

LONG-TERM ENVIRONMENTAL EFFECTS OF THE CHICXULUB IMPACT; K. H. Baines¹, K. O. Pope², A. C. Ocampo¹, and B. A. Ivanov³, ¹Jet Propulsion Laboratory, Pasadena, CA 91109, ² Geo Eco Arc Research. La Canada, CA 91011. ³ Russian Academy of Sciences. Moscow 117979.

The impact of a large bolide into the northern Yucatan peninsula 65 million years ago resulted in unusually prolonged global environmental effects which caused the mass extinction that marks the K/T boundary. As previously discussed [1], the impact explosively released into the stratosphere about 100 billion tons of sulfur dioxide excavated from the unusually sulfate-rich target rock, thereby producing a long-lasting reservoir of aerosol-generating material that severely affected the world climate. Here, we update our previous analysis [1] of the evolution of the impact-generated stratospheric sulfur dioxide reservoir to explicitly account for (1) the large amount of water injected into the stratosphere from the Chicxulub site and (2) the diffusion of stratospheric gases back into the troposphere. We have also performed a preliminary analysis of the role of excavated salts in modifying the stratospheric abundance of ozone-destroying chlorine. Salient new results are: (1) water abundance did not limit the formation rate of stratospheric sulfuric acid hazes, (2) these reflective hazes - responsible for severe global cooling - lasted between ten and eighteen years (a marked decrease from the one-century upper limit of [1]), and (3) the stratospheric chlorine abundance increased by 1-2 orders of magnitude over the ambient concentration.

The initial Chicxulub explosion injected hundreds of billions of tons of volatiles into the stratosphere and into space, most of which subsequently fell back to rest in the high stratosphere. Due to the relatively high temperatures of the stratosphere, the amount of water vapor initially stored there was nearly two orders of magnitude greater than the ambient water vapor reservoir dictated by the tropopausal coldtrap, i.e., about 200 gigatons vs about 3 gigatons ambient. The production rate of sulfuric acid hazes, then, was not driven by the availability of water vapor, but rather by the availability of odd oxygen needed to form SO₃ out of SO₂. The ultraviolet photolysis of oxygen compounds (principally O₂ and H₂O) required to generate this free oxygen was itself throttled by the uv-absorbing SO₂ gas (i.e., the Hartley bands, c.f. [2]) and the uv-reflecting sulfuric acid haze itself.

Due to the paucity of free oxygen available to form sulfuric acid clouds, the principal sink for sulfur dioxide was not the formation of H₂SO₄ hazes but rather diffusion into the troposphere. This diffusion limited the lifetime of the SO₂ reservoir (and hence stratospheric H₂SO₄ haze formation) from ten to eighteen years for initial stratospheric sulfur injections of 50 to 1000 gigatons.

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During this period, the global stratospheric conversion rate of sulfur dioxide varied from 2-4 gigatons initially (again depending on the initial mass of injected sulfur) to about 0.3 gigatons per year, resulting in globally-averaged sunlight transmission from 0.1-0.2 of normal, initially, to 0.8 of normal in the final year. This relatively longterm depletion of sunlight resulted in 10-18 years of global surface temperature forcing below freezing.

Subsequent to this global cooling, the relatively minor greenhouse warming due to the enhanced level of CO₂ also resulting from the vaporization of the target evaporites warmed the surface to about 0.5 K above pre-impact levels. Other longterm (multiple decade) effects include a severe alteration of the stratospheric ozone layer, caused largely by the injection of salt material into the stratosphere by the bolide impact. The vaporization of NaCl in the immediate vicinity of the impacting bolide and the chemical reaction of excavated salts with both tropospheric and stratospheric sulfuric acid resulted in the release of tens of megatons of chlorine into the stratosphere, i.e, 1-2 orders of magnitude above ambient levels. The catalytic destruction of ozone resulting from this enhanced chlorine abundance resulted in severe stratospheric global ozone depletion for several decades after the Chicxulub impact.

[1] Pope, K. O. et al. (1994) *Earth and Planet. Sci. Lett.*, 128, 719-725.

[2] Pinto, J. P. et al. (1989) *J.GR* ,94, 11165-11174.