TRACE ELEMENT CONCENTRATIONS IN THE FINE GRAIN-SIZE FRACTIONS OF EXPERIMENTAL REGOLITHS. R. L. Korotev, Department of Earth and Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130; T. H. See, Lockheed EMSCO, Houston, TX 77058; and F. Hörz, NASA JSC, Houston, TX 77058.

INTRODUCTION. The comminution of planetary surfaces by repetitive impact was simulated in a series of experiments using the vertical impact facilities at JSC and NASA Ames. The target was a coarse-grained terrestrial gabbro, crushed with a hammer into different grain-sizes. Each target weighed 4000 g and was housed in a cylindrical stainless steel container. The target for the first experiment (Series A) consisted of gabbro fragments 2-32 mm in diameter and employed stainless steel projectiles of 1.02 g in mass impacting at 1.35 km/s. A total of 200 shots were fired into the same target. A second experiment (Series B) employed targets of narrowly restricted grain sizes (0.25-0.5 or 2-4 mm gabbro fragments) impacted 25 times; all other conditions were identical to those of series A. Series C experiments again employed 2-32 mm fragments, but this target was impacted 50 times at 5.6 km/s with stainless steel projectiles weighing 0.12 g.

Although analysis of many of the experiments is still in progress, a major result documents mineral specific, differential comminution (7,8). Both petrographic and chemical (major element) analysis of the fine-grained material produced in these experiments indicates that plagioclase is enriched and pyroxene depleted in the fine material (<250 µm) compared to the whole rock. The enrichment of Al and depletion of Mg, Fe, and other elements associated with pyroxene in the fine grain-size fractions observed in these experiments is qualitatively similar to what is observed in many lunar soils (2,3,5,6,1,9). Variation in modal mineralogy with grain size of comminuted lunar rock ("differential comminution", 2) has been suggested as a cause for the variation in chemical composition of lunar soils with grain size (5,6,9).

In addition to being enriched in Al, the fine grain-size fractions of lunar soils are usually also enriched in incompatible trace elements (ITEs). The experiment of (5), in which a lunar mare basalt was struck several times with a hammer and the resulting material sieved into several grain-size fractions, also showed an enrichment of ITEs in the finest fraction. This was attributed to concentration of ITE-rich mesostasis. To test whether ITEs are also concentrated into the finest-grain-size fraction in the experimental regoliths, several samples from the Series A, B, and C experiments were analyzed by INAA. The results are tabulated in Table 1.

ELEMENTS ASSOCIATED WITH MAJOR MINERAL PHASES, AND CONTAMINATION. Data for the grain-size fractions are for the finer material produced (63-125 µm and < 63 µm). The greater concentrations of Na, Sr, and Eu in the <125 µm material compared to the whole rock (Table 1) reflects the plagioclase enrichment in the fine fractions reported by (7). Ba is also enriched in both <250 µm fractions compared to the whole rock, but is relatively more enriched in the <63 µm fraction. This is consistent with the trend of K enrichment in the finest fraction noted by (7) because a large proportion of the Ba is carried by orthoclase. The INAA data confirm the observation of (7) that the fine fractions are depleted in Fe. The fine fractions are also depleted by 20-30% in Sc, an element that concentrates in pyroxenes, particularly clinopyroxene, during igneous crystallization. Despite the potential for contamination by the steel projectile, Co is also 5-30 % depleted in the fine material compared to the whole rock. Most of this Co is probably carried by orthopyroxene. The higher Co concentrations in the Series A samples compared to the other sieved samples is probably contamination by whatever material is responsible for the exceedingly high Ni concentrations in these samples. (Analysis of the projectiles, which are not the same in the JSC and Ames experiments, is in progress. The stainless steel target containers, the sieves, and erosion of the gun barrels may also contribute some contamination.) The high Br, Sb, and Au concentrations, particularly in the <63 µm samples, and the high Cr in the Ames samples are probably also from contamination because they considerably exceed whole rock concentrations.

INCOMPATIBLE TRACE ELEMENTS. Concentrations of ITEs are usually greater in the <63 µm fractions than in the corresponding 63-125 µm fraction. The largest fractionations are obtained for the light REEs, Zr, Hf, Th, and U. These fractionations are the result of concentration of intergranular phases such as zircon and phosphate minerals into the finest fraction. The Zr, Hf, and U concentrations in the <63 µm fractions are typically 2x greater than those of the 63-125 µm fraction, indicating twice as much zircon in the finer grain-size fraction. The heavy REE are depleted, however, in both <125 µm fractions compared to the whole rock. Although both Yb and Lu are incompatible (i.e., partition coefficients of less than unity for major mineral phases), they partition much more favorably into clinopyroxene and less favorably into plagioclase than do the light REE during igneous crystal-
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...of clinopyroxene in the finer fractions.

EFFECTS OF EXPERIMENTAL CONDITIONS. Targets were produced by mechanical crushing, grinding, and sieving of the original gabro. Because the fine material produced was not included as target material, the initial targets were probably fractioned with respect to the target material. The greatest similarity in ITE concentrations between the 63-125 μm and 63 μm fractions (i.e., least fractionation) and the lowest absolute concentrations of ITEs (especially among the 63 μm fractions) occur for the Series B samples for which the grain size of the target is already fine as a result of this mechanical grinding, i.e., the 0.25-0.5 mm target material. This result is expected because most intergranular fracturing occurred during preparation, not impact, of the fine-grained target. Hence, compared to the 32 mm target material, a smaller portion of mesostasis was initially present in the 0.25-0.5 mm target.

For elements associated with major mineral phases there is little difference in concentration among the six samples of <125 μm material analyzed from the JSC experiments, despite differences in initial grain size and number of impacts. The <63 μm sample from the high velocity Ames experiment (Series C) is more similar in composition to the <63 μm samples from Series A and B than it is to the 63-125 μm Ames fraction. The only major difference between the higher velocity Ames experiments and the JSC experiments is that the 63-125 μm fraction appears to contain a greater proportion of pyroxene (based on Fe and Sc) than any of the JSC samples of the same grain size. Hörz et al. (7) note that strong fractionation occurs early and that the modal composition of a specific grain-size fraction remains constant with succeeding impacts after about the 50th impact because a significant amount of fine-fractionated material is produced by each impact upon coarse-grained material. The chemical observations made here suggest that the modal composition of the finer grain-size fractions (<125 μm), although strongly fractionated from that of the whole rock, is insensitive to initial grain size of the target and impact velocity.

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Table 1.

Results of instrumental neutron activation analysis of grain-size fractions of experimental regoliths.