INTERACTIONS BETWEEN CHICXULUB EJECTA AND THE ATMOSPHERE: THE DEPOSITION OF THE K/T DOUBLE LAYER. T. J. Goldin[1] and H. J. Melosh[2], [1]Department of Geosciences, University of Arizona, Tucson, Arizona 85721 (tgoldin@geo.arizona.edu), [2]Lunar and Planetary Lab, University of Arizona, Tucson, Arizona 85721 (jmelosh@lpl.arizona.edu).

Introduction: The mechanics of impact ejecta deposition are not well understood, especially for impacts onto planets with atmospheres, such as Earth, where complex interactions occur between the ejected particles and the surrounding atmosphere. Current models of ejecta emplacement, which rely on the fact that material is ejected from craters on ballistic trajectories, are unable to account for multiple layers of ejecta deposited around some terrestrial craters such as Chicxulub, where a dual ejecta layer is observed in North America. Studying the interactions between Chicxulub impact ejecta and the atmosphere is particularly important for understanding the environmental effects of this catastrophic impact.

Chicxulub Ejecta: The ejecta layer at the K/T boundary has been linked to the 65-Ma Chicxulub impact off the coast of the Yucatan, Mexico. The layer is found world-wide, increasing in thickness towards the crater. The distal ejecta layer, which is found at sites more than 7000 km from the crater, has a fairly constant thickness of 2-3 mm [1]. In general, the distal ejecta layer, the "fireball layer", consists of densely packed spherules (average diameter of 250 µm) with a spherule area density of ~20,000 per square centimeter [2]. The layer is also enriched in Iridium, an impact indicator, which suggests an origin from the impact vapor plume.

At sites of intermediate distance (2000-4000 km) from the crater in continental North America, the Chicxulub impact ejecta consists of two layers: In addition to the ~3 mm-thick upper layer containing the Iridium anomaly and spherules, there is a lower, thicker (i.e. ~2 cm-thick in Raton Basin, NM) layer consisting of mainly terrestrial claystone [2]. It has been suggested that the upper layer is equivalent to the distal fireball layer and the lower layer represents material from the ejecta curtain, but the mechanics of producing two distinct layers is unclear. The dual-layer stratigraphy has led to the argument of a second impact event, but it is also possible that atmospheric interactions can explain the emplacement of two distinct ejecta layers.

Additionally, a soot has been identified at the K/T boundary [3], suggesting the impact somehow triggered global wildfires. The soot is found *within* the ejecta layer [3] implicating the ignition of forests soon after the impact. The heating is linked to ejecta reentry [4], but models are needed to determine the distribution of this heat within the atmosphere.

Modeling: KFIX-LPL is a version of the KFIX code [5], which has been modified to suit the problem of impact sedimentation. KFIX is based on the original KACHINA code [6]. The finite-difference code models two-dimensional, two-phase fluid flow allowing us to examine the interactions between the atmosphere and ejected particles (spherules).

Distal fireball layer. We modeled a simplified distal Chicxulub scenario of the injection of uniform sized (250-µm diameter) spherules into the atmosphere at 8 km/s, at an altitude of 200 km and with a inflow density consistent with the volume of spherules observed in outcrops. The initial mesh approximates the Earth's atmosphere and employs an exponential pressure gradient, constant temperature (although, in reality, there is some temperature variation in the atmosphere), and standard gravity of 9.8 m/s^2. Air is modeled using the equation of state of a perfect gas and the spherules are modeled as a simple incompressible fluid with the properties of basaltic glass.

The particles fall through the thin upper atmosphere, pushing the atmosphere downwards until the particles decelerate due to drag and increasing atmospheric pressure. As can be observed in Figure 1, the particles accumulate a dense layer at ~50-km altitude. The deceleration of spherules heats the atmosphere (>700 K) around the particles causing expansion of the atmosphere, creating a sharp boundary between hot dense atmosphere below the spherules and cool thin atmosphere above.

Double layer. Deposits from the ejecta curtain are expected to extend to the intermediate distances (2000-4000 km from Chicxulub, [2]) where the double layer is observed. Thus, we employed an initial brief injection of terrestrial ejecta into our model atmosphere in addition to the more prolonged flux of fireball material. The compression of the atmosphere by the terrestrial material alters the structure of the atmosphere causing the fireball material to fall separately and resulting in the deposition of two distinct layers. Deposition of the lower terrestrial layer on the ground begins at ~80 minutes and that of the upper fireball layer begins at ~130 minutes. The layers are thus deposited quickly, aided by the development of instabilities in the atmosphere (Fig. 2).

Summary: Results from KFIX-LPL models suggest that the influx of distal ejecta spherules into the upper atmosphere following the K/T impact event compressed the upper atmosphere, disrupted the normal pressure gradient, and heated the atmosphere at an altitude ~50 km, causing expansion of the lower atmosphere. It has been proposed that thermal energy radiated from ejecta reentering the atmosphere caused global wildfires [4] and our models, which include thermal radiation, provide support for significant at-

mospheric heating. Such extreme changes to the atmosphere also explain the deposition of the vapor plume and ejecta curtain material as two distinct layers at intermediate distances from Chicxulub and our models suggest that deposition of both layers occurred over a timescale of hours. The double layer observed in North American localities does not require two impacts, and is, in fact, *expected* from a single impact.

References:

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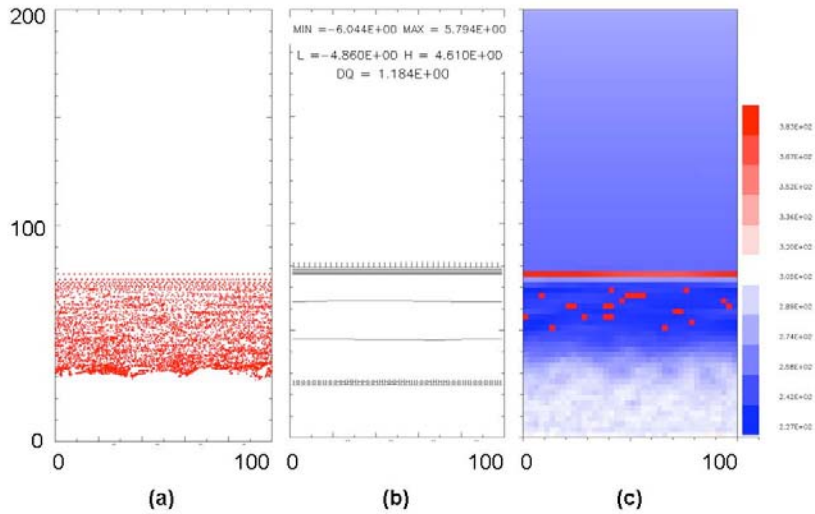

Fig. 1. Plots showing (a) the positions of injected liquid tracers (fireball spherules), (b) log pressure contours where pressure is measured in bars, and (c) temperature contours in Kelvin after 80 minutes (assuming simple black body thermal radiation) for the distal fireball layer model. Injection angle is 45 degrees and all axes are labeled in kilometers.

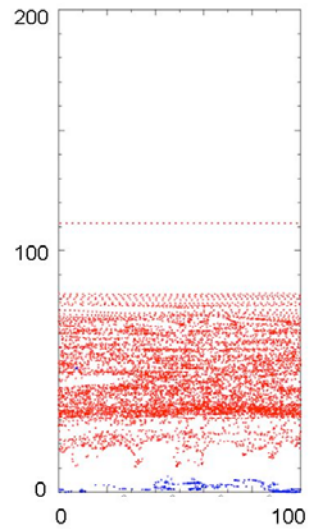

Fig. 2. The position of injected liquid tracers (spherules) after 90 minutes for locations ~2000 km from the point of impact, where there is both an initial ejecta curtain pulse (blue tracers) and the fireball pulse (red tracers). At 90 minutes, the ejecta curtain material is being deposited to form a lower layer, distinct from the fireball material which will form the upper layer. Note the irregular nature of both types of ejecta as they approach the ground. Tracers track movement of the spherule phase but do not represent spherule densities (i.e. total mass of the fireball pulse is much less than that of the ejecta curtain terrestrial pulse).