PROLONGED BIOSPHERIC EFFECTS OF SULFUR VAPORIZATION BY THE K/T CHICXULUB IMPACT; K.O. Pope, Geo Eco Arc Research, 2222 Foothill Blvd. Suite E-272, La Canada, CA 91011 USA. A.C. Ocampo and K.H. Baines, Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91109 USA, and B.A. Ivanov, Russian Academy of Sciences in the Institute for Dynamics of Geospheres, Leninskij prospect 38, korpus 6, Moscow, Russia.

One of the most potentially devastating biospheric effects of the Cretaceous/Tertiary (K/T) Chicxulub impact was the attenuation of sunlight by a massive sulfuric acid aerosol cloud created by the vaporization of anhydrite target rocks (1-3). Our previous studies (3) indicated that the sulfuric acid aerosol may have extended global blackout condition several months beyond that proposed for the dust, but these calculations were based on the assumption of rapid conversion of impact-generated stratospheric SO$_2$ to H$_2$SO$_4$ aerosol. We developed a more sophisticated model for our current study by incorporating more realistic H$_2$SO$_4$ production rates derived from studies of Venusian atmospheres and the scaling-up of Earth volcano models. Our results indicate that the Chicxulub impact caused prolonged, severe cooling, lasting many decades to several centuries. Temperatures gradually cooled to well below freezing for many years in regions not buffered by the heat released from the warm Cretaceous oceans.

We applied the results of our previous model of impact vaporization (3) with only slight modifications. This model predicts the mass of sulfur injected into the stratosphere by a 10 km or 20 km diameter asteroid. These two bolide diameters correspond to craters with diameters of about 180 km and 300 km, which bracket the proposed dimensions of the Chicxulub crater (4,5,6). The amount of SO$_2$ produced by the model impacts, given the two bolide diameters and total vaporization occurring between 30 and 60 GPa, ranged within an order of magnitude of 10$^{18}$ g.

The conversion rate of 10$^{18}$ g of SO$_2$ to H$_2$SO$_4$, when scaled-up using the rates established for large volcanic eruptions (7), gives a SO$_2$ lifetime of 200 yrs. The lifetime of SO$_2$ on Venus is also estimated to be 200 yrs (8), and the Venusian atmosphere has a sulfur mass similar to that produced by the Chicxulub impact. The relatively slow rate of acid production is due to limits on the photochemical oxidation of SO$_2$ caused in part by the attenuation of sunlight by the sulfur cloud (9).

We adapted our previous (3) atmospheric model to incorporate a range of potential SO$_2$ lifetimes from 50 to 1000 years. Our 1 D model predicts the reduction in solar energy reaching the Earth’s surface based on radiative transfer calculations including the processes of SO$_2$ to H$_2$SO$_4$ conversion, coagulation of acid aerosol droplets, and sedimentation. The model contains 12 stratospheric layers, and tracks the optical properties of the aerosol particles as they coagulate and fall, which on average takes about 1 yr. The final model results include predictions of surface temperature changes that would occur if equilibrium with incoming solar radiation was achieved (i.e. black body calculations neglecting the thermal reservoir effect of the oceans).
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Our baseline prediction of $10^{18}$ g of SO$_2$ converting completely to H$_2$SO$_4$ in 200 years would reduce the amount of solar radiation reaching the Earth's surface by about 90% for the 200 yr period. Faster conversion rates (i.e. SO$_2$ lifetimes of 100 or 50 yrs) would reduce solar input slightly more. An SO$_2$ lifetime of 1000 years would still reduce solar input by more than 75%. The equilibrium (black body) surface temperature for all these scenarios falls between 50-100$^\circ$C, which would have dropped surface temperatures well below freezing if equilibrium was achieved. Our model shows that even if only 1% of the SO$_2$ converted to H$_2$SO$_4$ over the proposed 200 yr lifetime (i.e. if there is another sulfur sink not accounted for in our model), equilibrium temperatures would still fall well below freezing.

Actual surface temperatures are difficult to estimate, and for a period the ocean thermal reservoir would have kept temperatures above freezing. General Circulation Models (GCMs) of temperature perturbations with impact aerosol loadings similar to our estimates predict actual surface freezing conditions in middle to high latitudes and continental regions within a month of the impact (10). Therefore it is reasonable to assume that within the first few years following the Chicxulub impact permanent freezing conditions would have developed in many continental regions, and that this cooling would have been much more severe than recent impact models have predicted (10). The GCMs have not been run for prolonged perturbations of decades to centuries, a time interval in which the oceans would cool significantly and freezing conditions may have expanded throughout much of the globe.

REFERENCES

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