PETROLOGY OF APOLLO 11 REGOLITH BRECCIAS; S.B. Simon and J.J. Papike, Institute for the Study of Mineral Deposits, South Dakota School of Mines and Technology, Rapid City, South Dakota 57701-3995

The value of lunar regolith breccias as sources of exotic lithic clasts and as analogs to meteoritic regolith breccias (howardites) has only recently generated interest (e.g. 1,2). A better understanding of the formation of regolith breccias and how accurately they reflect the petrology of the source material will not only increase our knowledge of the ancient lunar regolith but will also help in the interpretation of howardites as regolith from the howardite parent body.

This paper presents new data for sixteen Apollo 11 regolith breccias and discusses the petrology of the breccias. The breccias under study were subdivided into matrix (<20 μm), small clasts (200-20 μm), and large clasts (2000-200 μm). The breccias average 51.2 vol.% matrix, 29.7% small clasts, and 19.1% large clasts. Based on modal data for soils collected in a similar manner, the breccias are similar to immature through submature lunar soil (3,4,5,6,7,8). Mature soils tend to have fewer large clasts than the breccias, and ~60% or more matrix (6, 9). The modal data for the >20 μm size fraction are summarized in Fig. 1, in order of decreasing agglutinate abundances. Based on the fused soil (agglutinate + regolith breccia clasts) components, most of the breccias represent immature soils. For example, the coarse unit in the Apollo 17 deep drill core is immature (10) and it averages ~33% fused soil in the >20 μm fraction (6). As Fig. 1 shows, eleven of the sixteen breccias we studied have fused soil components (FSC's) of ~33% or less, which is much lower than that of A-11 soil 10084 (11, 12). Relatively low FSC's have also been reported for howardites (13, 14). Experimental work and/or detailed petrographic studies may be required to determine whether the low FSC's in lunar regolith breccias and in howardites reflect formation from immature soil, or, if the brecciation process and subsequent annealing history destroys agglutinates. A comparison of the petrology of the >20 μm FSC-free component of the breccias with that of soil 10084 is equivalent to a comparison between ancient regolith and the present day soil.

One feature to focus on is the highland component. We have identified highland fragments petrographically (see companion abstract, this volume) and highland mineral fragments compositionally, with the electron microprobe. Table 1 shows the minimum percentages of highland material in the lithic, pyroxene, olivine, plagioclase, and glass petrologic categories. These percentages, when combined with the normalized modal data, give the total minimum highland components in the matrix- and FSC-free portions of the soil and breccias. Table 1 shows that for the size fractions under consideration the average highland component in the breccias is similar to that of 10084, in agreement with the findings of Dorman et al. (15) which indicate that little or no highland material has been added to the regolith since the formation of the breccias. The petrologically estimated minimum highland components are a factor of 2 lower than those indicated by chemical mixing models for the bulk breccias (16, 17) and soil (18). Some of this disparity is a result of the fact that only a "minimum" highland component estimate can be made from mineral clast data because of compositional overlap of mare and highland minerals. However, up to about one half of the highland component in the soil and regolith breccias must reside in the fused soil (as both clasts and feldspathic agglomeritic glass) and in the fine (<20 μm) material.

Table 1. Highland Components in Matrix- Free A-11 Regolith Breccias and Soil 10084 (1000-90 µm)

<table>
<thead>
<tr>
<th></th>
<th>% Highland</th>
<th>Normalized Modal Abundance</th>
<th>Minimum Highland Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithics</td>
<td>(0)</td>
<td>5.1</td>
<td>53.0</td>
</tr>
<tr>
<td>Pyroxene</td>
<td>(5)</td>
<td>-2.0</td>
<td>16.8</td>
</tr>
<tr>
<td>Olivine</td>
<td>(7)</td>
<td>20.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>(8)</td>
<td>29.3</td>
<td>8.1</td>
</tr>
<tr>
<td>Glass</td>
<td>(8)</td>
<td>34.5</td>
<td>14.0</td>
</tr>
</tbody>
</table>

*Soil modal data from Simon et al. (12). Soil highland pyroxene, olivine, and plagioclase contents and olivine/pyroxene ratio from Labotka et al. (11). Modal abundances do not total 100% due to other components not included in the calculation (ilmenite, devitrified glass, others).

**(B) indicates breccia and (S) soil data.

Fig. 1 Matrix-free modal petrology of Apollo 11 regolith breccias, in order of decreasing agglutinate contents.