The Effect of the Atmosphere on Large-Scale Impacts - Extinction Mechanisms and The Origin of Tektites

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Alvarez, T., and others have provided physical evidence for the impact of an extraterrestrial object contemporaneous with the Cretaceous-Tertiary (K-T) boundary (63 Ma). A 1 to 150 cm clay layer, of globular extent, is enriched in noble metals and other elements relative to crustal abundances by a factor of 5 to 1000. Because the clay layer is at the K-T boundary, it has been argued that the impact is the cause of the K-T extinctions of biota. The most compelling evidence for the correlation of an impact event with the K-T extinctions is contained in the marine sediment record of the phytoplankton. The extinction of phytoplankton has also been correlated with layers of microtektites and small glass spherules (tektites?).

We have examined the mechanics of large-scale (diameters > 10 km) asteroidal, cometary, and meteorite swarm impact to determine whether or not the physical evidence is compatible with an impact event.

We estimate that 1 to 20 times the mass of the bolide is fine particles less than 1 mm that can be lofted to heights greater than 10 km and thus be distributed worldwide. Calculations of solar transmission reduction due to dust injection show that 10^8 g, uniformly distributed, would reduce photosynthesis by a factor of 10^4. Although the atmosphere receives little energy upon direct interaction with the bolide, once impact upon the surface occurs, the subsequent ejection transfers both kinetic and internal energy to the atmosphere. The energy transfer to the atmosphere was computed from transfer of kinetic energy by atmospheric drag and internal energy via thermal transfer, taking into account the particle size distributions for the vaporized, melted and solid ejecta. The fraction of bolide energy transferred to the atmosphere is ~15%. For 10^2 erg impact this would result in a global average temperature increase of ~ 1°C. Although this temperature excess is radiatively lost in several days, Emilian et al. suggest that it might be intolerable for many biota [especially larger reptiles (> 25 kg)]. The tropospheric temperature may then sharply decline due to the dust injection in the upper atmosphere.

References:
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Fig. 1 Log₁₀ (energy in melt and vapor ejecta, and total ejecta/initial meteorite energy), versus, log₁₀ (minimum ejecta height).

Fig. 2 Ejecta cumulative mass fraction, versus, ejecta diameter and maximum size fragment velocity.

Fig. 3 Maximum droplet size, versus, flow velocity difference for dynamic stability for liquid silicate (300 d/cm) drops.

Fig. 4 Flow field for impact of 10 km diameter silicate (An) projectile onto a 10 km thick 0.001 g/cm² atmosphere overlying a silicate (An) half-space.