CONDENSATION OF IMPACT PRODUCED VAPOR, John D. O'Keefe and Thomas J. Ahrens, Seismological Laboratory, California Institute of Technology, Pasadena, California 91125

Shock waves of amplitudes exceeding several megabars and vaporization of silicate and icy planetary surfaces extensively occurs when these are impacted at 10km/sec or greater by projectiles. When this process occurs on the earth later condensation of shock vaporized material will occur in the upper atmosphere and upon settling this material may give rise to, for example, the layers of fine-grained materials with meteoritical chemical affinities, often containing microtektites, such as found at the Cretaceous-Tertiary boundary all over the earth (Alvarez et al., 1980), and in marine sediments of at least five different distinct ages occurring in the middle Eocene to middle Oligocene (Keller et al., 1983). The velocities required for the onset of vaporization of a variety of silicates and oxide planetary materials and distensions have been computed (Ahrens and O'Keefe, 1971, 1984). The mass of vaporized material as a function of impact velocity can be obtained from equations of state and finite difference calculations (O'Keefe and Ahrens, 1977; Bjorkman, 1983). From these results the following scaling for a radius of vapor gas sphere at normal density was developed for an impact of a silicate projectile onto a silicate planet.

$$R\ (\text{vapor sphere}) = 4.9\text{x}10^{-5}\ R_I \text{ x } V^{2/3}\ (\text{cm})$$

where R_I is the radius of the impactor and V is the velocity of impact.

The condensation of the vapor sphere occurs because of cooling by isentropic expansion of the gas. The onset of the nucleation of the condensates is initiated when the gas reaches saturation conditions. The conditions for saturation were determined by computing the intersection of the release isentrope of the gas and the vapor-tension curve. We assumed that an initial internal energy density of the silicate vapor of $2\text{x}10^{12}$ ergs/g based on the calculations of O'Keefe and Ahrens (1977) and vapor tension curves for silicate and water of the form

$$\rho = \frac{C \exp\left[-H_v/RT\right]}{RT}$$

where H_v is related to the heat of vaporization and C is 3.9 x 10^{13} and 9.3 x 10^{11} dynes/cm^2 for silicate and water, respectively. The radius of the gas sphere in which saturation occurs was determined as a function of impactor diameter (Fig. 1).

The radius of nucleation condensates increases as the gas sphere expands and supercools. The time and radius at which the nucleation rate reaches a maximum was computed based upon a theory developed Yamamoto and Hasegawa (1977). We extended this theory to account for expansion as well as gas cooling. The growth of a condensate nucleii to their final size was computed as a function of impactor diameter and is shown in Fig. 2. The diameter of condensates are reduced slightly when the effects of quenching of the condensation process by expansion are included. In addition, because of quenching, not all of the gas sphere material condenses and a significant fraction would escape the gravitational field of the earth.

These results have implications regarding impact on a planetary surface such as the earth. In the case of large scale impacts (projectile diameter > 1 km) the condensation of the vapor does not occur until the vapor sphere has expanded to heights greater than the earth's atmospheric scale height. The average radius of the condensates in this case is in the centimeter range, implying much of the vaporized material condenses to large objects. This result agrees with previous calculations (O'Keefe and Ahrens, 1982) which were based on scaling Raizer's (1960) work on volatilized iron. Although impact vaporization-condensation kinetics represent a mechanism for producing spherules outside the earth's atmosphere some of which subsequently reenter and break-up in the atmosphere, it is hard to reconcile these mechanisms with uniform composition of tektites. We conclude that most of the submicron ejecta from very large impacts on the earth which we believe give rise to a worldwide stratospheric dust layer must originate from the more voluminous initially solid and liquid impact ejecta.

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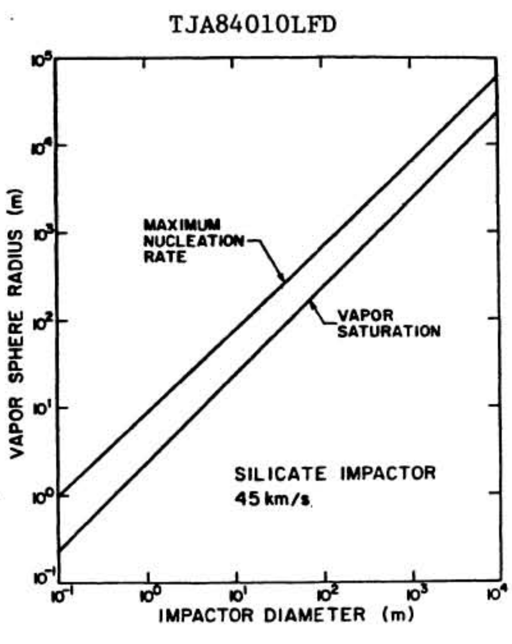

Fig. 1. Vapor sphere radius as a function of impactor diameter. The impact velocity is 45 km/s.

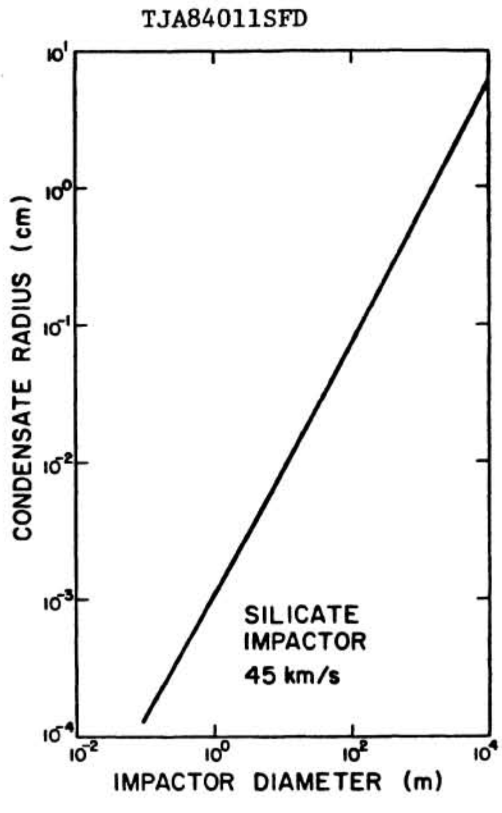

Fig. 2. The radius of the condensate as a function of impactor diameter. The impact velocity is 45 km/s.