LITHOLOGIES CONTRIBUTING TO THE CLAST POPULATION IN APOLLO 17 LKFM BASALTIC IMPACT MELTS. Marc D. Norman, G. Jeffrey Taylor, Paul Spudis, and Graham Ryder.

LKFM basaltic impact melts are abundant among Apollo lunar samples, especially those from Apollo 15, 16, and 17. They are generally basaltic in composition, but are found exclusively as impact melts. These breccias either, with some olivine and pyroxene grains from the lunar highlands. In addition, none of the mineral clasts could be unambiguously assigned to a ferroan anorthosite source. We have now extended this study to Apollo 17, starting with two LKFM impact melt breccias (76295 and 76315) from the Apollo 17 station 6 boulder. The results show that mineral clasts in these rocks are dominated by Mg-suite sources, but that once again.

Minor-element abundances in both olivine and pyroxene (Figs. 2 and 3) are unlike those found in rocks of the ferroan anorthosite suite (FAS) suggesting at most a small contribution from FAS rocks. Ferroan noritic anorthosites such as those found in 67215 and 67016 [9,10] are especially ruled out; any ferroan anorthosite component in the clast population must have been nearly pure anorthosite contrib-

![Histograms of plagioclase, olivine, and low-Ca pyroxene clast compositions in 76295 and 76315.](https://ntrs.nasa.gov/search.jsp?R=19930009617)
Fig. 2. Minor-element abundances in pyroxene clasts from 76295 and 76315 compared to fields representing compositions observed in pristine highland rocks (data from [13,11]). F = ferroan anorthosite suite, T = Mg-suite troctolites, N = Mg-suite norites, G = gabbro norites, AA = alkali anorthosites.

Fig. 3. Minor-element abundances in olivine clasts from 76295 and 76315 compared to fields representing compositions observed in pristine highland rocks. Source of pristine rock data and abbreviations same as Fig. 2 except that TD = troctolites and dunite.

utsing only plagioclase. Low-Ca pyroxenes in both 76295 and 76315 have an affinity with Mg-suite norites or gabbro norites, whereas several of the high-Ca pyroxene clasts have minor-element compositions outside the known ranges for pristine highland rocks. The abundance of high-Ca pyroxene clasts, together with their unusual compositions, suggests the presence of poorly sampled gabbroic lithologies in the target stratigraphy of these Apollo 17 LKFM impact melts. That gabbroic rock types may be more abundant in the lunar highlands than is apparent in the sample collection has been suggested by remote sensing studies [8]. Many of the olivine clasts have Cr and Ti contents considerably higher than those observed in pristine highland rocks, including 67667, which has an average olivine composition with 0.049% TiO₂ and 0.13% Cr₂O₃.

Plagioclase compositions are ambiguous with regard to distinguishing their source lithologies, but considering that mafic phases tend to be dissolved preferentially when incorporated into superheated impact melts, the relatively high abundance of olivine and pyroxene suggests that the clast assemblage is dominated by Mg-suite rocks. The abundance of high-Ca pyroxene combined with the relatively Fe-rich olivine and pyroxene compositions and sodic plagioclase suggest the presence of one or more evolved olivine gabbro norite components with overall characteristics generally similar to lherzolite 67667, but with distinct minor-element abundances in the mafic phases. Although some minor-element abundances are outside the ranges measured for minerals in identified pristine rocks, none have compositions suitable for the cryptic component rich in transition metals.

The clast populations in the two Apollo 17 LKFM melt rocks studied so far are dominated by Mg-suite norites, troctolites, and gabbro norites. Rock 76295 appears to contain a greater proportion of the norite or gabbro norite component whereas mineral clasts in 76315 were derived predominantly from troctolites. Differences in the proportions of clast types is not unusual for impact melt breccias from the same crater [12]. A dearth of ferroan anorthosite was also found in Apollo 15 LKFM breccias [6] and suggests either (1) it was never present in the basin target, (2) the FAS crust was removed before the
Serenitatis Basin impact event either by impact erosion or by assimilation during intense magmatic activity, or (3) impact dynamics during basin formation prevented upper crustal rocks from being included in the excavated impact melt.


**IMPACT GLASSES FROM THE <20-µM FRACTION OF APOLLO 17 SOILS 72501 AND 78221.** John A. Norris1, Lindsay P. Keller2, and David S. McKay3,1Department of Geology, University of Georgia, Athens GA 30602, USA,2Code SN, NASA Johnson Space Center, Houston TX 77058, USA.

Introduction: The chemical compositions of microscopic glasses produced during meteoroid impacts on the lunar surface provide information regarding the various fractionation processes that accompany these events. To learn more about these fractionation processes, we studied the compositions of submicrometer glass spheres from two Apollo 17 sampling sites using electron microscopy. The majority of the analyzed glasses show evidence for varying degrees of impact-induced chemical fractionation. Among these are HASP glasses (high-Al, Si-poor), which are believed to represent the refractory residuum left after the loss of volatile elements (e.g., Si, Fe, Na) from the precursor material [1-3]. In addition to HASP-type glasses, we also observed a group of VRAp glasses (volatile-rich, Al-poor) that represent condensates of vaporized volatile constituents, and are complementary to the HASP compositions [3]. High-Ti glasses were also found during the course of this study, and are documented here for the first time.

**TABLE 1. Average EDX analyses for subgroups of impact glasses in soils 72501 and 78221.**

<table>
<thead>
<tr>
<th></th>
<th>1a</th>
<th>1b</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al2O3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiO2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FeO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* High-Si glasses contain <2 wt.% each of Na2O, K2O, SO3, P2O5, MnO, and Cr2O3.

1a = group 1 HASP; 1b = group 1, high-Ti; 2 = group 2 HASP; 3 = group 3 HASP; 4 = basaltic glasses, and 5 = high-Si glasses.

Experimental: Samples from the <20-µm size fractions of two Apollo 17 soil samples (72501 from station 2 at the base of the South Massif, and 78221 from station 8 at the base of the Sculptured Hills) were embedded in low viscosity epoxy and cut into thin sections (~80–100 nm thick) using diamond-knife ultramicrotomy. The thin sections were analyzed using a PGT energy-dispersive X-ray (EDX) spectrometer with a JEOL 100CX TEM. EDX analyses were obtained for 107 spheres from 72501 and 115 from 78221. The apparent diameters of these spheres in thin section were typically between 100 and 400 nm, although the true diameter of any actual sphere may have been slightly larger. The relative errors associated with the EDX analyses were estimated by analyzing a grossular standard. The relative errors for Al, Si, Ca, and Fe are ~5%. These relative errors increase significantly for concentrations <5 wt%.

The glass compositions were initially divided into a "high-Si" group (SiO2 > 60 wt%) or a "low-Si" group (SiO2 < 60 wt%). For the "low-Si" compositions a standard CIPW norm was calculated. However, many of these glasses (e.g., HASP) contain insufficient Si to be used with this method. For these Si-poor compositions, a new normalization scheme was developed using three groups of progressively Si-deficient normative minerals. Group 1 HASP compositions contain insufficient Si to calculate any normative r- white (AN). Instead, the group 1 normative mineralogy includes gehu-nite (GH) + spinel (SP) + Ca aluminates. Group 2 HASP compositions consist of normative GH + AN + SP + olivine + Ca aluminates. The group 3

![Fig. 1. Compositions of submicrometer glasses in soil 72501.](image)

![Fig. 2. Compositions of submicrometer glasses in soil 78221.](image)