GLOBAL BLACKOUT FOLLOWING THE K/T CHICXULUB IMPACT: RESULTS OF IMPACT AND ATMOSPHERIC MODELING; K.O. Pope, Geo Eco Arc Research, La Canada, CA 91011, A.C. Ocampo and K.H. Baines, Jet Propulsion Laboratory, Pasadena, CA 91109, and B.A. Ivanov, Institute for Dynamics of Geospheres, Russian Academy of Sciences, Moscow 117979.

Several recent studies have suggested that shock decomposition of anhydrite ($CaSO_4$) target rocks during the K/T Chicxulub impact would have ejected tremendous amounts of sulfur gas into the stratosphere (1-4). One of the many potential biospheric effects of this sulfur gas is the generation of a sulfuric acid (H_2SO_4) aerosol layer capable of causing darkness and severe disruption of photosynthesis for periods of years. In this paper we report the preliminary results of our modeling of shock pressures within the anhydrites and of light attenuation by the H_2SO_4 aerosol cloud. These models indicate that earlier studies over-estimated the amount of sulfur gas produced, but that more than enough was produced to extend global blackout conditions 4-6 times longer than the ~3 month predictions for silicate dust alone (5).

The exact size of the Chicxulub crater is not known, but the probable minimum is the 180 km diameter proposed by Hildebrand et al. (6) based on circular gravity anomalies. Pope et al. (7) suggest the crater diameter may be > 200 km, based on structural geology and hydrology. The Chicxulub crater may be a multi-ring basin with multiple ring fault systems and associated slump blocks. An inner ring, which has a diameter of 170 km, is demarcated by a semi-circular ring of sink holes that may correspond to the crater floor (7). Additional rings at greater diameters are suggested by the possible off-sets of Cretaceous strata (7).

Given the uncertainty of the size of the Chicxulub crater, we chose to model craters of 180 km and 300 km. These diameters correspond to transient crater diameters of 81 km and 126 km, based on the models of Croft (8) and Ivanov (9). For our model we assume a silicate bolide impacting at 20 km/s. When scaling laws are applied these diameters correspond to bolide diameters of 11 km and 19 km for the smaller and larger crater respectively. We used a model for a homogeneous stony target that is capable of tracing shock pressures in two dimensions. The average thickness of the sedimentary rocks that comprised the upper strata at Chicxulub in the Late Cretaceous was ~2.5 km, for which we estimate 60% was anhydrite and 40 % carbonate (3,7). Approximately 30 GPa of shock pressure is required for decomposition of these sedimentary rocks (10, 11). The model predicts that shock pressures would have exceeded 30 GPa within the sedimentary layer to a radius of 9.4 km from the center of impact for the small bolide and to 16.5 km for the large one. Based upon the predicted volume of vaporized sedimentary rock, we estimate that 2.7 or 8.2 x 10^{17} g of sulfur were vaporized for the two impact scenarios. These estimates are an order of magnitude less than some previous estimates (3,4).

We applied a radiative transfer model in the study of sunlight transmission through the proposed H_2SO_4 aerosol cloud generated by the Chicxulub impact. At this stage in our modeling we assume that most of the sulfur gas generated by the impact was ejected into the stratosphere, where it was globally distributed and rapidly converted to H_2SO_4. The global H_2SO_4 stratospheric aerosol burden required to produce a global blackout is largely a function of particle radius and of the imaginary index of refraction (n_i), which is controlled by impurities in the aerosol. Global blackout is defined as an absorption optical depth (T_a) > 10 at a wavelength of 5000 A, which corresponds to total darkness. The true optical depth is much greater (~200) because absorption and multiple scattering occur.

Our model predicts that the amount of sulfur required for global blackout is a small percentage of the ejected sulfur mass predicted for the Chicxulub impact. Assuming a baseline sulfur ejection of 3×10^{17} g and 0.5 um diameter aerosols, ~0.3% of the ejected sulfur is required for global blackout for $n_i = 0.03$ (~7% of the value for soot); for $n_i = 0.0025$ (particles similar to volcanic dust) ~ 3% of the available sulfur is required. The two major factors controlling the duration of the blackout are particle sedimentation and coagulation, the latter of which causes rapid sedimentation when atmospheric loading is high and therefore limits the effects of large impacts (5). The model predicts a blackout duration of ~1.5 years for 0.5 um particles with $n_i = 0.03$, and ~1.0 year if $n_i = 0.0025$. These estimates represent minimum durations for the blackout event. Photosynthesis would be disrupted with an aerosol loading of about 5% of the blackout estimate, which could have lasted for 5-10 years.

In conclusion, our analyses show that global blackout is not very sensitive to our variable crater size estimates, and only a fraction of the sulfur produced need be converted to H_2SO_4 aerosol. The duration of the blackout is 4-6 times longer than that proposed for the dust alone (5), and therefore dramatic cooling of the surface and prolonged disruption of photosynthesis is indicated.

REFERENCES

(1) Brett, R. (1992), LPSC XXIII, 157-158.
(2) Perry, E.C., Winter, D.J, Sager, B., and Wu, B. (1992), LPSC XXIII, 1057-1058.
(3) Pope, K.O. and Ocampo, A.C. (1992), LPSC XXIII, 1097-1098.
(4) Sigurdsson H., D'Hondt, S., and Carey, S. (in press), Earth and Planet. Sci. Lett.
(5) Toon, O.B., Pollack, J.B., Ackerman, T.P., Turco, R.P., McKay, C.P., and Liu, M.S. (1982), GSA Spec. Paper 190, 187-200.
(6) Hildebrand, A.R., Penfield, G.T., Kring, D.A., Pilkington, M., Camargo Z., A., Jacobsen, S.B., and Boynton, W.V. (1991), Geology 19, 867-871.
(7) Pope K.O., Ocampo A.C., and Duller C.E. (1991), Nature 351, 105.
(8) Croft, S.K. (1985), Proc. Lunar Planet. Sci. Conf. XV, 828-842.
(9) Ivanov, B.A. (1989), LPSC XIX, 531-532.
(10) Florensky, C.P., Basilevsky, A.T., Ivanov, B.A. et al. (1983), Impact Craters on the Moon and Planets. Moscow, Nauka Press.
(11) O'Keefe, J.D. and Ahrens, T.J. (1989), Nature 338, 247-249.