THE DISTRIBUTION OF WILDFIRES IGNITED BY HIGH-ENERGY EJECTA FROM THE CHICXULUB IMPACT EVENT.

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Introduction: One of the largest disruptions of the global carbon cycle in Earth history occurred 65 million years ago following the Chicxulub impact event. In the marine environment, it appears the flux of organic material to the deep sea took about 3 million years to recover [1]. In a continental setting, specifically the western interior of North America, it may have have taken as long as 130,000 ± 5,000 years for the carbon cycle to recover [2]. One of the largest disturbances was caused when impact ejecta shock-heated the atmosphere so severely that wildfires were produced [3]. The remnants of these wildfires are found in the form of charcoal and soot in layers of sediment deposited at the time of impact [e.g., 4,5]. Because forests (at least modern ones) contain ≥80% of all above ground carbon [6], the loss of these ecosystems would have severely perturbed the carbon cycle. Previously, the wildfires were thought to be global. However, recent calculations of the trajectories of high-energy ejecta indicate this debris was heterogeneously distributed around the world [7], which likely affected atmospheric heating and the distribution of wildfires. For that reason, we have reinvestigated the degree of atmospheric heating and the distribution of wildfires around the world.

Model Calculations: The trajectories and distribution of high-energy ejecta were calculated using a numerical code that was optimized for Earth's shape, gravity, and rotation [7]. These results indicate that material reaccreted to all areas of the globe, but that debris was preferentially concentrated near the impact site and at the antipode, which, 65 million years ago, occurred over the Indian sub-continent and the proto-Indian Ocean. In addition, the calculations indicate high-energy ejecta would be concentrated in the path of the projectile's trajectory (e.g., to the SE of the impact site if the trajectory was SE to NW).

To determine the amount of atmospheric heating generated when the material reaccreted, we assigned mass to the tracer particles in that simulation. Mass was assigned using the results of a second set of simulations [8], which used a hydrocode to calculate the amount of material ejected from the crater. Three of these simulations (each with different impact parameters) produced craters the size of Chicxulub, indicating a possible range of ejected mass entrained in the vapor plume from 1 to 2.5×10^{16} kg. Distributing this mass to the tracer particles in the numerical code that modeled the trajectories of ejecta, we then calculated the power delivered by this material as a function of time and for all locations around the world. As examples of these results, the power as a function of time delivered to the atmosphere above Colorado, India (the antipode), Amazonia, and Europe are shown in Fig. 1.

The debris reaches Colorado first and delivered ~125 kW/m^2 to the atmosphere. Much more power is delivered to the atmosphere above India (~350 kW/m^2) 1 to 2 hrs after the impact event. Much less power is delivered to Amazonia and Europe. While we have focused on the first 36 hrs following the impact in Fig. 1, material continues to accrete to the Earth over an ~3 day period. During this period, there are intervals, separated by ~24 hrs, when the accretion rate is particularly high, corresponding to when each locality rotates beneath the densest part of the ejected vapor plume.

As discussed previously [3], not all of the power deposited in the atmosphere is radiated to the ground. About half of it is radiated into space and some of it is absorbed by atmospheric H_2O and CO_2. However, about 1/3 of the total radiation reaches the ground and any power delivered in excess of 12.5 kW/m^2 for >20 min can ignite vegetation, even if it is initially wet. The results of our calculations indicate that portions of North America, South America, Africa, and Asia were consumed by fire, even in humid environments like rain forests and swamps.

The full extent of these fires is dependent in part on the trajectory of the projectile and on the velocity distribution of material in the expanding vapor plume which carries the high-energy ejecta. The results in Fig. 1 are for a vertical impact. We have also calculated the distribution of wildfires produced by an impact with a trajectory from the SE to the NW. In this case, the amount of heating over North America is much less while the amount of heating throughout the southern hemisphere is much larger. Nearly all of the vegetation in South America and Africa would be consumed with fire. Vegetation in Antarctica, India, and possibly Australia may also be consumed. It is clear that neither a vertical impact nor any impact with a trajectory from the south will produce wildfires in Europe or northern Asia. Consequently, if the distribution of wildfires can be determined from the stratigraphic record, it can potentially be used to determine the trajectory of the projectile.

Ecosystem Implications: While wildfires were not ignited globally, they were ignited on several continents. Once ignited, the fires may have spread across the continents. Unfortunately, at the moment it is unclear how precipitation was affected by the atmospheric perturbations and, thus, whether it was capable of stemming the spread of wildfires. Based on measurements of soot in several localities, it has been estimated that the fires released ~5 x 10^{16} g of soot into the atmosphere [5,9], which implies ~10^4 GT CO_2, 10^2 GT CH_4, and 10^3 GT CO were released into the atmosphere based on the production of these gases in modern large scale forest fires [10]. These are orders of magnitude larger than the C produced by fossil fuel burning (5.4 ± 0.5 GT/yr) and land use change (1.6 ± 1.0 GT/yr) today [6]. The amount of C-bearing gas released into the atmosphere by the wildfires is also similar to, if not larger than, the 350 to 3500 GT of CO_2 injected into the stratosphere when C-bearing rock was vaporized at the impact site [8].

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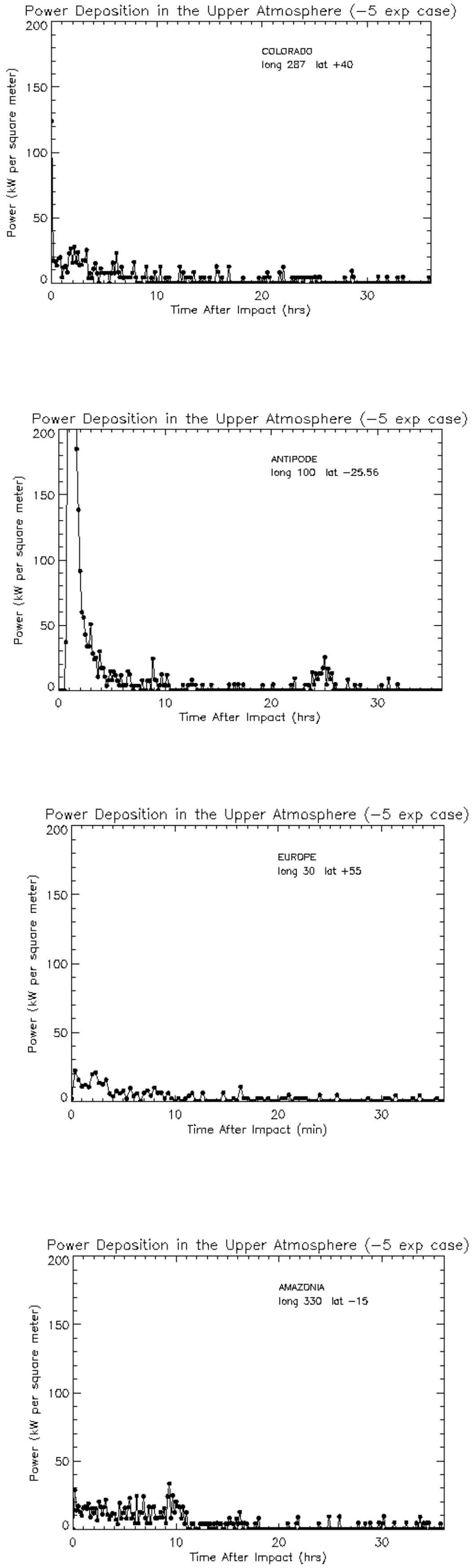

Figure 1. The power delivered to the upper atmosphere by high-energy ejecta as a function of time. Enough power was deposited above Colorado (~125 kW/m^2, very close to 0 hr) and at the antipode (~350 kW/m^2) to ignite wildfires on the ground. A second pulse of accreting material can be seen in the case of the antipode, which arrives ~24 hrs after the initial pulse.