MINERAL-DEPENDENT COMMINUTION DURING IMPACT CRATERING; Mark J. Cintala and Friedrich Hörz, Code SN21, NASA Johnson Space Center, Houston, TX 77058.

Experimentation has demonstrated that multiple impacts into fragmental gabbro targets produce debris with compositions that differ from that of the bulk rock; the variation in composition from that of the whole rock is dependent on the size fraction being considered.[1] In particular, the finer fractions of the debris were increasingly enriched in feldspar at the expense of pyroxene. On the basis of this observation, it was concluded that feldspar comminutes more severely under impact-induced stress than does pyroxene. Since lunar regoliths also appear to have undergone a similar enrichment/depletion process, a subsequent series of experiments was performed to evaluate the relative comminution behaviors of monomineralic rocks.[2] While each of the three materials (anorthosite, dunite, and single crystals of pyroxene) demonstrated a distinct trend, independent experiments indicated that these patterns were likely influenced by grain-boundary effects in the anorthosite and dunite.[3] In order to eliminate possible complications due to grain-boundary effects, fragmental targets composed of single crystals are being employed in a group of experiments currently underway. Intermediate results are presented below.

Experimental Conditions -- The protocol followed in these experiments is essentially identical to that used in the previous experiments.[1,2,4] Target materials used are albite (Bancroft, Ontario), augite (Harcourt, Ontario), forsterite (San Carlos, NM), and transparent quartz (Hot Springs, AR). Each target was composed of fragments 2-4 mm in dimension. The feldspar, pyroxene, and quartz were broken with a hammer and further fragmented with a jaw crusher; the olivine crystals were obtained as a "gravel" from which the desired sizes were sieved. Earlier experiments utilized 4000-g targets and 6.35-mm stainless-steel projectiles, but 500-g targets are used in this series, as it has been found that "scaled" experiments provide equally valid results[3] and that smaller target masses are less unwieldy to sieve. The target containers are proportionately smaller, and 3.175-mm stainless-steel spheres are employed as impactors. Ideal impact velocities are 1.4 km/s, and actual velocities differ little (typically less than 1.5%) from that figure. The targets were dry sieved after shots 1, 5, and every fifth shot thereafter. At the time of this writing, ten shots were performed in each of the feldspar, pyroxene, and olivine targets; the quartz had sustained 15 impacts.

Comminuted Masses -- In keeping with usage in earlier reports (*e.g.*, *1*, *3*), all material smaller than the lower bound of the initial size range (2 mm in this case) is defined as "comminuted." Figure 1 illustrates the results for the four targets. Note that the dispersion along the vertical axis for the first shot of each series is greater than that of the multiple-impact points; this effect is due to random effects that are prevalent during impacts into such relatively coarse-grained targets.[5] It is immediately apparent that larger quantities of quartz and feldspar have been comminuted than have either the pyroxene or olivine. In turn, the pyroxene appears to be less resistant than the olivine, although the difference between the latter two is smaller than the variation between the two pairs of minerals. Inspection of the size distributions of the comminuted masses from the four charges (Fig.2) yields additional observations. All four targets possess very similar trends, with the cumulative size fraction decreasing smoothly

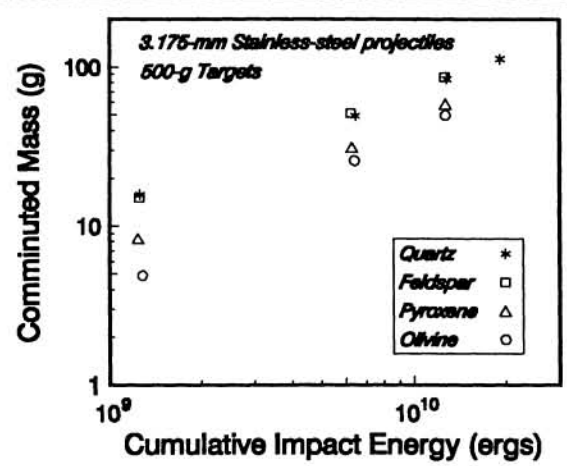

Figure 1. Comminuted mass as a function of the cumulative impact energy for the four targets. The wide dispersion for the group representing the first shot of each series (the points nearest the vertical axis) is likely due to random factors; see the text.

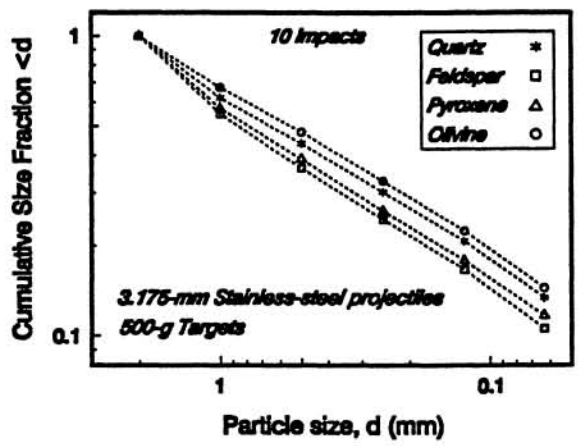

Figure 2. Cumulative size fraction of comminuted material after ten impacts plotted against particle size.

with the particle size. The relative positions of the different materials, however, is somewhat unexpected in light of Figure 1. Even though the olivine was the most resistant to comminution in terms of the *mass* of debris produced, it is finer grained than any of the other three. Conversely, while the feldspar effectively equalled the quartz in comminuted mass, it yielded the smallest relative fraction of fines. The enhanced production of fines in olivine was observed in a previous study,[2] but was thought subsequently to be predominantly a manifestation of grain-boundary effects. These earlier data and the present results indicate that the earlier observations were, in fact, a mineral-dependent phenomenon.

New Surface Areas -- The new surface area created by the impacts was calculated for each of the four targets[5] and is plotted in Figure 3. Although the relative relations are similar when compared to Figure 1, the quartz is displaced slightly above the feldspar, while the difference between the pyroxene and olivine is even smaller than it is for the comminuted mass. Since it is likely that the surface area is a good indicator of the amount of work done during comminution, this plot is useful from the standpoint of energetics: under the assumption that an equal quantity of impactor energy is partitioned into comminution for each target material, quartz is the easiest of the four to pulverize, while the olivine and pyroxene are the most resistant.

Discussion -- The four minerals exhibit distinct differences in their comminution behavior during impact. Not only do variations exist in the quantities of debris produced, but the size distributions of the debris also differ. Since the cumulative impact energies deposited in each target were virtually identical, variations in the surface area produced in the different materials are almost certainly attributable to mineralogical differences in strength. Although incomplete, these data, taken in the context of previous studies of experimental regoliths, further illustrate the potential significance of mineral-specific comminution. It appears to be an important process during the breakup of coherent rock, and the present data suggest that it continues to be prominent in the continuing evolution of monomineralic regolith constituents. It is hoped that, upon completion of this series of experiments, quantitative description of mineral-dependent, dynamic comminution will be possible.

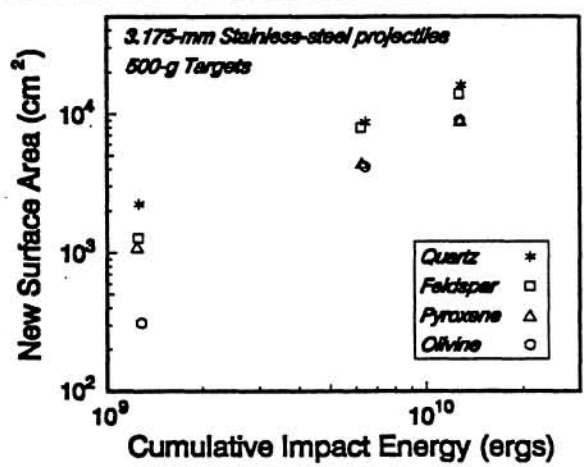

Figure 3. New surface area created by the comminution process as a function of the cumulative impact energy.

References: *1* F. Hörz *et al.* (1984) *PLPSC 15, JGR* **89**, C183-C196. *2* F. Hörz *et al.* (1985) *LPS XVI*, 362-363. *3* M.J. Cintala and F. Hörz (1990) *Meteoritics*, in press. *4* T.H. See and F. Hörz (1988) *PLPSC 18*, 423-434. *5* M.J. Cintala and F. Hörz (1988) *PLPSC 18*, 409-422.