Formation of the K-Pg Boundary Layer

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Introduction: Although it is widely agreed that the K-Pg boundary layer contains ejecta from the Chicxulub impact [1], the mode of transport of ejecta around the world to its final destination remains enigmatic. After impact, vaporised, melted and lithic fragments from the asteroid and target rocks leave Chicxulub within a plume and ejecta curtain, with the impact plume initially rising upwards surrounded by a cone-shaped ejecta curtain [2]. Numerical simulations of ejection of material from Chicxulub reveal that the first ejecta to leave the impact site, within the plume and uppermost part of the ejecta curtain, leaves at the highest velocity (> 7 km/s) and is dominantly formed of vaporised projectile and decomposed sediments [3-4]. Impact melt from the Chicxulub basement, which was > 3 km below surface at the time of impact, is ejected later at lower velocities, while all solid (shocked) basement leaves at velocities of < 3 km/s. These observations are intriguing since, in the K-Pg layer at proximal and intermediate sites (< 4000 km from Chicxulub), splash form microtektites sit below the iridium-rich layer that also contains the shocked quartz [1]. It is widely agreed that the microtektites are formed from droplets of melt from the Chicxulub basement mixed with sedimentary material [5], that the iridium is from the asteroid [1], while the shocked quartz is from the basement [3].

In numerical simulations, interactions between the atmosphere and Chicxulub ejecta curtain lead to its collapse to form a fast-moving cloud that travels all around the globe [4]. The majority of the projectile sits at the front end of the cloud, which reaches ~8000 km from Chicxulub after 2 hours, and is travelling at speeds of 1- 3 km/s above the mesosphere. In contrast, the majority of the shocked basement is nearer to the back of the cloud, and moving at speeds of < 1 km/s. The precise mass of the cloud at any time, and fallout of ejecta particles from the cloud as it travels away from Chicxulub, is dependent on the assumptions used on initial particle-size distribution. Proposed size-frequency distributions from the literature suggest *b* exponent values of between 0.8 and 1.2, with the ejected mass dominated by finer grain sizes for the higher *b* exponent values [4]. Whichever size-distributions are used, all particles greater than 8 mm in diameter leave the cloud (reach altitudes of below 8 km) within 1-2 hours of impact and proceed to settle at the Earth’s surface up to distances of ~1000 km from Chicxulub [4]. In addition, most (> 99%) solid basement particles with diameters of < 8 mm fallout in less than 2 hours. With regards to basement ejected as melt, which (on average) is travelling within the cloud at slightly faster velocities than shocked basement, 90-99% of particles 0.1 – 8 mm in diameter and 85-95% of particles of < 0.1 mm in diameter fall out within 2 hours.

The gradual fallout of larger particles as the cloud moves away from Chicxulub, as well as the rapid decrease in shocked basement particles in the cloud in the first 2 hours, is consistent with observational data. Microtektites are larger (1 – 8 mm in diameter) at proximal sites (e.g. Beloc, Mimbral and Blake Nose), and smaller (0.2 – 1.4 mm) at intermediate sites (e.g. Tanis and Gorgonilla) [6,7]. The total number per gram and size of shocked quartz gradually decrease with distance from Chicxulub [8]. In the USA there are >1000 fragments of shocked quartz per g with an average diameter of 60 µm (max 200 µm), and there are < 100 per g in New Zealand, with an average diameter of 30 µm (max 60 µm) [8]. In addition, the microtektites reach the surface of the Earth before the shocked quartz due to their higher average velocity in the cloud and their larger size – once below ~8 km altitude a 1-mm-diameter microtektite settles to surface in ~1000s, whereas a shocked quartz particle of 0.1 mm in diameter arrives after >10,000s. Finally, the presence of microtektites in Italy [9] is also consistent with the simulations, since smaller particles of initially melted basement remain in the cloud for > 2 hours. More difficult to explain is the lack of any clear change in particle size or number per gram with distance from Chicxulub for the microkrystites (MK). It is possible that: MK have a restricted size-range on formation, that larger MK ablate within the cloud during transportation, and smaller MK degrade quickly and do not survive long after deposition.

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