NUMERICAL SIMULATIONS OF CHICXULUB EJECTA

N. Artemieva[1] and J. V. Morgan[2], [1] Planetary Science Insititute, 1700 East Fort Lowell, Tucson, AZ, USA, 85719, artemeva@psi.edu, [2]Department of Earth Science and Engineering, Imperial College London, SW7 2AZ, UK, j.morgan@imperial.ac.uk

Introduction: The origin, composition and formation of the K-Pg boundary clay layer have all been topics of intense scrutiny since the extra-terrestrial hypothesis was first proposed in 1980 [1, 2]. Although it is widely agreed that the layer is formed from ejecta from the Chicxulub impact crater, the mechanics of ejecta dispersal remain uncertain [3, 4, 5]. The consensus is that spherules (microtektites) close to the impact site and within the lower layer in North America were formed from melted target rock that traveled within an ejecta curtain on a ballistic path, whereas the upper layer and distal layer (> 6000 km from Chicxulub) were formed from projectile and target material ejected at high velocity within an expanding plume, and that smaller spherules (microcrystites) in this layer condensed from the impact plume [3, 6]. To further explore how ejecta arrive at their final destination, we model: 1) the impact, including the formation of a transient cavity, ejecta curtain and plume; 2) the interaction of the ejecta curtain and plume with an atmosphere; 3) ejecta travel around the globe; and 4) ejecta re-entry from space. We use the SOVA hydrocode [7] to model ejecta dispersal and re-entry, and use a 60-degree impact angle for our models, which is in accordance with new 3D models of the formation of the Chicxulub crater that suggest a 60 ± 10 degree impact towards the southwest best explains the crater structure constrained using geophysical data [8].

Results: Significantly, the largest mass of ejecta material (> 80%) lies within the ejecta curtain, not the impact plume, which means that there is not enough mass within the plume to form all the microcrystites within the distal ejecta layer. Moreover, partially vaporized ejected projectile materials outnumber the vaporized basement even if we assume extremely low critical pressure for the onset of silica vaporization in accordance with recent experiments [9]. The atmosphere is highly disturbed by impact-generated shock waves and the ejecta itself, and this leads to ejecta curtain material being spread out laterally, such that these ejecta do not follow a purely ballistic path. The passage of ejecta through the atmosphere causes intense heating and expansion of the atmosphere, which leads to finer particles being re-directed and suspended for longer than predicted for ballistic travel [5, 10]. These ejecta-atmosphere interactions have several important consequences: 1) That the deposited ejecta curtain material has a more constant thickness than predicted for pure ballistic travel, which is consistent with the near-constant thickness of the K-Pg layer across North America; 2) Projectile-rich material in the uppermost ejecta curtain, that travels at higher velocities (>3 km/s) is vaporized on re-entry and thus, could, contribute to the formation of the microcrystites; 3) Basement-rich material in the lowermost ejecta curtain, which travels at lower velocities (1-2 km/s), passes through the atmosphere without being vaporized, in accordance with the composition of the lower layer in NA and presence of shocked quartz worldwide [5, 6]; and 4) Some solid sedimentary ejecta, which is a large component of the entire ejecta curtain, is vaporized upon re-entry, leading to the release of additional climatic gases by this impact event [11].

Open questions: 1) The modeled composition of K-Pg sites with a dual layer stratigraphy (> 2000 km and < 4000 km from Chicxulub) contain too much projectile in the lower layer, which is inconsistent with the observed absence of highly siderophile elements (HSE), hence, an additional mechanism is required to separate HSE from silicate melts; 2) Fast back reactions could substantially decrease the total amount of climate-active gases in atmosphere; 3) Fine (<1 μm) dust could stay in the upper atmosphere for years and cause an extended global winter, but current numerical estimates are poorly constrained.

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References: [1] Smit J. and Hertogen J. 1980, *Nature* 285, 198-200. [2] Alvarez L.W. et al. 1980, *Science* 208, 1095–1108. [3] Alvarez W. et al., 1995, *Science* 269, 930–935. [4] Kring D.A. and Durda D.D., 2002, *Journal of Geophysical Research* 107, 10.1029/2001JE001532 [5] Artemieva N., and Morgan J., 2009, *Icarus* 201, 768-780. [6] Pollastro R. M. and Bohor B. F., 1993, *Clays and Clay Minerals* 41, 7-25. [7] Shuvalov, V.V., 1999, *Shock Waves* 9, 381-390. [8] Collins G. S. et al., 2017, *LPS XLVII*, Abstract # 1832. [9] Kraus R.G. et al. , 2012, *JGR Planets* 117, E9009. [10] Goldin T. J. and Melosh H. J., 2007, *LPS XXXVIII*, Abstract #1338. [11] Artemieva N. et al. 2017, *Geophysical Research* Letters 44, 10180-10188. [12] Morgan J.V. et al., 2016, *Science* 354, 878-882.