PRODUCTION OF AGGLUTINATES IN THE LUNAR REGOLITH. A. Basu, Department of Geological Sciences, Indiana University, 1001 East 10th Street, Bloomington, IN 47405 (basu@indiana.edu)

Introduction: Agglutinates, especially agglutinitic glass *per se*, have lately become the focus of several investigations. Taylor et al. [1] have developed an electron microprobe chemical method of not only identifying minerals in polished grain mounts of lunar soils but also to identify different kinds of glass including those that provide the bonding in agglutinates. One important finding is that the proportion of agglutinitic glass increases in finer grain size fractions [2, 3]. There is a growing body of data suggesting that the finer fractions of a lunar soil dominate the reflectance spectrum of the bulk soil [e.g., 3-6]. Keller et al. [7-9] document micro-splashes and micro-patina on grain surfaces of mature lunar soils, and agglutinitic glass containing nanophase Fe$^{0}$ as inclusions. Finally, Papike spoke forcefully at the Workshop on New Views of the Moon II in support of his F$^{3}$ model [10,11] and was supported by L. A. Taylor. The finest fractions of lunar soils and agglutinitic glass are inseparably linked. These new findings, in combination with previous data on agglutinates, agglutinitic glass, and grain size fractions of lunar soils, provide the potential of additional insight into the process of agglutination. A few of them are explored in this abstract.

Size-range of agglutinate production: There is a consensus that agglutinates are products of micrometeorite-impact-melting of lunar soils. However, the size-ranges in which the whole-agglutinate particles or the melts are produced are not known.

Whole-agglutinates, once produced, must be comminuted to smaller sizes; they also increase in size through re-agglutination in the recycling process [12, 13]. With increasing maturity, a steady state of agglutinate size may be reached. Or possibly, there is a slow and subtle decrease in the average grain size of agglutinates in soils undergoing in situ maturation [14], which will reduce the mean grain size over time. In many lunar soils, the abundance of whole-agglutinates peaks between 45µm and 90µm. If comminution is more effective than reagglutination, the mean size of agglutinate production is $>$45µm.

Taylor et al. [1,2] determined the modal proportions of glass and mineral phases in several mare soils using an electron beam spot of 1µm or smaller size. In this method, Taylor et al. were able to determine the actual mineral proportions irrespective of occurrence as a free grain or in a rock (e.g., a basalt). The methodology also determined the proportions of glass and mineral fragments in agglutinates, the latter being a composite particle like basalt [1]. The proportion of agglutinitic glass reported in these papers are "modes or modal percentages, *sensu stricto*" [1], i.e., the glass may occur as a free grain or more commonly as parts of composite grains..

This method is identical to the Gazzi-Dickinson method of modal analysis of sandstones, which renders the results independent of grain size [15, 16]. This means that if the proportion of one or more phases changes in different grain size fractions of the same material, and especially if the change is systematic, then there must be a systematic addition or removal of the phase from appropriate grain size fractions. Thus, the new data indicate that agglutinitic glass *per se* is produced in the <10µm fraction of lunar soils. Preferential melting of the finest fraction is a process that may produce agglutinitic glass also in the finest fraction. Differential comminution is another process that produces differential distribution of phases in grain size fractions.

Our optical and electron microscopic observation of the last 25 years is compatible with this result, i.e., in general we do not see large ($>>10\mu m$) *glassy* areas in most agglutinates. Larger areas seem to be amalgamations of small homogeneous domains [17]. These are essentially areas where re-agglutination of previously existing agglutinates has taken place; i.e., these are products of the recycling process in the lunar regolith.

Composition of agglutinitic glass: Compositions of individual domains of agglutinitic glass vary significantly, commonly from close to that of a plagioclase to that of a pyroxene [17]. Total
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melting of a micro-target likely produced each domain of micro-melt that bonds agglutinates. Yet, the average composition of agglutinatic glass in a soil generally deviates from that of the bulk composition towards that of the finest fraction of the soil [10, 11, 2].

Fusion of the finest fraction (F3) is the simplest explanation. However, that may not be the sole explanation. Agglutinatic glass is strewn with submicron sized inclusions, many of which are vapor deposits [18, 19]. Analytical methods that encompass volumes larger than the inclusions end up analyzing the inclusions as well. Solar wind element (SWE) concentrations in grain size fractions show that SWE occur mostly as coatings on grains except in agglutinates in which, in addition, they become volume correlated because finer particles are incorporated in agglutinates [20, 21]. Although many of the finest particles must melt during agglutination, presumably releasing solar gases that make the vesicles, some survive with their surface-coated SWE inside agglutinatic glass. If nanophase Fe0 is surface concentrated on fine particles [7], then their existence inside agglutinatic glass suggests that such fine particles are either incorporated in the agglutinatic glass or may have melted preferentially leaving the nanophase Fe0 intact.

Several mechanisms may contribute to the melting of the finest fraction. If melting is achieved by the passage of shock waves through solid grains and super-heating, then the melting is likely to be total, and size-independent. The melt produced, however, may assimilate grains caught up in the melt. This assimilation mechanism is size-dependent [10, 11]. Smaller grains allow easier transfer of heat and assimilate completely while only the rinds of larger grains may assimilate in the same melt. However, if the volume of melt produced upon micrometeorite impact is small, which cools rapidly, there may not be sufficient time to preferentially melt only the finest particles. If the micrometeorite impact melt formed is extremely small, and thus by inference formed only from extremely small particles, it is not necessary to invoke preferential assimilation of the finest fraction to explain the compositional characteristics of average agglutinatic glass.

**Conclusion:** Much of agglutinatic glass forms in extremely small quantities melt, in the <10µm range from the finer fractions of lunar soils, and incorporating SWE and vapor-deposit enriched fine grains. Shock melting of micrometeorite impact possibly produces the homogeneous domains of micromelts that may or may not preferentially assimilate the finest fraction.

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**References:**