ION MICROPROBE STUDY OF GLASS PARTICLES FROM LUNAR SAMPLE 15101.

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Walker et al. (1,2) were the first to observe that statistically preferred compositions of aluminous glass particles from lunar soils correspond closely to points and curves of multiple crystal saturation in the experimental system silica-anorthite-olivine (Fe/Fe+Mg=3). A popular interpretation has been that these glass clusters represent parental rocks that were produced by equilibrium igneous processes at low pressure (1-8). It is important to collect additional data to test this interpretation and, if possible, to establish the chemical trends of these lunar "rock types".

In this study we have used an ARL-ion microprobe (IMP) to analyze for Li, Be, B, F, Y, Zr, Ba, La and Ce in 37 relatively homogeneous glass particles (100-200 μm) from lunar sample 15101. The data were collected as mass spectra (6-150 amu) using repeatable magnet sweeping (50-100 cycles, 41 sec each) and integration in a multichannel analyzer. For Li, Ba, La and Ce, peak heights (relative to silicon) were compared with those collected on a glass standard (12033,97,1A) previously analyzed by isotope dilution (9). For Be, B, F, Y and Zr, relative sensitivities collected on other silicate materials were used to reduce data. Figure 1 compares the relative sensitivities of many elements in a wide variety of silicate matrices under constant experimental conditions. The level of detectability (Table I) of the IMP technique is determined by the relative sensitivity, the relative abundance of the isotope used and, at low mass resolution, by molecular ion interferences from the matrix elements. In this study the important interferences were H3O+ for F, Si2O5+ for Y and Zr, CaSiO3+ for Ba, La and Ce. We have found that only those elements reported in this study generally have abundances high enough to be measured by low mass resolution IMP analysis of lunar glass. Prinz et al. (10) have previously reported analyses of 6 aluminous glasses from 15353.

Each glass particle was also analyzed by an automated MAC electron probe for Si, Ti, Al, Cr, Fe, Mn, Mg, Na, K and P. Particles of green glass (6) in the same sample provided a useful secondary standard. The major element analyses were used to group the particles (Table I) and these groupings were found to be roughly similar to some of the "preferred" compositions of Reid et al.(6).

Table I gives the averages of the trace-element analyses for each group. In general, the ratios of the trace-elements with respect to Ba are within the range measured by other techniques on larger samples. All of the trace-elements measured increase with increasing Ba. In the case of Group 8 (green glass) the analyses for Ba, La, Ce and Y approach the levels of molecular ion interferences. However, the concentrations of the trace elements in the other particles were sufficiently high to ignore these interferences.

Figure 2 gives the analyses of Ba for individual fragments as a function of Al2O3. The highest Ba (and other trace elements) occur at intermediate alumina concentrations (Al2O3=14-19%). Note that there are also numerous fragments with low or intermediate Ba values in the same alumina range. This verifies the observation of Reid et al. (6), using K vs Al2O3, that there are separate groups of glasses at this range of composition.

When the individual analyses of aluminous glass particles are plotted on the Walker diagram (figure 3) they generally lie near the cotectic. The concentrations of Ce and B for these particles are plotted vs the "SiO2".
parameter of the Walker diagram (figure 4). There is a general increase in all these trace-elements with increasing SiO₂. No systematic difference for the data from homogeneous vs inhomogeneous glass could be found.

The bulk composition of 15101 is similar to that of Group 3 (Table I) and also plots near the cotectic on the Walker diagram (figure 3). However, this rather mature soil is petrographically and chemically observed to be a mixture of a wide variety of rock types. At least some of the glass in this soil has been made by melting of the soil itself. However, Group 3 is represented by both homogeneous and inhomogeneous glasses and the trace element data do not distinguish particles of such glass from those that may belong to a true "rock type" with this composition. Since no fragments with igneous texture and this composition have been reported, the existence of a "primary rock type" with this composition is uncertain and problematical.

The average composition of Group 4 corresponds to the composition of the peritectic liquid (point B) on the Walker diagram and is similar to what has previously been called KREEP, Fra Mauro and alkaline high-alumina basalts. However, it is again possible that one or more particles in the group are contaminated by mixing with another rock type which would alter the chemical composition of the average.

Group 5 consists of only 2 particles (out of 37). These are extremely enriched in the trace-elements measured in this study and also have the highest silica contents and Fe/Fe+Mg ratios. Previous studies have reported similar glass fragments which also plot rather close to the plagioclase-pyroxene cotectic from points B to C. Such materials could have been formed by separation of pyroxene and plagioclase from a magma of KREEP composition (Group 4, liquid B) (2). Alternatively, such material could have formed partial remelting of Group 4 or even Group 3 materials (11). Several fragments of igneous textured KREEP basalt (such as 15382 and 15386) also lie on this cotectic, but these fragments are distinguished by higher Cr contents than these glasses. No soils are known to have the
The trace element compositions of the aluminous particles (Groups 1 and 2) are rather high compared to what is known about anorthositic materials. It is possible that the trace-element contents of each of these particles has been altered by admixture with Group 3, 4 or 5 materials. One way to test this will be to compare the trace-element compositions of these particles with those of aluminous particles from other landing sites which have a smaller proportion of trace-element rich material. Future IMP analyses for H or Ni may allow particles derived from the regolith to be distinguished from those derived from bedrock.

Finally, we have also analyzed 3 red-brown glasses from 10084 (Table I). These particles form a tight compositional cluster (12) and have other similarities to the Apollo 17 orange and Apollo 15 green glasses that were apparently formed by lava fountaining. One of these similarities is that they all have high B/Ba ratios.