A REASSESSMENT OF IMPACT MELTING AND VAPORIZATION IN THE REGOLITH OF MERCURY: COMPARISON WITH THE MOON; Mark J. Cintala, Code SN21, NASA JSC, Houston, TX 77058.

An earlier attempt[1] to evaluate the rate of production of impact melt in the regolith of Mercury applied a variety of assumptions and factors that require revision. In particular, idealized fluxes were employed over an artificially and very restricted mass range, and the technique[2] used to calculate melt volumes has been improved,[3] following the results from more complex models.[4] This contribution presents a reevaluation of the rates of melting and vaporization as caused by micrometeorite impact on Mercury and compares them to those calculated for the Moon.

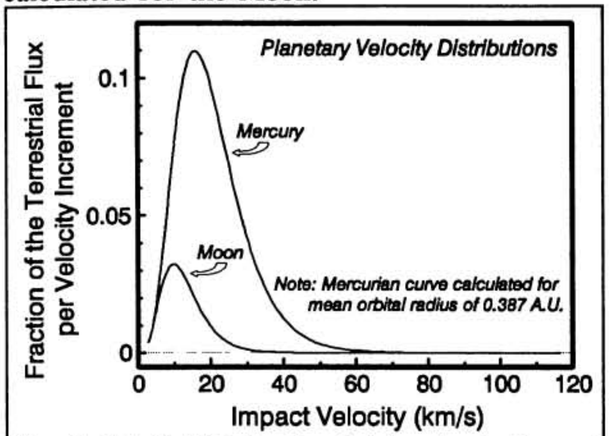

Figure 1. Velocity distributions for objects impacting the Moon and Mercury. Multiplication of each of these functions by the mass distribution of micrometeoroids would yield the absolute differential-flux functions for each planet.

Impact Fluxes: Beginning with the velocity distribution as given for the Earth by Southworth and Sekanina,[5] the technique of calculating impact rates on gravitating bodies as formulated by Zook[6] was utilized here, with the exception that absolute fluxes were used in place of normalized rates.[7] The resulting distributions are presented graphically in Fig. 1. It is obvious that the flux at Mercury is much greater than that at the Moon (a good visual gauge of which is the area under each curve); in addition, the modal and mean impact velocities are considerably higher at Mercury. It is assumed here that the micrometeoroids impacting the two planets possess the same size distribution, and that the spatial density of these micrometeoroids varies as $r^{-1.3}$, where r is distance from the sun.[8]

Parameters Affecting Impact-Melt and Vapor Generation -- ***Impact Velocity*:** Above a velocity threshold characteristic of the target and projectile materials, it has been calculated[4] that the volumes of impact melt and vapor grow essentially in proportion to the square of the impact velocity. The model used here provides very similar results, examples of which are given in Fig. 2 for impacts of diabase into regolith. The equation of state for the regolith is derived from data for lunar regolith,[9] merged into the equation of state of a basalt at higher shock stresses.[3] ***Target Temperature*:** Because hotter targets are closer to their melting and vaporization points in terms of internal energy, the temperature of the regolith being impacted should contribute to the volumes of melt and vapor produced during a given impact. This effect for regolith over a range of temperatures is shown in Fig. 3 for the pure and mixed phases considered here. The results indicate that (1) changing the target temperature affects the production of melt more than vapor, and (2) the target temperature has a substantially smaller effect on melt and vapor production than do changes in impact velocity (*cf.* Fig.2). The higher internal energy represented by the hotter target is a greater fraction of the energy required to begin melting than of that necessary for vaporization; thus, the lower-energy phases are affected more by changes in target temperature. In the results presented below, it is assumed that the lunar and mercurian regoliths have average temperatures of 273 and 400 K, respectively.

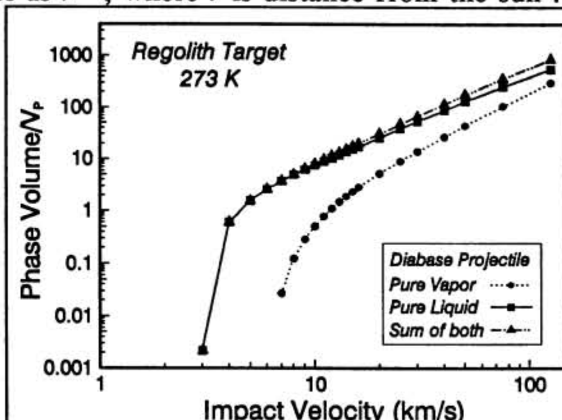

Figure 2. Volumes of pure impact melt, impact vapor, and the sum of both (expressed in units of projectile volume) for diabase impacting regolith.

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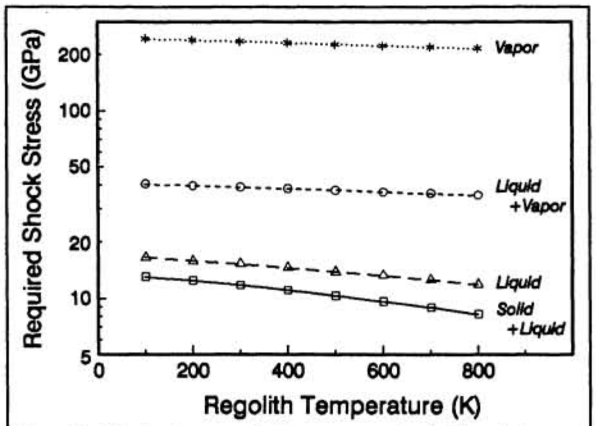

Figure 3. Shock stress required to generate the indicated phase or mixture of phases as a function of initial regolith temperature.

Generation Rates of Melt and Vapor: The velocity distributions as shown in Fig. 1 can be convolved with both the size distribution of meteoroids as found by Grün *et al.*[10] and polynomials fit to the curves in Fig. 2 to yield the rates of melt and vapor generation on the two planets. In the velocity integrations, the minimum limit of integration for each body is its escape velocity (the lunar escape velocity plus the escape velocity from the Earth at the Moon's distance for the case of the Moon), while the maximum limit is the sum of its orbital velocity around the Sun and the escape velocity from the Sun at the planet's mean orbital radius. (A circular orbit for Mercury at its mean distance of 0.387 AU is used here.) Taking the upper limit of integration for the meteoroid mass as 0.1 grams, Figure 4 illustrates the cumulative masses of melt and vapor produced per unit area and unit time as a function of the minimum projectile mass (*i.e.*, the lower limit in the mass integration). It is apparent from the curves that the great majority of both melt and vapor is created by the larger projectiles, and that the rates of production of both phases on Mercury are much greater than on the Moon. A factor of 13.7 times more melt and 20.7 times more vapor are produced in a given period of time on Mercury; indeed, *vapor* production on Mercury outstrips *melt* production on the Moon by a factor of more than 2.9.

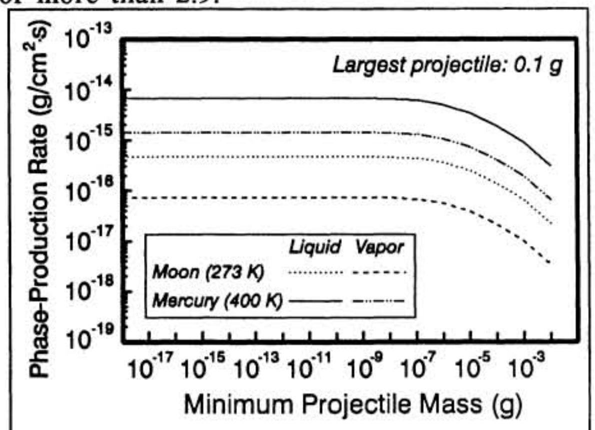

Figure 4. Cumulative production rates of impact melt and vapor for the Moon and Mercury as a function of the minimum projectile mass in the integration.

Comparison with Previous Work -- *The Moon:* Although the conditions used by Gault *et al.*[11] were somewhat different than those used here, their estimates of melt and vapor production are lower by just over a factor of two and higher by about 40 percent, respectively. Zook[6] provided estimates of melt and vapor generation for identical projectile and target materials; his values bracket those obtained for "regolith" projectiles using this method. Comparison with the vaporization calculations of Morgan *et al.*[12] is difficult because of the averaging techniques they employed; nevertheless, allowing for the differences between the two approaches, it is estimated that their rate would be slightly lower than that found here, but well within a factor of two. ***Mercury:*** The earlier estimate of melting[1] was performed for artificially restrictive conditions, and will not be considered here. After making the necessary changes for projectile types, assumed velocity distributions, and the sound-speed of the target,[4] the vaporization results of Morgan *et al.*[7] and those found here are virtually indistinguishable.

Conclusions: Compared to the more familiar lunar case, the regolith of Mercury has suffered severe melting and vaporization effects due to impact. Although the analysis summarized above carries explicit and implicit assumptions whose validities are unknown at present -- similar size distributions and projectile compositions, for example -- it is likely that variations caused by any potential differences are small relative to the first-order results. Such intensive melting should have observable consequences, some of which are discussed elsewhere in this volume.

References: **1** M.J. Cintala (1981) *LPS 12*, 141. **2** D.E. Gault and E.D. Heitowit (1963) *6th Hypervel. Impact Symp.*, 419. **3** M.J. Cintala (1984) *LPS 15*, 154; M.J. Cintala and R.A.F. Grieve, this volume. **4** J.D. O'Keefe and T.J. Ahrens (1977) *PLSC 8*, 3357. **5** Southworth and Sekanina (1973) NASA CR-2316. **6** H.A. Zook (1975) *PLSC 6*, 1653. **7** T.H. Morgan *et al.* (1988) *Icarus, 75*, 156. **8** C. Leinert *et al.* (1981) *Astron. Astrophys.*, *103*, 177. **9** T.J. Ahrens and D.M. Cole (1974) *PLSC 5*, 2333. **10** E. Grün *et al.* (1985) *Icarus, 62*, 244. **11** D.E. Gault *et al.* (1972) *PLSC 3*, 2713. **12** T.H. Morgan *et al.* (1988) *PLPSC 19*, 297.

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