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**LITHOLOGIES CONTRIBUTING TO THE CLAST POPULATION IN APOLLO 17 LKFM BASALTIC IMPACT MELTS.** Marc D. Norman<sup>1</sup>, G. Jeffrey Taylor<sup>1</sup>, Paul Spudis<sup>2</sup>, and Graham Ryder<sup>2</sup>, <sup>1</sup>Planetary Geosciences, Department of Geology and Geophysics, University of Hawaii, Honolulu HI 96822, USA, <sup>2</sup>Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058, USA.

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 [1]. They seem to be related to basins and so could represent the composition of the lower lunar crust [2-4]. They contain lithic clasts that cannot be mixed in any proportion to produce the composition of the melt matrix; components rich in transition elements (Ti, Cr, Sc) and REE are not accounted for [5]. To search for the mysterious cryptic component, we previously investigated the mineral clast population in two Apollo 14 LKFM basaltic impact melts, 15445 and 15455 [6]. The cryptic component was not present in the mineral clast assemblage of these breccias either, but some olivine and pyroxene grains appeared to be from lithologies not represented among identified igneous rocks 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

lithologies not recognized as pristine rocks are represented in the mineral clasts. The compositions and relative abundances of mineral clasts suggest a significant contribution from olivine gabbronorites similar to lherzolite 67667. Little, if any, ferroan anorthosite was detected. The cryptic component remains enigmatic.

Rocks 76295 and 76315 are fine-grained impact melt breccias that display little reaction between clasts and the melt matrices [7]. We analyzed virtually all olivine, pyroxene, and plagioclase clasts larger than 50  $\mu\text{m}$  in one thin section of each rock. Data were obtained with a new Cameca SX50 electron microprobe using procedures designed to obtain precise analyses for minor elements. The two rocks differ in the relative abundances of pyroxene to olivine, mafics to plagioclase, and mineral compositions (Fig. 1); these results are generally consistent with published data [7]. For both rocks, plagioclase ranges from An72 to An97 with a mode around An94-96 and a tail to sodic values (Fig. 1). Plagioclase  $\geq$ An95 is abundant in 76315 and comparatively uncommon in 76295. Olivine and pyroxene clasts have diverse compositions (Figs. 1-3). 76295 contains less magnesian olivine than does 76315, and the olivine/pyroxene ratio is 0.85 in 76295 compared to 5.2 in 76315. In both samples, the ratio of high-Ca pyroxene to low-Ca pyroxene is surprisingly high, about 0.5.

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-

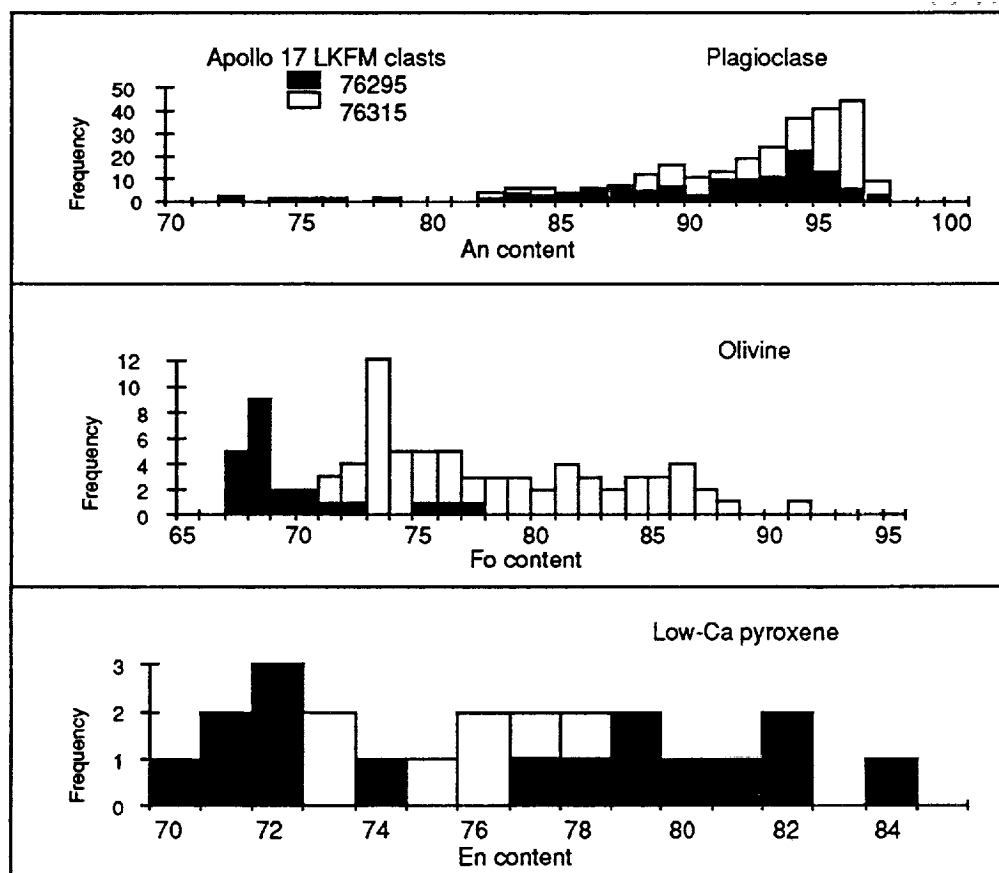


Fig. 1. Histograms of plagioclase, olivine, and low-Ca pyroxene clast compositions in 76295 and 76315.

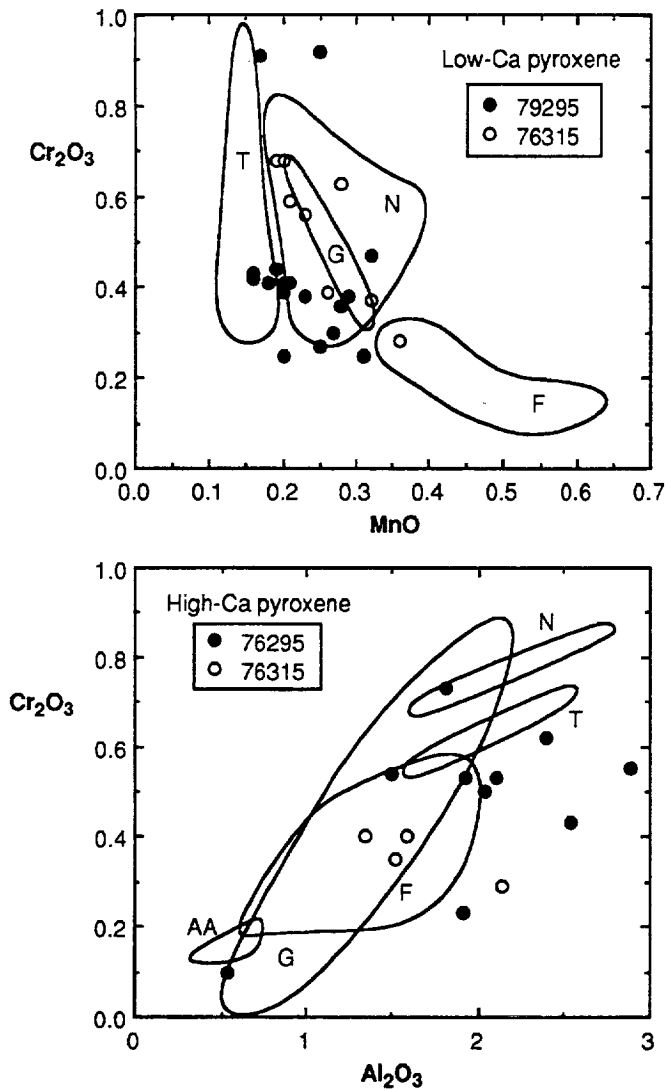


Fig. 2. Minor-element abundances in pyroxene clasts from 76295 and 76315 compared to fields representing compositions observed in pristine highland rocks (data from [13,11]). F = ferroan anorthosite suite, T = Mg-suite troctolites, N = Mg-suite norites, G = gabbronorites, AA = alkali anorthosites.

using only plagioclase. Low-Ca pyroxenes in both 76295 and 76315 have an affinity with Mg-suite norites or gabbronorites, 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%  $\text{TiO}_2$  and 0.13%  $\text{Cr}_2\text{O}_3$ .

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

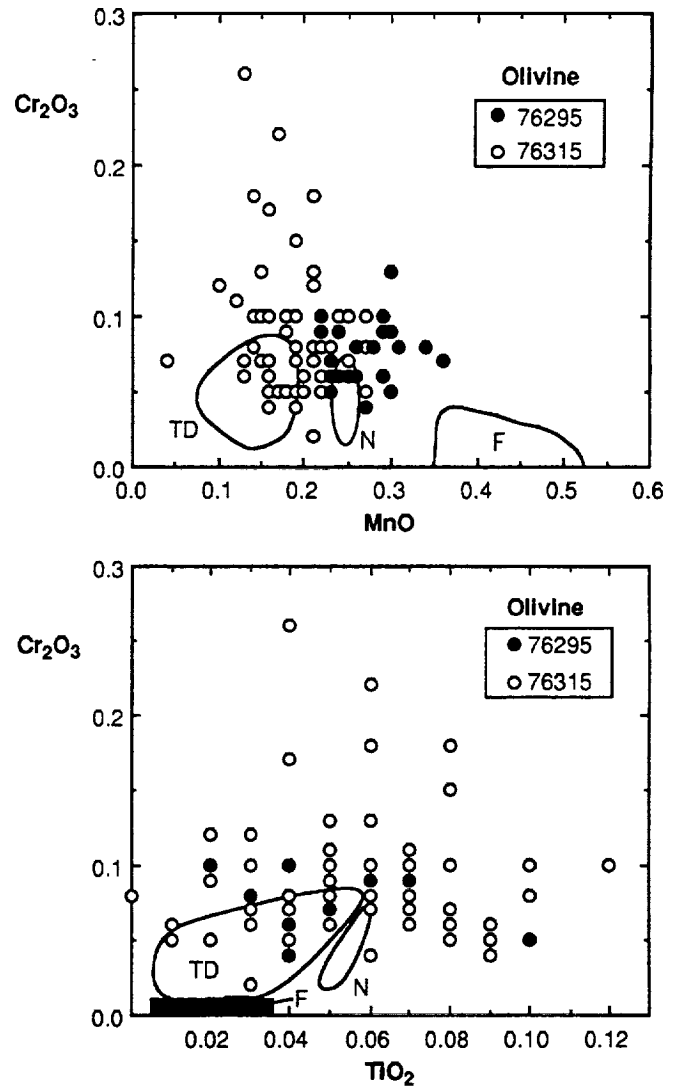


Fig. 3. Minor-element abundances in olivine clasts from 76295 and 76315 compared to fields representing compositions observed in pristine highland rocks. Source of pristine rock data and abbreviations same as Fig. 2 except that TD = troctolites and dunite.

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 gabbronorite components with overall characteristics generally similar to ilherzolite 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 gabbronorites. Rock 76295 appears to contain a greater proportion of the norite or gabbronorite 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.

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**IMPACT GLASSES FROM THE <20- $\mu$ m FRACTION OF APOLLO 17 SOILS 72501 AND 78221.** John A. Norris<sup>1</sup>, Lindsay P. Keller<sup>2</sup>, and David S. McKay<sup>2</sup>, <sup>1</sup>Department of Geology, University of Georgia, Athens GA 30602, USA, <sup>2</sup>Code 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.

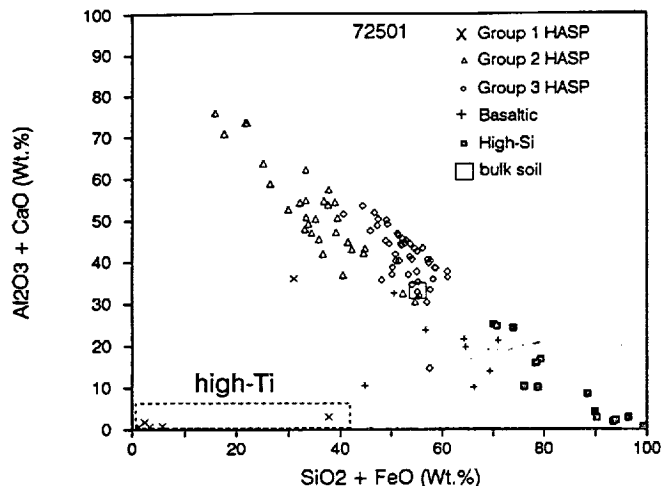


Fig. 1. Compositions of submicrometer glasses in soil 72501.

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

	1a	1b	2	3	4	5*
MgO	7.0	4.0	9.0	6.0	14.0	3.1
Al <sub>2</sub> O <sub>3</sub>	53.0	4.0	34.0	27.0	14.0	5.2
SiO <sub>2</sub>	10.0	7.5	30.0	49.0	46.0	65.0
CaO	23.0	1.5	18.0	11.0	9.0	2.1
TiO <sub>2</sub>	3.3	64.0	3.0	1.0	3.0	0.6
FeO	3.7	19.0	6.0	6.0	14.0	20.0

\* High-Si glasses contain <2 wt.% each of Na<sub>2</sub>O, K<sub>2</sub>O, SO<sub>3</sub>, P<sub>2</sub>O<sub>5</sub>, MnO, and Cr<sub>2</sub>O<sub>3</sub>.

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- $\mu$ m 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 (SiO<sub>2</sub> > 60 wt%) or a "low-Si" group (SiO<sub>2</sub> < 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 anorthite (AN). Instead, the group 1 normative mineralogy includes gehlenite (GH) + spinel (SP) + Ca aluminates. Group 2 HASP compositions consist of normative GH + AN + SP + olivine + Ca aluminates. The group 3

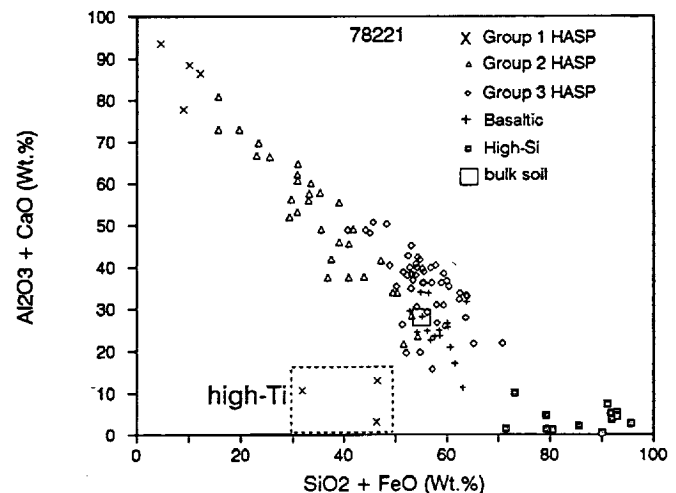


Fig. 2. Compositions of submicrometer glasses in soil 78221.