HETEROGENEITY IN SMALL ALIQUOTS OF APOLLO 15 OLIVINE NORMATIVE BASALT: IMPLICATIONS FOR BRECCIA CLAST STUDIES.

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Most of the recent advances in lunar petrology are the direct result of breccia pull-apart studies, which have identified a wide array of new highland and mare basalt rock types that occur only as clasts within the breccias. These rocks show that the lunar crust is far more complex than suspected previously, and that processes such as magma mixing and wall-rock assimilation were important in its petrogenesis. These studies are based on the implicit assumption that the breccia clasts, which range in size from a few mm to several cm across, are representative of the parent rock from which they were derived. In many cases, the aliquot allocated for analysis may be only a few grain diameters across. While this problem is most acute for coarse-grained highland rocks, it can also cause considerable uncertainty in the analysis of mare basalt clasts. Similar problems arise with small aliquots of individual hand samples (e.g., Ryder and Steele, 1987).

We report here on our study of sample heterogeneity in 9 samples of Apollo 15 olivine normative basalt (ONB) which exhibit a range in average grain size from coarse to fine (15536, 15537, 15538, 15546, 15547, 15548, 15598, 15605, and 15636). Seven of these samples have not been analyzed previously, one has been analyzed by INAA only (15605; Ma et al, 1978), and one has been analyzed by XRF+INAA (15636; Compston et al, 1972; Fruchter et al, 1972). Our goal is to assess the effects of small aliquot size on the bulk chemistry of large mare basalt samples, and to extend this assessment to analyses of small breccia clasts.

METHODS: Five samples were received as 2 aliquots of 150 mg each taken from different parts of the parent sample; the other four were received as single 200 mg fragments, each of which were split into two 100 mg aliquots before crushing. Each aliquot was powdered in an agate mortar and divided into two splits: 70-100 mg for INAA (selected major and trace elements) and 30-50 mg for fused bead EMP analysis (major elements). All samples were studied petrographically in thin section, and phase compositions were determined by EMP analysis.

RESULTS : All of the samples are low-SiO2 ONBs typical of the Apollo 15 site; seven are olivine microgabbros, the other two are medium to fine-grained olivine-phyric basalts. Olivine (Fo65 to Fo30) is the primary liquidus phase and occurs as subhedral to rounded grains which may be jacketed by pyroxene. Plagioclase most commonly occurs as large, poikolitic laths that enclose both pyroxene and olivine. Several samples contain mafic-rich clots up to several mm across which have little or no feldspar. Late phases include fayalite, ilmenite, spinel, cristobalite, whitlockite, and K,Si-rich glass. The late phases are commonly associated spatially, and in the coarser-grained samples (15547, 15636) they are concentrated in the mafic-rich clots. All of the phases are relatively Fe-rich relative to the A-15 QNB suite; phase compositions are shown in figure 1.

Major element analyses of aliquots from the same sample generally agree within analytical uncertainty, except for samples 15547 and 15636. These samples are higher in Fe, Ti, P2O5, and La than the other samples, and correspoding aliquots exhibit large differences in composition (figure 2). These differences are shown in figure 3 as the function delta/sigma, where delta equals the deviation of the samples from their mean and sigma is the average analytical uncertainty (one sigma). Total analytical uncertainty (at the two sigma level) is shown by the dashed line. Three samples (15536, 15537, and 15605) shown no variation at the 2 sigma level, and four samples (15538, 15546, 15548, 15598) show minor differences between aliquots (one or two elements vary at the 3 sigma level). There is no consistent relationship to grain size -- fine and coarse-grained samples are present in each group. The largest variations are shown by 15547 and 15636, in which aliquots differ by up to 14 sigma from the mean (figure 3). Short count trace element data exhibit more scatter than do the major elements, and differences between aliquots can be substantial, even when major element differences are small. These differences cannot be quantified, however, until more reliable long count data become available.

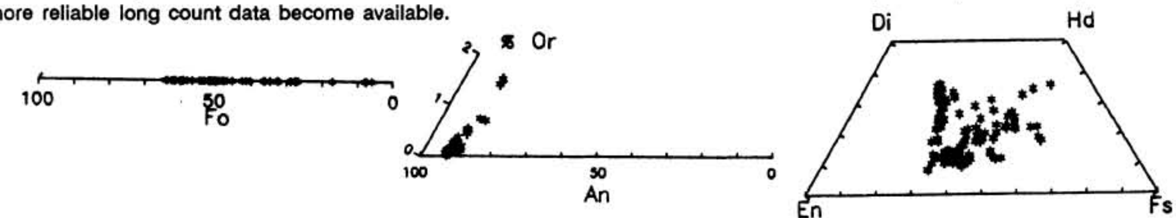
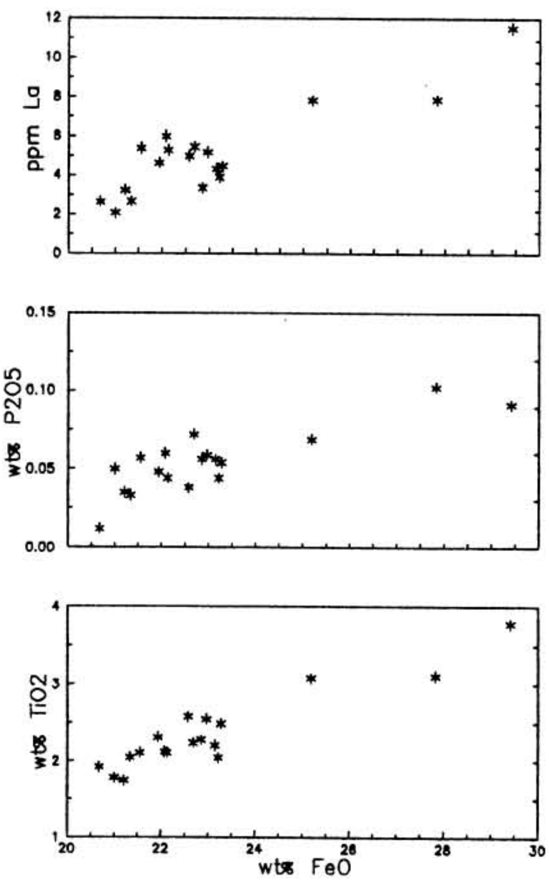


Figure 1. Olivine, pyroxene, and plagioclase compositions in Apollo 15 olivine basalts.

DISCUSSION : The dispersion of chemical data about a mean of replicate analyses is caused by (1) analytical uncertainty and (2) sample heterogeneity on a scale larger than the sample size. When viewed in terms of analytical uncertainty at the two sigma level, most of aliquot pairs in this study are identical or nearly identical in major element composition, regardless of grain size or texture. The two samples which exhibit large differences between aliquot pairs are characterized by heterogeneous distribution of mafic-minerals and late-forming mesostasis phases. Figure 4 is a BSE image of a typical mesostasis clot in 15636 containing fayalite, ilmenite, cristobalite, glass, and apatite, surrounded by zoned pyroxene and plagioclase. The mesostasis phases contain most of the Fe (fayalite, ilmenite), Ti (ilmenite), P (apatite), and REE (apatite) found in the sample. The positive correlation between these elements seen in figure 2 implies that the chemical heterogeneity exhibited by 15547 and 15636 is due largely to the heterogeneous distribution of late-forming mesostasis phases. Similar coarse-grained microgabbro samples in which these phases are more evenly distributed do not show significant chemical dispersion, and even the small aliquots studied here are representative for the major elements. Trace elements seem to be more sensitive, and detailed geochemical modeling based trace element concentrations in very small samples may be subject to large uncertainties. Because the sample aliquots studied here are about the same size as most aliquots of breccia clasts, the same conclusions will apply to clast studies.

References:
Compston et al (1972) A-15 Lunar Samples, 347-351.
Ma et al (1978) PLPSC 9, 523-533.
Ryder, G. and Steele, A. (1987) LPS XVIII, 862.

Figure 2. Whole rock chemical variations in aliquots of Apollo 15 olivine basalt. Note positive correlation of Fe, Ti, P, and La (below).



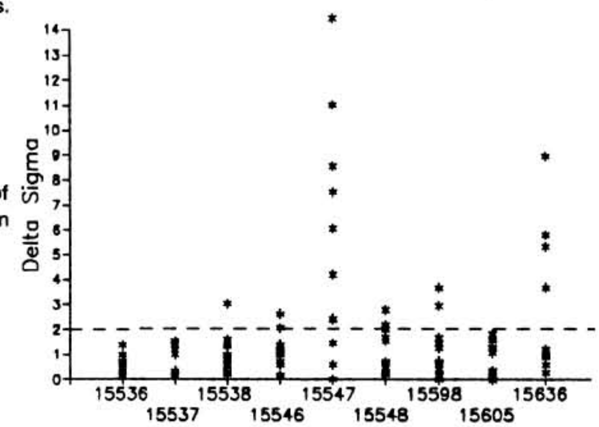


Figure 3. Chemical dispersion of olivine basalt aliquots relative to analytical uncertainty. Function delta/sigma equals deviation of analysis from mean, divided by uncertainty for that element (above).

Figure 4. BSE image of mesostasis clot in 15636. Bright = Fayalite; dark grey = feldspar, cristobalite, and glass; light grey = whitlockite; zoned grey = pyroxene. Bar scale = 200 microns.