THE FATE OF EJECTA RAYS IN THE EARTH'S ATMOSPHERE: FROM POPIGAI TO CHICXULUB

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Introduction: Long rays emanating from lunar craters suggest heterogeneous distribution of distal ejecta by impact processes. Rays of distal ejecta have been recently proposed for the Late Eocene clinopyroxene (cpx) spherule layer [1], which is linked to the 100-km diameter Popigai crater in Siberia. Known cpx spherule sites are found within three wide rays radiating from Popigai [1] and follow predicted ballistic trajectories [2]. However, the distal spherule layer from the 180-km diameter Chicxulub impact is fairly uniform [3] and previous modeling work [4] suggested that interactions between falling Chicxulub spherules and atmosphere led to lateral migration of ejecta and uniform deposition. Why then might we observe ejecta rays around Popigai? Our models show that the degree of lateral ejecta spreading depends on the spherule density delivered to the upper atmosphere, consistent with the observed wide rays around Popigai and continuous distal ejecta around the larger Chicxulub structure.

Modeling: We model the interactions between ejecta rays and the atmosphere using the two-dimensional, two-phase fluid flow code KFIX-LPL which is a modified version of KFIX [5]. Starting with a rectangular mesh representing a slice of Earth's atmosphere with an exponential pressure gradient, we inject a "ray" of spherical particles vertically into the middle of the mesh at 8 km/s. Spherule entry fluxes and spherule sizes are varied, including Popigai- and Chicxulub-like scenarios.

Atmospheric Spreading: The falling spherules decelerate due to drag and accumulate in a band at ~70 km altitude. The decelerating spherules compress the upper atmosphere, creating a pressure gradient between compressed and uncompressed atmosphere and leading to lateral spreading of spherules. Horizontal spreading velocities are enhanced for (1) higher spherule entry fluxes due to increased pressure gradients across the edges of the rays and (2) smaller spherule sizes. Compared to the layer thickness and average spherule size at Chicxulub sites (2-3 mm, 250 µm [3]), the cpx spherule layer is thinner and the spherules are smaller (~0.6 cm, ~200 µm [6]). Although the size distribution of cpx spherules has not been studied in detail, droplet formation models [7] suggest a characteristic size similar to Chicxulub spherules. In our simulations, spreading is reduced in the Popigai scenario due to lower spherule fluxes. According to our models, wider rays should be observed around bigger craters and, for the largest impacts, such as Chicxulub, only a uniform layer remains. Our models also predict that, if the proposed Popigai rays are real, decreased layer thickness and mean spherule size should be observed towards the edges of any ray transect.

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