PROJECTILE-TARGET MIXING IN MELTED EJECTA FORMED DURING A HYPERVELOCITY IMPACT CRATERING EVENT; Noreen Joyce Evans, Thomas J. Ahrens, M. Shahinpoor and W.W. Anderson. Lindhurst Laboratory of Experimental Geophysics, Seismological Laboratory, California Institute of Technology, Pasadena, CA 91125

Tektites contain little to no projectile contamination (1) while, in contrast, some distal ejecta deposits can be relatively projectile-rich (eg. the Cretaceous-Tertiary (K-T) boundary clay;(2))). This compositional difference motivated an experimental study of hypervelocity target-projectile mixing processes. We hope to scale up the results from these experiments and apply them to terrestrial impact structures like the Chicxulub Crater, Yucutan, Mexico, the leading contender as the site for the impact that caused the mass extinction that marks the K-T boundary (3). Shock decomposition of the $\approx$500m thickness of anhydrite, or greater thickness of limestone, in the target rocks at Chicxulub (4) may have been a critical mechanism for either global cooling via SO_3, and subsequently H_2SO_4, formation, or possibly, global warming via increased CO2 formation (4). Understanding target-projectile mixing processes during hypervelocity impact may permit more accurate estimates of the amount of potentially toxic, target-derived material reaching stratospheric heights.

A two-stage light gas gun was used to launch 6-7 km/s Fe alloy projectiles into Mo targets. Ejecta fragments (<5-180 μm diameter) were captured by 0.032 g/cm^3 polystyrene foam (5cm thick) witness plates. After the impact, the witness plates were X-rayed and then sliced at regular longitudinal and transverse intervals to determine the depth of penetration and angular distribution of captured ejecta. Each section was dissolved in chloroform and the ejecta recovered. It was observed that a portion of the ejecta was in the form of metal spheres with distinct quench textures, indicating that melting had occurred during impact.

The spheres were analysed by electron microprobe to determine the component of target (Mo) and projectile (Fe) material in each (Figure 1). Sphere velocities were estimated by balancing the energy expended during passage through the polystyrene foam against the initial kinetic energies of the spheres. Setting these energies equal and solving for velocity yields;

$$v = \sqrt{((2AD(S_{\rho_{oo}} + \rho_{oo}E_{vap})) / m)} \qquad (1)$$

where A is the cross-sectional area of the hole created by the sphere penetration, D is the penetration depth, ρ_{oo} is the foam density (0.319 g/cm^3) and E_{vap} is the vaporization energy of polystyrene. The force exerted by the sphere on the foam is approximated by $S_{\rho_{oo}}A$, where $S_{\rho_{oo}}$ is the penetration strength of the foam (0.5MPa;(5)). The mass of the sphere is given by m.

Velocity values (Figure 2) are bracketed by uncertainty in E_{vap}. If the decomposition of polystyrene produces the intermediate products acetylene and benzene, the value of E_{vap} is 2.5 x 10^6 J/kg. However, further dissociation of the benzene monomer to acetylene brings the value of E_{vap} is closer to 10^7 J/kg (6). The limiting case for application of the above model is when the internal energy gain by the foam is less than E_{vap}. For these limiting cases, an equation for hypervelocity penetration of impact fragments into soft materials (5) was used.

Combining ejection angle, velocity and compositional data (Figures 1 and 2) reveals that high angle, high velocity ejecta contains a higher projectile component than low angle, low velocity ejecta. This supports numerical predictive calculation (7). Not predicted by calculation but observed in the present experiment is a break in the compositional trend, where from 50-70°, the Fe/Mo (ie. projectile/target) ratio drops dramatically (Figure 1). Although relatively fewer spheres were recovered in this section (Figure 3), the Fe/Mo ratio for this section is based on 20 analyses and is statistically significant. Although more experiments are needed to establish with confidence that this "break zone" in the sphere composition is reproducible, subsequent experiments have shown that the sphere mass distribution (Figure 3) is reproducible.

The low angle, low velocity material generated by this experiment is not completely analogous to natural tektites for the following reasons; Firstly, the experimentally-derived material has too high a projectile component to allow a comparison with tektites which are known to contain negligible projectile contamination (2,6). Secondly, some tektites, australites for example, have travelled >5000 km from the target site and have, therefore, been ejected at relatively high angles. The high angle, high velocity material may be analogous to the projectile-rich material in ejecta deposits, such as that at the K-T boundary. If subsequent experiments support the incorporation of less than 20% target material in high angle ejecta, we may be able to more accurately model the target contribution to the stratospherically distributed dust, aerosols and gas derived from, for example, the Chicxulub target rocks.

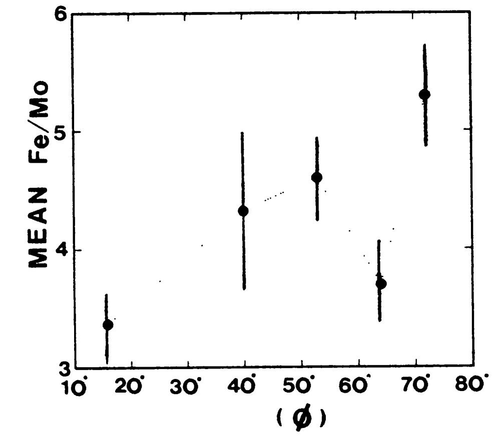

Figure 1. Mean Fe/Mo (mass ratio) versus angle of ejection (ϕ, angle from target surface). A rapid increase in the Fe/Mo ratio is interrupted by a zone from 50 to 70° where the ratio drops suddenly, only to increase to the highest values at higher ejection angles.

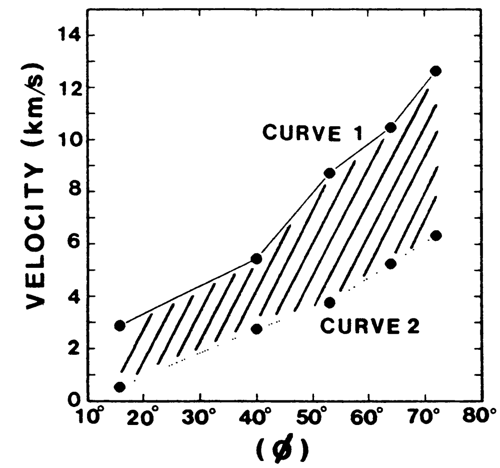

Figure 2. Mean sphere velocity (km/s) versus ejection angle (ϕ). Curve 1 and 2 correspond to E_{vap} values of 1.0 x 10^7 J/kg and 2.5 x 10^6 J/kg, respectively.

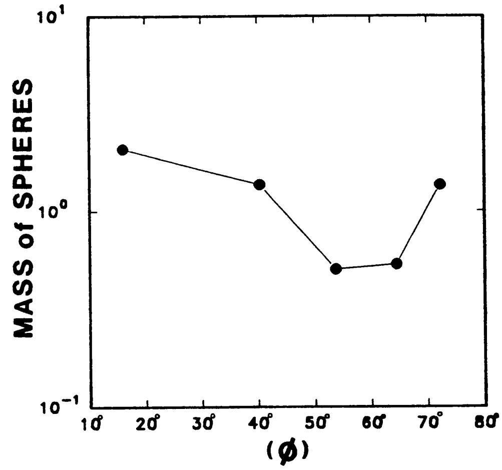

Figure 3. Sphere mass (normalized to the projectile mass, 0.09g) versus angle of ejection (ϕ).

(1) Alvarez, L.W., Alvarez, W., Asaro, F. and Michel, H.V., 1980, *Science*, 208, 1095-1108. (2) Taylor, S.R., 1973, *Earth Sci. Rev.* 9, 101-123. (3) Sharpton, V.L, Dalrymple, G.B., Marin, L.E., Ryder, G., Schuraytz, B.C. and Urrutia-Fucugauchi, J., 1992, *Nature*, v. 359, p. 819-821. (4) Brett, R., 1992, *Geochim. Cosmochim. Acta*, v. 56. p. 3603-3606. (5) Shahinpoor, M., Evans, N.J. and Ahrens, T.J., Anderson, W.W., 1992. *in prep.* for Intl. J. Impact Engng. (6) Van Krevelen, D.W., 1972. *Properties of polymers; Correlations with chemical structure*. New York, Elsevier, 427 pp. (7) O'Keefe, J.D. and Ahrens, T.J., 1982, *in* Silver, L.T., and Schultz, P.H., eds., *Geological Implications of Impacts of Large Asteroids and Comets on the Earth*: Geological Society of America Special Paper 190, p. 103-120. (8) Blum, J.D., Papanastassiou, D.A., Koeberl, C. and Wasserberg, G.J., 1992, *Geochim. Cosmochim. Acta*, v. 56. p. 483-492.