FRACTIONATION TRENDS DURING IMPACT COMMINUTION OF MODALLY CONTROLLED REGOLITHS. A.M. Therriault,1 F. Hörz,2 M.J. Cintala,2 F. Cardenas,3 and G.L. Haynes;3 1Department of Geosciences, University of Houston, TX 77204; 2Code SN21, NASA JSC, Houston, TX 77058; 3Code C23, Lockheed ESC, Houston, TX 77058.

Distinct compositional differences exist between lunar bulk soils and their finest grain size fractions. Some workers attribute these variations to differential comminution of local rocks and others to grain size dependent, ballistic transport over substantial lateral distances.1,2,3,4,5 We demonstrated experimentally that the lunar trends can be reproduced by the comminution of lithic (i.e., gabbro) fragments6 owing to mineral specific comminution behavior, that we subsequently quantified in more detail with experiments into monomineralic, fragmental targets7 and by exploring velocity and initial grain-size as possibly important factors.8 We now report on multiple impact experiments into modally controlled targets. The objective was to more closely simulate and isolate the role of monomineralic clasts in lunar soil evolution as opposed to coexisting lithic clasts. Monomineralic fragments are a substantial fraction of lunar soils, on occasion approaching the abundance of lithic fragments.9 Also, modally different targets were assembled in such proportions that they simulated a number of major lunar rock-types and their comminution behavior. The latter should illuminate possible effects of variable matrices on the specific comminution behavior of a single mineral species, particularly of feldspar, which seems to dominate all natural and experimental evidence for mineral specific comminution and associated fractionation.

Experimental Procedures: Single-crystal crushed fragments, 2-4 mm in size, of feldspar (oligoclase, Na0.87Ca0.12Al1.17Si2.86O8, and orthoclase, K0.96Na0.04Al1.02Si2.91O8, as anorthite), pyroxene (augite, (Na0.01Ca0.03Mg0.74Fe0.2Al0.03)(Si1.07Al0.03)O6), and olivine (forsterite, Mg1.94Fe0.01Si0.96O4), were mixed to simulate three lunar rocks: (1) gabbroic anorthosite (by weight = 80% feldspar, 15% augite, and 5% forsterite), (2) olivine microgabbro (35% feldspar, 50% augite, and 15% forsterite), and (3) feldspathic peridotite (10% feldspar, 45% augite, and 45% forsterite). These targets were impacted 25 times with stainless steel projectiles (diameter = 3.2 mm; mass = 0.128 g), at nominal velocities of 1.7 km/s for all three compositions and at 1.2 km/s for a second olivine microgabbro target. After shots 1, 5, and every fifth shot thereafter, sieving was performed for all targets. While aliquots were taken for each grain-size fraction following sieving, only 4 fractions (0.125-0.500 mm; 0.044-0.063; 0.020-0.044; <0.020) were used to manufacture melt-beads for the analysis of bulk composition via Electron Microprobe (30 nA, 15 kV; beam diameter some 10µm; 30-45 points per melt-bead).

Results: We illustrate the compositional data and associated fractionation trends via AFM diagrams with the major component minerals essentially representing the end-members (Figure 1). The finest grain-size fractions are all enriched in feldspar, despite widely variable absolute abundances, from 80 to 10% (weight) in the initial targets. There are no systematic trends for progressively increased fractionation with increasingly larger numbers of impacts. Obviously, even after 25 impacts, the bulk-targets were insufficiently processed in the sense that the first and last impact still encountered a target of similar grain size distribution to produce essentially identical amounts of comminuted mass that furthermore contained similarly fractionated fines. While total comminuted mass increases of course with time, mineral specific fractionation within a specific grain size will essentially remain unchanged, unless such a stage of soil maturity is reached, that overall modal composition and/or grain size is dramatically altered. For clarity, the most fractionated fines (<0.020 mm) are plotted separately in Figure 2 and in such a fashion, that enrichment (s) and depletion (s) of specific oxides/minerals become more obvious. While the basic trend of feldspar enrichment at the expense of olivine and pyroxene is demonstrated once again, some data scatter is also prominent. We attribute the latter to either vagaries of precise impact point (s) of projectiles of dimensions that approach those of individual regolith components (e.g., shot 5 in olivine microgabbro) or to sample preparation (loss of alkalis during melt-bead manufacture) or analysis methods (loss of alkalis during probe analysis).

Discussion: The results of these experiments, show that the overall trends correspond to the results of earlier experiments8,10 indicating a depletion in pyroxene and olivine, and an enrichment in feldspar in the fine-grained fractions of regoliths produced by multiple impacts. In addition, we reinforce the statement that this differential comminution, occurs at relatively low velocities. Moreover, identical fractionation trends are produced in freshly excavated pyroclastic or monomineralic rocks as well as in clastic debris composed of monomineralic grains.
COMMINUTION OF MODALLY CONTROLLED REGOLITHS; Theriault, A.M., et al.