L. A. Taylor², ¹Dept. Geological Sciences, Brown Univ., Providence, RI 02912 (pieters@mare.geo.brown.edu), ²Planetary Geosciences Institute, Univ. of Tennessee, Knoxville, TN 37996.

Introduction: Since the return of the first lunar samples it has been well known that glass-welded aggregates (agglutinates) accumulate in lunar soil as the result of multiple processes, many of which are driven by micrometeorite impacts. The proportion of agglutinates increases with increasing exposure to the space environment, and for an individual soil the proportion of agglutinates also increases with decreasing particle size [e.g., 1, 2]. Detailed chemical and petrographic analyses of a suite of mare soils and their agglutinate constituents prepared by the Lunar Soil Characterization Consortium [1] appeared to confirm the “Fusion of the Finest Fraction” model for agglutinate formation (or F^3) proposed by Papike et al [3]. However, recent LSCC data for highland soils are *not* consistent with the F^3 model and alternate models for agglutinate formation must be revisited. Instead, we suggest differential melting of soil species may be more consistent with the full range of soil data to date.

Mare soils. LSCC data for mare soils were fully consistent with most paradigms for soil formation. As discussed in [1, 2] and shown in Fig 1, the plagioclase component of soils increases with decreasing particle size and the composition of agglutinitic glass clusters near the smallest size fraction ($<10\mu\text{m}$). It should be noted that agglutinitic glass is heterogeneous [e.g. 4] and standard deviations about the mean are quite large.

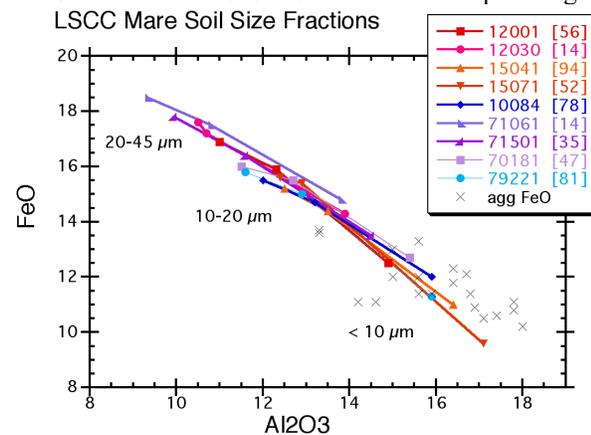


Figure 1. Composition of LSCC mare soils and agglutinates.

The only troubling note concerned TiO_2 in Ti-rich soils. Although ilmenite was present in the finest fraction in proportions consistent with the basalt type, the agglutinitic glass was depleted in TiO_2 by more than a factor of two [5], strongly suggesting ilmenite did not enter the glass in proportion to its abundance.

Highland soils. Similar detailed analyses are near completion for a suite of soils from Apollo 14 and 16. Bulk chemistry has been obtained for all size fractions [6, 2]; preliminary mineralogy and mineral composition is available for a few size fractions [7, 2]. Coordinated spectra have been obtained for initial analysis [8].

As shown in Figs. 2 and 3, the plagioclase component also increases with decreasing particle size for both the Apollo 14 and Apollo 16 soils. This is consistent with the expected differential comminution of plagioclase during soil formation that concentrates plagioclase components in the finer fractions.

The mean composition of the agglutinitic glass, however, is clearly not associated with the finest fraction for these soils. This is most obvious for Apollo 16 where the glasses are more FeO-rich than even the bulk soil. Although the standard deviation of the average agglutinate composition is large, the data are systematic.

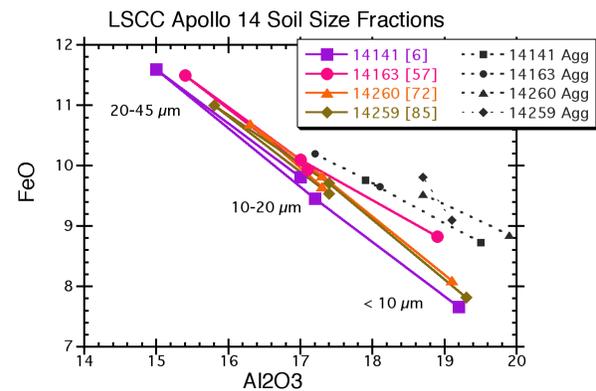


Figure 2. Composition of LSCC soils and agglutinates from Apollo 14.

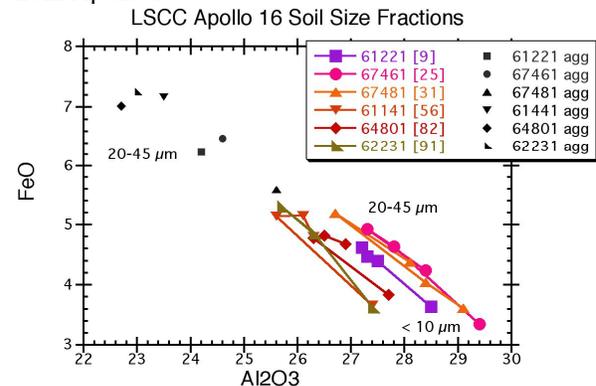


Figure 3. Composition of LSCC soils and agglutinates from Apollo 16.

Discussion. The combined LSCC FeO vs Al_2O_3 data [2] for both mare and highland soil size fractions and agglutinitic glass components are shown in Fig. 4. The well-known trend from mare to highland compositions is evident. The agglutinitic glass appears to form a mixing line between the two. However there are several possible explanations for these observed compositional trends that are linked to origin of the agglutinatic component:

- Fusion of the Finest Fraction (F3).
- Mare – Highland mixing
- Foreign (meteoritic) contamination
- Selective melting of soil species

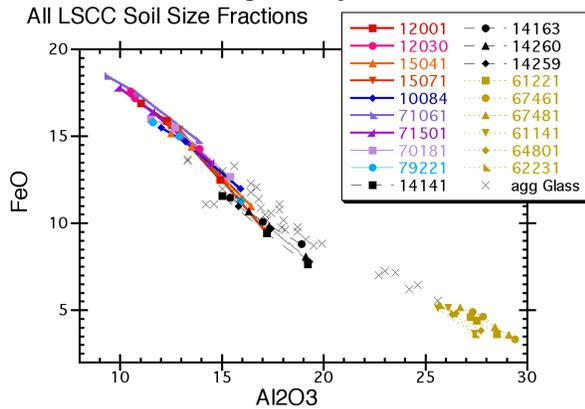


Fig. 4. Composition of all mare and highland LSCC soil size fractions and agglutinates.

Other variations in composition among LSCC soils may provide insight into which of these possibilities dominates in soil formation. Shown in Fig. 5 are compositional trends of 3 mature soils with particle size scaled to the composition of the bulk <45 μm soil. (see [5] for similar plots of all mare soils.

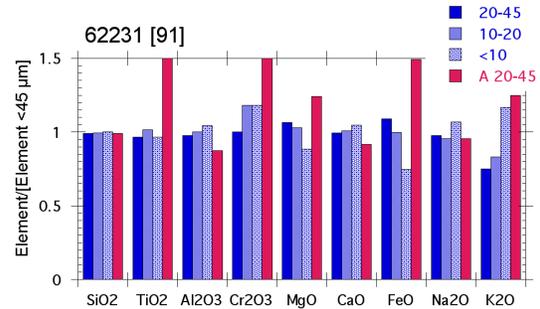
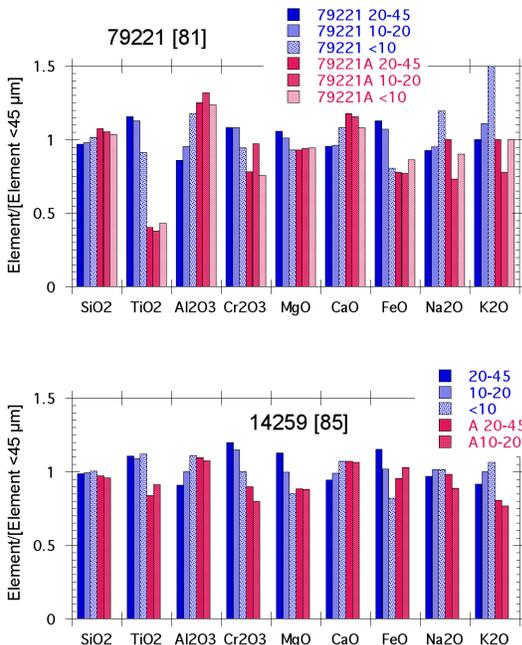


Figure 5. Chemistry of soil size fractions relative to the chemistry of the bulk soil (<45 μm) for three representative mature soils. A: Agglutinitic glass composition.

The data in figures 2, 3, and 5 are not consistent with agglutinatic glass being formed by simple melting of the finest fraction. Although the agglutinate data (e.g. fig 4) appears to form a mixing line between highland and mare compositions, there is no physical mechanism that can perform such mixing of *only the glass component* without influencing the rest of the size fractions in which they reside. Contamination of the glass by foreign material is viable, but there is no common meteorite composition that could produce the observed trends. The depletion of TiO_2 in agglutinatic glass of Ti-rich mare soils strongly suggests differential melting of mineral species during glass formation. On the other hand, the enrichment of TiO_2 and FeO , and to a lesser extent MgO and Cr_2O_3 in agglutinatic glass from Apollo 16 soils suggests at least one mafic mineral enters the melt before plagioclase. Our tentative estimate of the preference for entering the melt during agglutinate formation is orthopyroxene > plagioclase > clinopyroxene >> ilmenite.

Summary and Conclusions. Based on LSCC data for mare soils (Fig. 1), our preferred model [1] for agglutinatic glass formation originally was the F3 model. However, the additional LSCC data for Apollo 14 and Apollo 16 soils force us to reconsider. Although some combination of soil formation processes (a – d) is likely, differential melting of specific mineral species during soil formation (d) appears to be a dominant process most consistent with all the data.

References [1] Taylor et al, *JGR* 105 E11, 27985, 2001. [2]. Taylor et al. LPS34, 2003 these volumes. [3] Papike et al, PLPSC 12th, 409, 1981. F3 ref. [4] Basu A et al., *MaPS* 37 N12, 1835, 2002. [5] Pieters et al. LPS33 #1886, 2002. [6] Taylor et al. LPS33, #1291. [7] Taylor et al. LPS33 #1303, 2002. [8] Shkuratov et al. LPS34 these volumes 2003.

Acknowledgments. Support for this work by NASA grants NAG5-10469 (CMP) and NAG5-11978 (LAT) is gratefully acknowledged.