IMPACT SPALL AS A MECHANISM FOR SURFACE MATERIAL EJECTION

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In view of the evidence that the SNC meteorites originated from Mars, mechanisms for material ejection from a planetary surface are being postulated and studied. Spall of material from a large impact event is one of those postulated mechanisms.

In a number of recent and interesting papers [1-7], *Melosh* has postulated and developed a model of this spall mechanism. He concludes that there is a layer of near-surface material that is ejected at large velocity, but, being near the free surface, is never subjected to the large shock pressures characteristic of the material lofted during the primary cratering flow.

In view of the interesting ramifications of this theory, we have looked in some detail at the model, and have performed numerical code calculations to study the problem from a different approach. It is the purpose here to present some preliminary results of this study. Complete results will be given at the conference.

The approach of *Melosh's* model follows an analysis for the surface spall of water from buried explosive events [8]. That analysis considers the superposition of two stress waves: a direct compressive wave from the buried explosion, and a tensile wave reflecting from the free surface. Depending on the burial depth, wave speed, pulse length, and on the position of the point in question, the net result can have a tensile stress sufficient to overcome the spall strength of the material.

In addition to the linearity assumption, in order to adopt this approach to the case of an impact, *Melosh* introduces additional assumptions about an equivalent burial depth, the stress decay with range and the stess pulse duration. In addition to these model assumptions, there are also algebraic approximations introduced in order to obtain a closed-form final solution.

The validity of some of the assumptions are subject to question. For example, the linearity assumption is in direct conflict with the assumed decay of stress with range. Further, while at sufficient ranges the linearity assumption is reasonable, it certainly cannot hold for the history of the pulse from the impactor to the range where it does become true, and for features depending on that previous history. For example, for an impact into a real material, measures of the impactor are not maintained as they would be for a linear material. The assumption that the pulse duration is given by a/U (the impactor radius divided by the impact veloocity) can only hold very close to the impactor; as the wave propagates outward, the impact velocity is no longer individually important. Instead, there is a single measure, of the form aU^{μ}, that characterizes the magnitude of the impact [9]. The pulse duration must be larger when that measure is larger, and, in particular it will <u>increase</u> for larger impact velocities (and larger energy) not <u>decrease</u> as the model assumes.

In regard to the algebraic approximations, they can be shown to be increasingly in error for the range of the model that becomes interesting. Fig. 1 shows the spall thickness versus velocity given in [1], and the result of exactly the same model, but without the algebraic simplifications [*Housen*, personal communication]. Note the difference of over an order of magnitude in the spall thickness at the spall velocity of 1 km/sec. Further, the spall velosity of 1 km/sec corresponds to a range of only one impactor radius, far too close to the impactor for the model to be accurate. At the ranges of several impactor radii, the spall velocities are only about 100 m/sec and smaller.

Melosh's basic approach is attractive insofar as it gives specific results, thus, it would be useful to try to generalize some of the assumptions and approach. Instead, at present, we have performed a numerical calculation of one specific impact event with sufficient detail to look critically at the stress histories for near-surface material, and to test for spall behaviour, and to compare to features of *Melosh's* model. This calculation is for a *1 km* radius impactor impacting a generic silicate rock at *10 km/sec*. The material model utilizes specific melt and vapor phase changes. The zones of this calculation are only 1/100 of the impactor radius near the surface and under the impact point. There are a total of over 25,000 zones in the problem. It is believed that this gives sufficient resolution to obtain the correct pulse lengths and the correct superposition of the resulting waves near the surface, and to compare to aspects of Melosh's model.

Fig. 2 shows the stress histories at a number of depths from 10 to 30 km directly under the impact point, and therefore shows only the direct pulse. The smallest depth has a peak stress of about 500 kbar, and the peak stress decays to about 200 kabar at the deeper position. Over this small range, little broadening of the pulse with range is evident.

Figure 3 and 4 show the stress pulse at points near the free surface. Fig. 3 is for a point at 300 meter depth and a range of *20 km*. Fig 4 is for a depth of 200 meters, and a range of *12 km*. The most significant aspect of these stress histories in comparison to the Melosh model is the complete absence of a tensile portion to the history. The pulse duration is sufficiently long, and the reflected tensile pulse sufficiently weak that it cannot overcome the compressive direct wave.

The problem is to be run further, and more detailed comparisons with the previous Melosh model will be presented later.

REFERENCES. [1] Melosh, *Icarus* **59**, 234 (1984). [2] Melosh, *Geology* **13**, 144 (1985). [3-6] Melosh, *LPSC XIV ,XV,XVI,XVII* (1983,4,5,6). [7] Melosh, *Proc. 1986 Hypervel. Impact Symp*, Pergamon(1986). [8] Cole, <u>Underwater Explosions</u>,(1948). [9] Holsapple, *Proc. 1986 Hypervel. Impact Symp*, Pergamon(1986).

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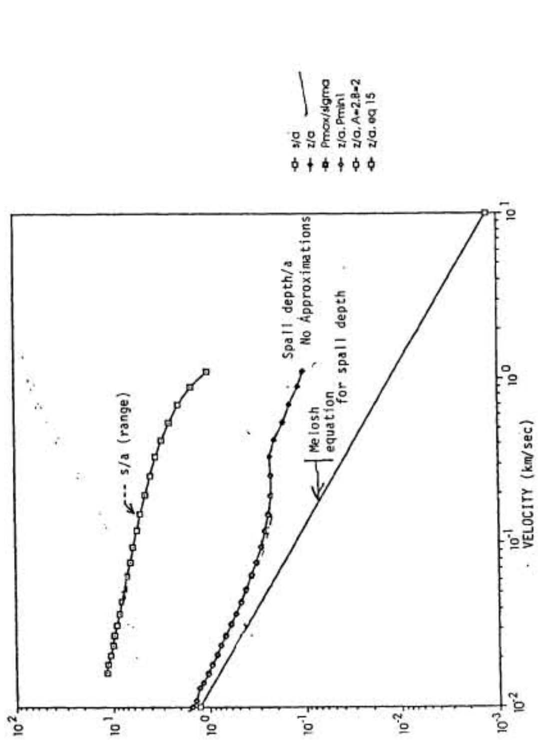

Figure 1.

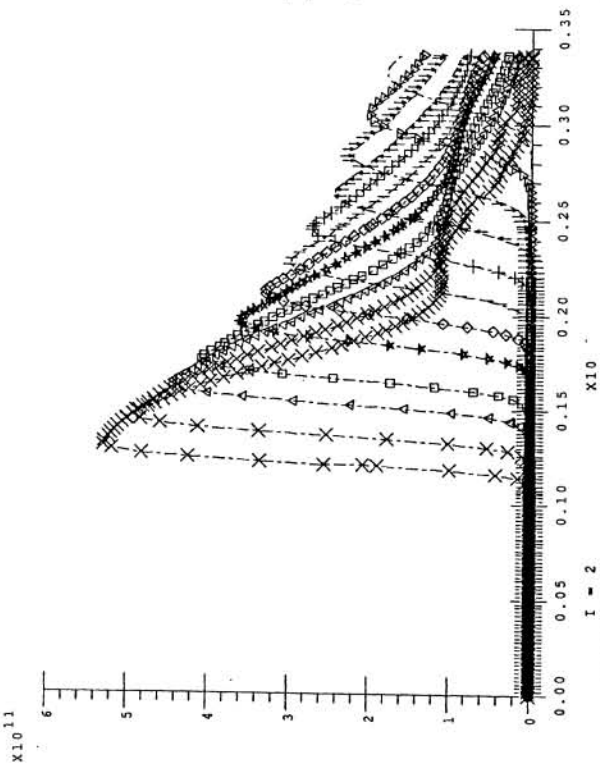

Figure 2.

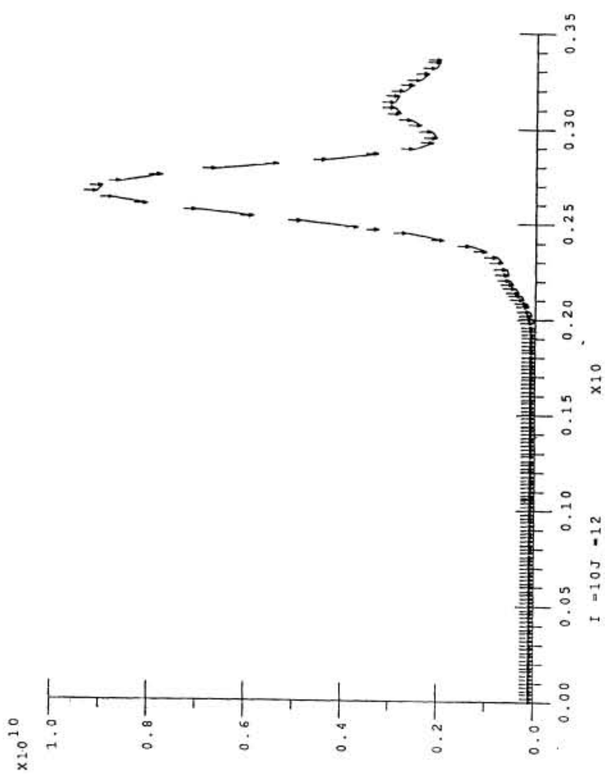

Figure 3.

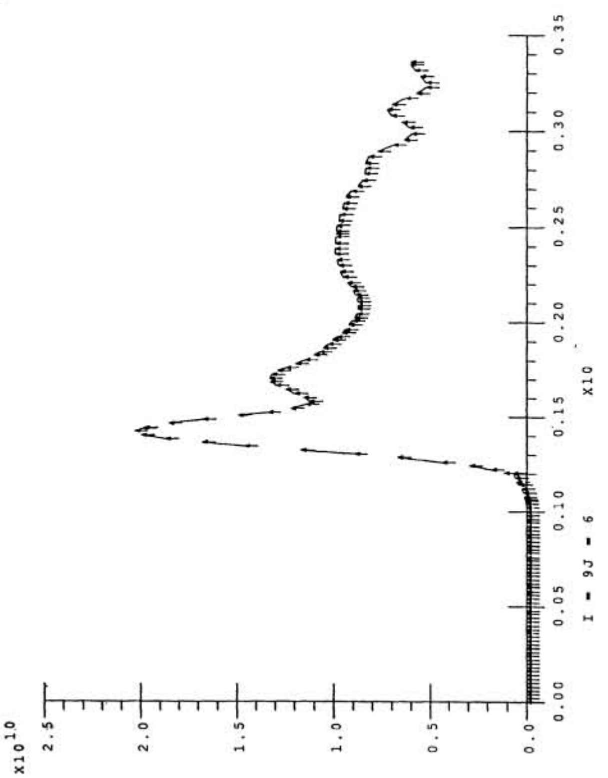

Figure 4.