
The major element chemistry of glassy agglutinates has been of some considerable interest in recent years (1-4). In 1975 it was suggested (1) that agglutinate fractions isolated by magnetic separation techniques are enriched in ferromagnesian elements relative to the bulk lunar soil by a selective partial melting mechanism. A painstaking electron microprobe study by Taylor has lead to the conclusion (4) that no appreciable fractionation of major or minor elements develops during agglutination. Taylor attributes the enrichments observed by others to a bias introduced by the magnetic separation technique.

Our group is currently undertaking a systematic investigation of hydrolysable carbon Cnyd and finely-divided iron (FeOsp) within a variety of soil separates, particularly agglutinates. For the interpretation of the data it is important to recognise any variation in bulk FeO content among the samples studied since the generation, by exposure processes, of both Cnyd and FeOsp is dependent on the abundance of ferrous iron (5). The magnetic separations which we carry out are aimed towards obtaining as pure and uncontaminated samples of agglutinate as possible, rather than complete collection of magnetic or non-magnetic material. A wide variety of agglutinates of different sizes, density and magnetic characteristics have been obtained from soils 15601 and 12023 (refs 6 & 7 give details of sample handling procedures). In the case of 15601, visual inspection and SEM and PTV studies have confirmed the integrity of the particles isolated. The analytical data afforded by these samples support the views of Taylor, although 15601 may be a special case.

Sample aliquots (ca. 1mg) were digested in HF/HNO3 and solutions made up to 40ml with doubly distilled water and adjusted to pH 2. Solutions were passed repeatedly through Reeve-Angel SA-2 cation exchange resin paper. The dried discs were presented to XRF in the same way as pressed pellets. Quantitation was carried out by comparison to standard solutions and international geochemical standards. Inter-element effects were negligible at the concentrations employed since the method may be classed as a thin film technique. Results obtained by XRF for FeO, CaO and MgO by the above method compare favourably with atomic absorption analysis performed directly on solutions. Our data for FeO give good agreement with values obtained by Wänke on selected samples (8) using neutron activation. Results obtained for Luna 24 samples by our method are in agreement with those presented by other analysts. The XRF data for 15601 agglutinates have been confirmed by electron probe analysis of selected grain mounts. Although we have every confidence in our method we are disturbed by the gross differences which can be seen from a comparison of our analyses for sieved fractions with the analysis of bulk 12023 by Morris et al. (9). Our sample 12023,7 which came from the organic environmental container appears to be a comparatively typical Al2 specimen.

Table 1 sets out the data from 12023 and allows comparison of the chemistries of four bulk soil fractions with low density, highly magnetic agglutinates in the same size range. Agglutinates having different densities and different amounts of metallic iron in the constant size range, 106-150µm, may also be compared to bulk unseparated material having the same particle size. There is
CHEMISTRY OF AGGLUTINATES

Woodcock M.R. and Pillinger C.T.

no systematic increase of Fe, Mg and Ti in the agglutinates compared to the bulk material. Thus, within the limits of the experimental data for the samples studied there is no apparent fractionation accompanying agglutination. At the present time, however, we cannot assume that solar wind reduction processes do not cause major element enrichments which associate with agglutinates (9). In order to establish whether such a process is taking place we would need to compare the chemistry of the agglutinates with the chemistry of the precursor material before any agglutination had taken place. At present this is not feasible.

Major element chemical data for 15601 bulk size fractions and two agglutinate populations (material $\rho < 2.96 \text{g/cm}^3$ moving 2mm to a magnet (LA) and material $\rho = 2.96-3.3 \text{g/cm}^3$ but with the same magnetic properties (HA)) are given in Table 2. Our preliminary data (6) and analyses by the Wänke group (8) for the LA samples have been reported earlier. Quite clearly the agglutinates from 15601 are depleted in Fe, Mg and Ti relative to the bulk sieved fraction. For the light agglutinates, the feldspathic elements Ca, Al, are enriched in the fine fractions compared to the coarse. A mixing model with bulk 15601, anorthosite and KREEP end members has been proposed (8) to explain this trend. Fine-grained agglutinates must be made up of even finer material therefore, it is perhaps not surprising to find an increase of exotic material within such samples. Fine agglutinates isolated from the 2.96-3.3 density fraction do not show the increased feldspathic contribution observed for the less dense fraction.

When only two samples have been studied it is difficult to decide if one is atypical. However, since none of the studies performed previously to compare
the chemistry of agglutinates with that of the samples from which these particles were isolated have recognised such large differences, 15601 is probably a special case. The soil 15601 is generally considered to be sub-mature, but if it were in fact a mixture of immature fresh material having a high FeO and MgO content and a component of mature soil lower in ferromagnesian elements both its exposure history and chemical characteristics could be satisfied. It seems likely to us that the recycling processes of comminution and agglutination should homogenise soils and hence the bulk samples and agglutinates would have a similar composition at maturity. Soil 15601 has not reached this stage. Immature and sub-mature samples could have some agglutinates which are either enriched or depleted in ferromagnesian elements depending on the source of input. Other soils and further 12023 samples, particularly fine-grained materials, are under investigation.