

IMPACT PHYSICS CONSTRAINTS ON THE ORIGIN OF TEKTITES. H. J. Melosh, Lunar and Planetary Laboratory, University of Arizona, Tucson AZ 85721.

Tektites are typically cm-size glassy blobs of formerly melted material that sometimes show evidence of aerodynamic shaping while molten. Although J. A. O'Keefe, in the 1960s, argued strenuously that they originated on the Moon, geochemical comparison between tektites and lunar rocks make it clear that they are in fact of terrestrial origin. The presence of shocked minerals in some tektites and the association of many tektites with impact craters (e.g., Moldavites with the Ries Crater, Ivory Coast with Bosumtwi crater in Ghana and the North American tektites with the Chesapeake Bay crater) make it most probable that tektites are produced during some phase of the impact cratering process.

Although a great deal is presently known about the chemistry of tektite glasses, less is known about the physical processes that produced them. Nevertheless, a few clues can be gleaned from the chemical and dynamical facts known about tektites. First, the lack of elevated abundances of siderophile elements in most tektites immediately rules out the most widely-cited origin of tektites as the products of "jetting." Since jetting occurs only from the interface of the projectile and target materials, its products would be heavily contaminated with material from the projectile, of which hardly a trace is observed. Evidently, tektites originate from deeper within the target rocks, yet close enough to the impact site to experience shock pressures in excess of that required for complete melting (typically about 100 GPa for silicates). High shock pressures are also consistent with ejection from the impact site at high speeds (2 to 5 km/sec, derived from the ranges of 400 to 1000 km observed between tektites and their craters of origin).

Other heretofore unexplained facts about tektites are their strong depletion in water compared to their source rocks (tektites typically possess less than 100 ppm of water, compared to a few percent for volcanic glasses of similar compositions) and the almost invariable predominance of reduced iron (tektites are typically black or green in color). Indeed, J. A. O'Keefe considered the water depletion to be one of the most significant facts about tektites and continues to oppose a terrestrial origin on the basis of the difficulty in removing water from glass, as experienced in industrial glass-making operations.

In the course of studying the physics and chemistry of impact melting and vaporization, I have looked in detail at the thermodynamic history of shock melted materials, and have uncovered some

circumstances that may explain these difficulties. Shock compression is a rapid and irreversible thermodynamic process that deposits energy in the compressed materials. Shocked to pressures of 100 GPa, silicates often reach instantaneous temperatures in excess of 50,000 K. This compression is followed by pressure release as rarefaction waves propagate downward from the target's free surfaces. This release is, to a first approximation, adiabatic and isentropic. At first, the release path decompresses a single phase supercritical silicate fluid. However, when pressures drop below about 0.1 GPa the critical point is reached and both a liquid and vapor phase appear. The liquid splash-forms of tektites suggests that their precursors reach the phase curve on the liquid side of the critical point and that rapid boiling ensues as the pressure and density continue to drop. The exsolved silicate vapor expands rapidly and accelerates the still-liquid droplets along with it. Temperatures at this time are on the order of 5000 to 10000 K, and may remain in this vicinity for tens of seconds after the impact of a 1 km diameter projectile, buffered by the later condensation of vapor back to liquid. The melt droplets at this time are being rapidly accelerated in the expanding liquid/vapor plume, with accelerations in the vicinity of 50 g. Silicate viscosities at these temperatures are very low, typically in the range of 10^{-7} Pa-sec (five orders of magnitude less than that of liquid water!). Under these conditions it seems probable that volatile-containing bubbles in the melt droplets would rapidly move to their surfaces and burst, carrying volatiles such as water, N, Ar, other rare gases and even Na and K out of the tektite glass. Furthermore, since O₂ gas seems to be a predominant phase in the vapor over silicate melts, it seems likely that O is preferentially lost from the tektite glass at this point, setting the stage for further electron transfers that finally reduce all the Fe remaining in the glass to Fe⁺. Since many bubbles could form in the very fluid melt, diffusion paths between melt and bubbles will be short so that no diffusion profiles should be observable (and they generally are not).

These events during the high temperature decompression of shocked silicates are beyond the original estimates of J. A. O'Keefe and are very different from conditions encountered during industrial glass making. However, these conditions seem to provide a natural and simple explanation for some of the major chemical traits exhibited by tektites and thus tend to confirm the idea that tektites are the products of shock melting in impacts.