THE EVOLUTION OF EXPERIMENTAL REGOLITHS: EFFECTS OF IMPACT VELOCITY.

Mark J. Cintala,* Friedrich Hörz,* Thomas H. See,+ and Francisco Cardenas,+
*NASA Johnson Space Center, +Lockheed EMSCO, both in Houston, TX 77058.

Following an earlier study of regolith formation in the laboratory [1], we have begun exploring individual parameters that appear to affect the paths available to a regolith during its evolution. The effects of mineralogy and the target's initial fragment size have been investigated [2,3]; this report addresses the role of the impact velocity.

Experimental Conditions: The same gabbro utilized in the initial study was chosen, and all other target-related conditions were identical to those of [1], including the initial fragment-size distribution (>2-31.5 mm). Stainless-steel projectiles 6.35 mm in diameter were employed in all shots, which were subdivided by velocity into three distinct series. As the original experiments were performed at 1.4 km/s, a low-velocity set was performed at 0.7 km/s (half that of the former), and a third was completed at 1.9 km/s, the highest velocity comfortably attainable with the JSC Vertical Gun and this projectile mass. Each of the latter two series consisted of 25 shots; the target was sieved after shots 1, 5, 10, 15, 20, and 25. An independent 50-shot series performed at NASA Ames also yielded data applicable to this investigation, with 3.18 mm spheres accelerated to a nominal velocity of 5.5 km/s into an identical gabbro target. The Ames projectiles, composed of a Ni-rich alloy [4], were somewhat higher in density than the SS spheres (8.47 *vs.* 7.67 g/cm^3). Coincidentally, due to the difference in mass between the two projectile types, each Ames shot possessed virtually the same kinetic energy as a typical 1.9 km/s JSC impactor.

Results: <u>Comminuted Mass</u> --As discussed in [1], a detailed tracking of the fate of the fragments in a given size bin at any particular time is not possible under the conditions of these experiments, since comminution products from that bin can migrate to any of the smaller sizes in a highly complex manner. In order to obtain some measure of the comminution susceptibility of the target at a given impact velocity, therefore, only those fragments smaller than 2 mm in size were considered; because all particles in the initial target were larger than 2 mm, it is certain that these were derived from the larger materials. The cumulative mass of the comminution products <2 mm in size was normalized to the projectile mass and is plotted in Fig. 1 as a function of the cumulative impact energy deposited in the target. It is apparent that the three JSC series produced similar trends: (a) Their slopes are all slightly less than 1, implying a decrease in the efficiency of comminution as the cumulative energy increases (or, alternatively, as time increases and the amount of comminuted material also grows). Insofar as the amount of energy required to comminute a given mass becomes greater as the mean grain size of the target decreases [1,3], this drop in efficiency is expected. (b) It is also obvious that the amount of energy necessary to comminute a given normalized mass is directly related to the impact velocity. As the impact velocity into a given target increases, larger fractions of the available energy are lost to entropy production, with less consequently becoming available for other processes, such as comminution [5,6]. Thus, the progression observed in Fig. 1 is clearly in the expected direction; although it is uncertain whether sufficiently large differences in entropy production exist at such low velocities, the most rapid rates of increase in waste heating occurs at the lower end of the velocity spectrum [7]. (c) At first glance, the Ames results appear to be at variance with this hypothesis. It has been demonstrated, however, that much less specific energy (*i.e.*, ergs/g) is required to disrupt larger fragments than smaller ones [3]. Thus, because the initial fragment sizes were twice as large relative to the Ames projectile, a comparison between the JSC series and the Ames experiments in this context would be premature. Experiments are currently underway to extend the data for the smaller projectile to lower velocities. <u>Surface Areas</u> -- The work done in comminuting a rock is ideally expended in breaking atomic and molecular bonds and in moving the fragments against friction, forces which control the amount of free-surface area created by an impact. It is therefore informative to examine the free-surface area of the comminuted mass as a function of accummulated impact energy. The free-surface area normalized to the cross-sectional area of the projectile is plotted in Fig. 2 as a function of the cumulative impact energy. (The surface

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areas were calculated from the model used by [4], which assumes a spherical geometry for all fragments). The slopes of all four distributions are very close to unity, implying little change in the efficiency of free-surface formation for a given series. This is in keeping with the results of [3], who found that the amount of area generated is virtually independent of the target's fragment-size distribution, at least over the range studied (>0.25-31.5 mm). Taken in concert with Fig. 1, this indicates that, although less mass is comminuted as the target becomes more finely pulverized, the new fragments possess more surface area per unit mass, simply because they are smaller.

Conclusions: Along with other factors -- the fragment-size distribution and mineralogy of the target, for example -- the impact velocity is a significant parameter contributing to the evolution of a regolith. Not only is target comminution a strong function of that quantity, but constructive processes such as agglutinate formation also depend on the impact velocity [8]. Extension of the comminution results to the higher velocity regime of the Ames series is complicated by the difference in projectile size relative to the initial target configuration. It is anticipated that experiments now underway will permit a more detailed understanding of these processes, including those at the higher velocities.

References: [1] F. Hörz et al. (1984) PLPSC 15, JGR 89, C183. [2] F. Hörz et al. (1985) Lunar Science XVI, 362. [3] F. Hörz et al., this volume. [4] R. Korotev (1986), per. comm. [5] D.E. Gault and E.D. Heitowit (1963) Proc. 6th Hypervel. Impact Sympos. 2, 419. [6] J.D. O'Keefe and T.J. Ahrens (1977) PLSC 8, 3357. [7] R.A.F. Grieve and M.J. Cintala (1981) PLPSC 12, 1607. [8] T.H.See et al., this volume.

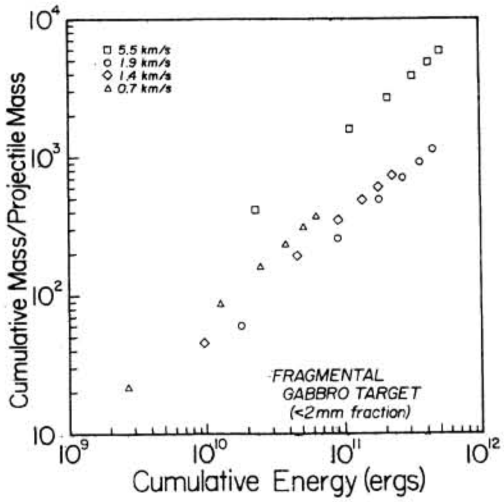

Figure 1. Cumulative mass in the <2mm grain-size fraction normalized to the projectile mass. Each point represents a sieved and analyzed shot in that series. The cumulative energy axis represents the energy deposited in the target at that point in the series.

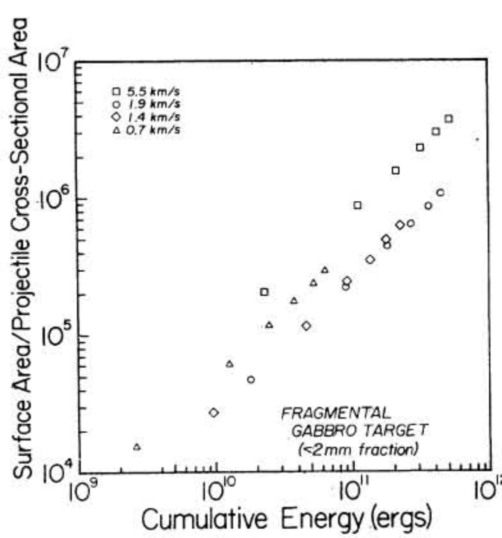

Figure 2. Surface area generated in the <2 mm grain-size fraction normalized to the cross-sectional area of the projectile. The points represent the same shots as those in Fig. 1; horizontal axis is also the same.