IMPACT PRODUCED CONDENSATE AND DROPLET SIZE DISTRIBUTIONS, John D. O'Keefe and Thomas J. Ahrens, Seismological Laboratory 252-21, California Institute of Technology, Pasadena, CA 91125.

The range of impact velocities that are typical of the latter stages of accretion are sufficient to produce vaporization on the terrestrial planets (>5-11 km/sec) and on the regoliths of the larger icy satellites (>1.5-2 km/sec). The vapor upon expansion from the impact site will condense into solid particles. The melt entrained in the expanding vapor will be broken up into small droplets. These particles can play an important role in the early evolution of a planet's proto-atmosphere (Abe and Matsui [1], O'Keefe and Ahrens [2]). Moreover, the degree to which impact ejecta upon loading the upper atmosphere with aerosols contributes to decreases in solar insolation may play a critical role in the causes of mass extinction (Alvarez et al. [3]).

The velocities required for the onset of vaporization for the impact of a silicate body on a silicate planet is in the range of 2-15 km/s depending upon material and its porosity [4]. The mass of vapor produced has been previously calculated [5].

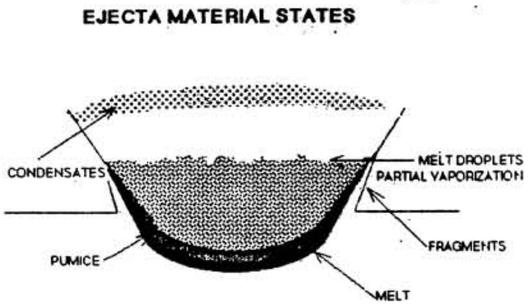
There are two vaporization regimes of interest: complete and partial. Complete vaporization occurs when there is no remaining liquid upon expansion to a partial pressure of one atmosphere. Partial vaporization is when upon release to one atmosphere, liquid is entrained in the expanding vapor (Fig. 1). The initial material that expands away from the impact site is highly shocked and is completely vaporized. This vapor will expand to a height that is many times the initial impactor radius before condensation begins. The material below the pure vapor contains both vapor and entrained melt. Local pockets of vapor are produced which expand and accelerate the surrounding melt and break it up into small droplets. When the fraction of the vapor to melt is low, expansion is incomplete and frothy pumice-like rocks are produced (e.g. fall-back ejecta at Barringer (Meteor) crater [6]).

We have developed a model for the impacts of silicate and ice projectiles on silicate and ice planets which describes the vapor saturation, the nucleation and growth of the condensates, and condensate and droplet size distributions.

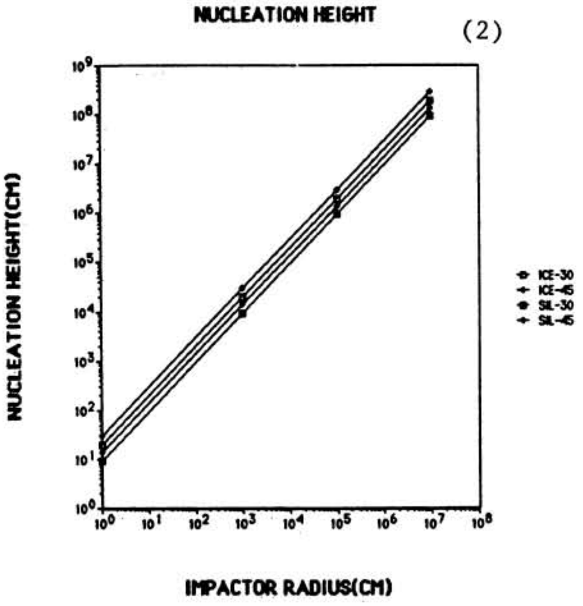
Using previous calculations [5] to determine the mass and thermodynamic state of vapor, we computed the altitude for saturation (Fig. 2). Nucleation and growth of condensates was calculated using the homogeneous nucleation theory of Yamamoto and Hasegawa [7] and Lattimer [8]. The altitude for which maximum nucleation occurs ranges from 7 to 20 impactor radii for silicate impacts and 10 to 40 for ice impacts. For a projectile, possibly representative of the K-T bolide [3] (5 km radius silicate, impacting the Earth at 30 km/s), the altitude where condensation would be initiated is > 35 km. This far exceeds the atmospheric scale height (7 km) and implies that the condensates would be produced outside the Earth's atmosphere and could be propelled on ballistic trajectories that would result in global distribution. These particles would reenter the atmosphere and the larger ones may have ablation features. The mean condensate radii were calculated and as a function of the impactor radius (Figure 3). The mean condensation radius is proportional to impactor size for a given velocity. Increasing the impact velocity increases the vapor mass produced which increases the mean condensate radii, however, the average internal energy also increases, this decreases the mean radii. The net result is that the mean radii increases slowly with impact velocity.

At impact velocities above 10 km/s silicate materials are partially vaporized. We assume the melt is entrained and accelerated by the vapor and the droplet sizes depend on their stability with respect to velocity fluctuations. The number distribution of particles from this model is comparable to the measured microtektite distributions in Figure 4.

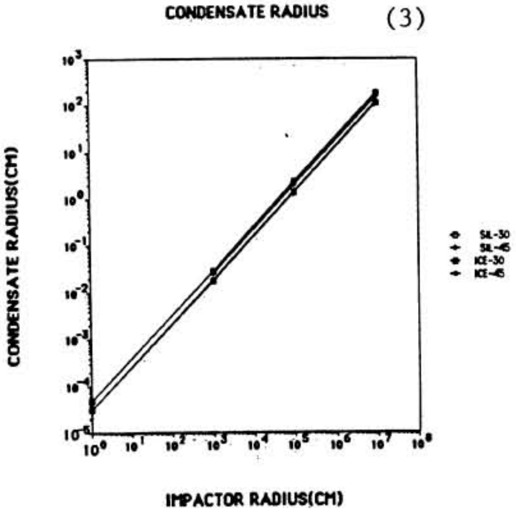
(1)



(2)



(3)



(4)

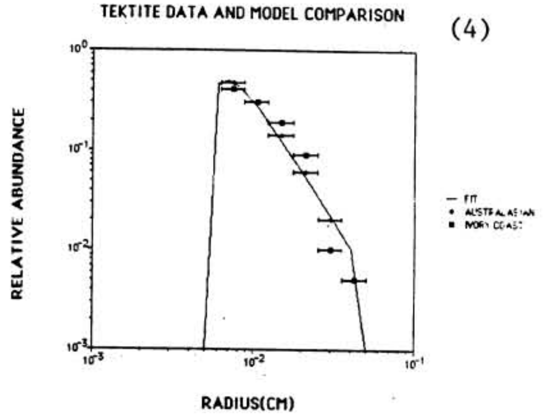


Fig. 1. Schematic distribution of material ejected from a high speed impact onto a silicate. TJA88019STR

Fig. 2. Nucleation heights as a function of impactor radius for impacts of silicate on silicate and water ice on water ice. Impact velocities are 30 and 45 km/s. TJA88020SFD

Fig. 3. Condensate particle radius versus impactor radius for impacts of silicates on silicates and water ice on water ice. Impact velocities are 30 and 45 km/s. TJA88021SFD

Fig. 4. Relative abundances of microtektites [9]. Solid line is the calculated distribution using the present partial vaporization model. TJA88022SFD

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