EPSC Abstracts
Vol. 8, EPSC2013-586-1, 2013
European Planetary Science Congress 2013

K-Pg Wildfires: modeling, experiments and observations

J. Morgan (1) N. Artemieva (2,3) C. Belcher (4), R. Hadden (5) G. Rein (5) and T. Goldin (6)
(1) Department of Earth Science and Engineering, Imperial College London, UK (j.morgan@imperial.ac.uk)
(2) Planetary Science Institute, 1700 E. Fort Lowell Road, Suite 106, Tucson, USA
(3) Institute for Dynamics of Geospheres, Moscow, 117979, Russia
(4) College of Life and Environmental Sciences, University of Exeter, Hatherly Laboratories, Exeter, UK.
(5) Department of Mechanical Engineering, Imperial College London, London, UK
(6) Nature Geoscience, Nature Publishing Group, 4 Crinan Street, London, UK

Abstract

The discovery of soot in K-Pg boundary clays [1] started a long debate about whether the asteroid impact ignited global wildfires. The K-Pg layer is formed from material ejected from the Chicxulub site, which travelled at hypervelocities around the world. When such ejecta re-enters the Earth's atmosphere it decelerates and heats up, and delivers a pulse of radiation to the Earth's surface. Recent estimates of the radiation associated with ejecta re-entry [2] are argued to be large enough to have ignited fires globally [3]. Here, we present new 3D models of the thermal pulse that takes into account the asymmetric distribution of ejecta, which depends on the angle and direction of the Chicxulub impact [4]. We have replicated some of the modeled thermal pulses with a Fire propagation Apparatus (FPA), to investigate their effect on both dry and living plant matter. The models, experiments and observational data are consistent with some wildfires being ignited as a direct result of the impact, but the mass flux of ejecta at sites uprange of Chicxulub is too low to ignite even the most susceptible of plant matter.

1. Introduction

The discovery of large amounts of soot in K-Pg boundary clays led to the hypothesis that major wildfires were a consequence of an asteroid impact [1]. Subsequently, several lines of evidence, including the lack of charcoal in North American sites, were used to argue against global wildfires [5]. Close to the impact site fires are likely to be directly ignited by the impact fireball, whereas globally they could be ignited by radiation from the re-entry of hypervelocity ejecta. To-date, models of the latter have made assumptions about the re-entry velocity and mass flow rate of ejecta, and assumed that ejecta re-enters the atmosphere close to its final destination. Such models fail to take into account that ejection is asymmetric and dependent on impact angle, and that ejecta travels significant distances laterally after its arrival at the top of the Earth's atmosphere [4]. Importantly, radiation is delivered to the Earth's surface where the ejecta re-enters the atmosphere, not its final destination.

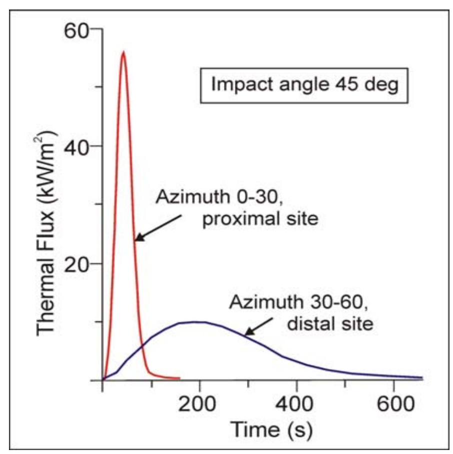

Figure 1: Examples of modeled radiation for a 45-degree impact angle. The two pulses are for proximal and distal sites, 2000-2500 km and 7000-8000 km from Chicxulub, respectively. For the azimuths shown, 0 degrees is the downrange direction.

2. Modeling

We have modeled impact angles of 45 and 60 degrees, as these values cover the range that appears to best fit the total volume and meteoritic composition of the global ejecta layer [4]. We model the impact and ejection of material from Chicxulub, its travel on a ballistic path around the Earth, and the thermal radiation associated with its passage through the Earth's atmosphere. Modeled thermal pulses are highest in the downrange direction at sites close to Chicxulub (Figure 1). Radiation at locations in different directions and/or further away from Chicxulub is less intense but of a longer duration. The mass flow of ejecta in the uprange direction (azimuths of 90-180 degrees), and associated radiation, are low.

3. Experiments

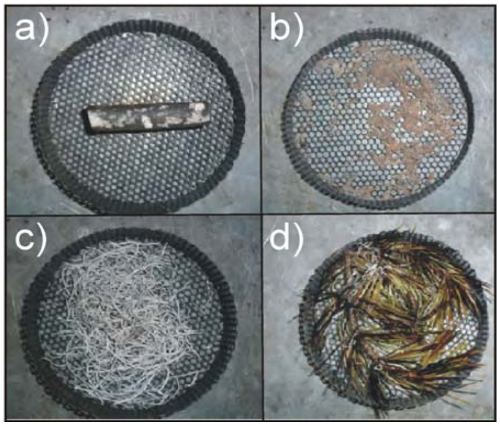

Figure 2: Example plant remains after the FPA tests. a) Picea glauca, b) Querus sp (dead and dry), c) Pinus pinaster, (dead and dry) and d) Pinus sylvestric

We have reproduced a selection of our modeled thermal pulses with a FPA [see 6 for details on FPA] to examine their effect on a variety of plant materials (Figure 2). We observed that ignition was most likely to occur in samples of dry litter, which indicates that some surface fires were a direct result of the Chicxulub impact. Living plant matter was more resistant to ignition; these samples tended to undergo water evaporation and/or pyrolysis reactions, leaving them dried and, in some cases, charred (e.g. Figure 2a and 2d). Such effects are likely to have increased the potential for tree mortality, as well as ignition through natural mechanisms in the days/months that followed the impact.

4. Summary and Conclusions

We conclude that some wildfires were ignited by the impact fireball and ejecta re-entry, but that fires were not ignited globally as a direct and immediate result of the Chicxulub impact. The desiccation of flora by ejecta re-entry in the downrange direction of impact, as well as the effects of post-impact global cooling/darkness, probably left much of the terrestrial flora susceptible to necrosis and post-impact fires. Our results are consistent with the observational data, including the global soot record [1], the presence of fungal and fern spores at K-Pg boundary sites [7], and the charcoal record in North America [5].

Acknowledgements

JM acknowledges funding from the Leverhulme Trust to undertake this project. CB acknowledges funding from a Marie Curie Career Integration Grant (PyroMap PCIG10-GA-2011-303610) and U. Exeter.

References

[1] Wolbach, W.S., Lewis., R.S., & Anders, E., Cretaceous extinctions: evidence for wildfires and search for meteoritic material, Science, vol. 230, pp. 167-170, 1985.

[2] Goldin, T., & Melosh, H.J., Self shielding of thermal radiation by Chicxulub impact ejecta: firestorm or frizzle. Geology, vol. 37, pp. 1135-1138, 2009.

[3] Robertson, D.S., Lewis, W.M., Sheehan, P.M., & Toon, O.B. K/Pg Extinction: Re-evaluation of the Heat/Fire Hypothesis. J. Geophys. Res., DOI: 10.1002 jgrg.200182013, 2013.

[4] Artemieva, N., & Morgan, J. Modeling the formation of the K-Pg boundary layer, Icarus, vol. 201, pp. 768-780, 2009.

[5] Belcher, C.M., Collinson, M.E., Sweet, A.R., Hildebrand, A.R., and Scott, A.C., Fireball passes and nothing burns – The role of thermal radiation in The C-T event: Evidence from the charcoal record of North America, Geology, vol. 31, pp. 1061-1064, 2003.

[6] Belcher, C. L Mander, G Rein, FX Jervis, M Haworth, S Hesselbo, IJ Glasspool, JC McElwain, Increased fire activity at the T/J boundary in Greenland due to climate driven floral change, Nat. Geosci. vol. 3, pp. 426-429, 2010

[7] Vajda, V., Raine, J. I., and Hollis, C. J., Indication of global deforestation at the Cretaceous-Tertiary boundary by New Zealand fern spike, Science, vol. 294, pp. 1700-1702, 2001.