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PRODUCTION OF IMPACT MELT IN CRATERS ON VENUS, EARTH, AND THE MOON, A. M. Vickery and H.J. Melosh, Lunar and Planetary Lab, The University of Arizona, Tucson, AZ 85721

Impact craters imaged by Magellan clearly show large amounts of flow-like ejecta whose morphology suggests that the flows comprise low-viscosity material (1). Phillips et al. (1) suggest that this material may be either turbidity flows of very fine-grained ejecta, flows of ejecta plus magma, or impact melt. We here consider the last of these hypotheses.

If these flows are composed of impact melt, there is much more melt relative to the crater volume than is observed on the moon. Basilevsky and Ivanov (2) used the approach of Onarato et al. (3) to estimate the amount of "excess" melt that might be produced in Venusian craters. In this model the amount of melt depends on the temperature on incorporated solid clasts. Because the clasts produced by impacts on Venus are assumed to be initially hotter than those produced by impacts on earth, their effectiveness in cooling the melt is less. Basilevsky and Ivanov found that Venusian craters should contain only 50% more impact melt than similar size craters on earth, which is not enough of an enhancement to account for the observed flows.

Other mechanisms for producing relatively more melt on Venus take into account the effects of ambient temperature and pressure as well as gravity. In general material shocked from some initial temperature and pressure will, upon release to ambient pressure, be at a higher temperature than originally because of the internal energy deposited in them by the shock wave. If the release temperature is high enough, the rocks will be melted. It is logical to assume that rocks whose pre-shock temperature and pressure are higher will require lower shock pressures in order to melt upon release. The shock wave generated by an impact initially propagates into the target material as a hemisphere, and the maximum shock pressure decreases away from the center of impact. Decreasing the shock pressure required for melting (P_m), then, increases the amount of material shocked to P_m and increases the amount of melt produced.

Gravity affects the relative amount of melt produced by changing the size of the crater produced. A given impactor size and impact velocity will produce a given amount of melt, but the crater formed will be smaller on a planet with higher gravity so that the amount of melt produced for a given crater size will be larger.

We used the ANEOS equation of state program (4) for dunite (5) to estimate the shock pressures required for melting, with initial conditions appropriate for Venus, Earth, and the moon. Assuming that ambient pressure and temperature on Earth and the moon are similar, we find that P_m = 139 GPa for earth and the moon and P_m = 122 GPa for Venus. We then developed a simple model, based on the Z-model for excavation flow and on crater scaling relations that allow us to estimate the ratio of melt ejecta to total ejecta as a function of crater size on the three bodies. If the difference in Pm is dominant in producing larger melt volumes, then the results for the moon and earth should be similar to each other and different from those for Venus, but if gravity plays the dominant role, then the results for earth and Venus should be similar to each other and different from those for the moon.

The impact of a projectile of radius a and velocity v_i impacting at an angle θ (measured from the horizontal) produces in the target a hemispherical core region in which the particle velocity is $v_{pc} = (1/2)\, v_i \sin\theta$. We estimate the radius of the core region, r_c, by assuming that the kinetic energy of the impact is initially equally partitioned between kinetic and internal energies of the core:

$r_c = a(2/\sin^2\theta)^{1/3}$. Momentum conservation requires that the particle velocity decline with increasing distance r as $v_p = v_{pc}(r_c/r)^2$, and the second Hugoniot relation gives the pressure as a function of v_p: $P = \rho_o v_p (c + s v_p)$, where ρ_o is the uncompressed density of the target material and c and s are material constants. Setting P equal to P_m, these two equations are solved to find r_m, the radius within which melting occurs. We next use the Z-model (6) to estimate the ratio of the amount of melt ejected to the total amount of ejecta. For Z = 3, appropriate for near-surface flow, we find the melt fraction, $F_m = 4\{1 - 0.75(r_m/r_o)\}(r_m/r_o)^3$, where r_o is the radius of the apparent transient crater. This radius is estimated from scaling relations (7,8) as $r_o = 0.997(v_i^2/g)^{0.22}a^{0.78}(\sin\theta)^{1/3}$.

The results of these calculations are presented in the accompanying figures, in which the melt fraction is plotted against crater size: the labels on the curves indicate impact angle in degrees. The similarity between the results for earth and Venus, and the contrast between these results and those for the moon, clearly indicate the dominant role of gravity in producing large amounts of melt for a given crater size. These results are consistent with the interpretation of the flow-like ejecta associated with Venusian craters as impact melt.

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