FEASIBILITY OF DETERMINING IMPACT CONDITIONS FROM TOTAL CRATER MELT

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In the past, authors have used parameters such as kinetic energy or momentum to scale crater volume and total melt volume (sum of that in crater and ejecta) produced by impact. The converse procedure; determining impact characteristics from, for example, the crater volume, will not determine impactor radius, a, and velocity, U, individually, but only as a product of powers of a and U. Recently, Grieve and Cintala (1) proposed to solve crater volume and total melt volume relations simultaneously to determine a and U individually for a terrestial crater. Their analysis pointed out that published total melt volume scaling relations varied from energy scaling (2) to momentum scaling (3), with no indication of the domain of applicability. The coupling parameter notion, described below, has the potential to unify the melt scaling relations and identify which materials nearly energy scale and which momentum scale.

The author examined the scaling of depth of melted planetary material along the axis of impact and showed (4) that a coupling parameter of the form $C = a\,U^{\mu}\,\delta^{\nu}$, $\mu = 0.58$, $\nu = 0.66$, which governs crater depth in nonporous materials like rocks and metals, also governs melt depth. The parameter δ is impactor density. This result necessarily follows from the fact that C determines sources which produce equivalent flow fields at intermediate and late times (5).

If the source variables a, U and δ only enter the scaling of melt depth D_m via C, then, $D_m = f(C, \rho, E_m)$, where ρ is the planet density and E_m is the specific energy of the Hugoniot state from which isentropic release ends at the 1 atm point on the liquidus. Dimensional analysis results in $D_m/a \propto (U^2/E_m)^{\mu/2}\,(\delta/\rho)^{\nu}$. Figure 1 is a plot of melt depths calculated with hydrocodes (2,6,7). If the above scaling relation holds, then the curve should be horizontal. Figure 1 shows that C does govern the melt depth for $v^2/E_m \geq 8$ (where v is the particle velocity at impact).

A similar analysis was performed for total melt volume (2,6-8) but did not demonstrate the coupling parameter governs melt volume. Figure 2 shows the data are not horizontal, and appear to be closer to energy scaling, $\mu = 0.67$. Perhaps crater and melt volume scale differently, however, this is difficult to understand, because they both stem from the same flow field, which has been shown to scale with $\mu = 0.58$ (9). The different scaling for the melt depth and melt volume is being looked into, and is suspected to result from free-surface effects.

The melt depth and melt volume scaling relations are both significantly different from momentum scaling, $\mu = 0.33$, however. The momentum scaling result (3) for total melt volume was obtained from an analytic model which prohibited ejection of material from the crater. This prevents multiplication of the downwards directed momentum and thus precludes any result other than momentum scaling. Momentum scaling of crater volume has been observed only for porous materials; it is therefore possible that the scaling relation from ref (3) applies to porous materials only.

If the present approach is correct, then it is not possible to distinguish the effects of the impactor radius and its velocity U separately using late time phenomena like total crater melt, crater dimensions or phase transitions in rocks below the crater. Only material from near the impact would retain information about a and U separately. Search for this material is complicated by ejection to great distances. Even if crater melt volume does scale with energy, $\mu = 0.67$ and crater volume with $\mu = 0.58$, the difference is not great enough to allow one to determine a and U separately to any useful accuracy.

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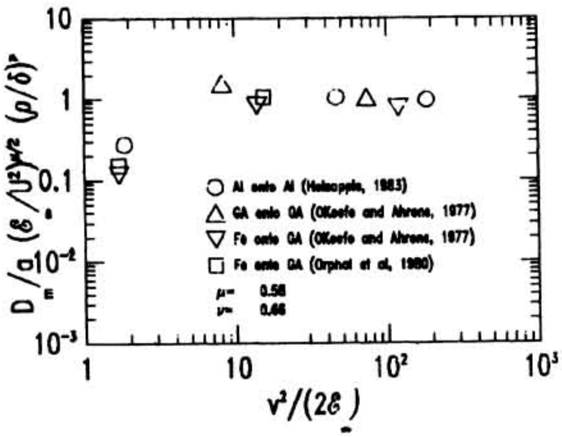

Figure 1. Scaled melt depths.

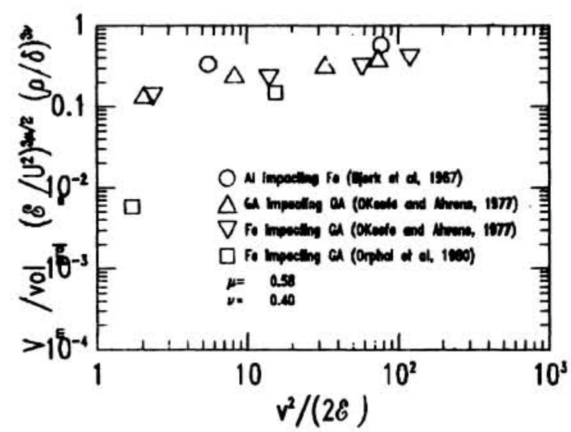

Figure 2. Scaled melt volumes.