ANHYDRITE: A LETHAL TARGET ROCK AT THE CHICXULUB IMPACT SITE, R. Brett

Hildebrand et al.[1] provide persuasive evidence that the Chicxulub structure, 180 km in diameter, on the Yucatan Peninsula, Mexico, is an impact crater formed at about the time of the Cretaceous-Tertiary (K-T) boundary. One drill hole in the structure penetrated melt rock and bottomed in anhydrite; other drill holes just outside the structure show 300-800m of anydrite beds below a depth of 900-1,000m[2].

Experimental studies indicate that anhydrite decomposes in an open crucible above 1200°C[3]. Thermodynamic calculation and extrapolation using the free energy of formation of anhydrite and its reaction products[4] as a function of T up to 1400 K give an equilibrium pressure of 1 bar SO_2 over the reaction $2CaSO_4 = 2CaO + 2SO_2 + O_2$ at a temperature of about 1800 K. Isotopic studies indicate that the source of high Ca, and S in impact glass from the Haitian K-T boundary ejecta site was anhydrite[5].

Roddy and et al.[6] modeled a 10-km bolide impacting continental crust at 20 km/s. They calculated that the transient cavity would be 100 km in diameter and 40 km deep before becoming a permanent crater about 150 km across and a few km deep. The approximate amount of energy required to raise anhydrite from 383 K to 1800 K is 1900 J/g[6]. Roddy et al. state that 7.6×10^{12} tonnes of material is raised 2000 J/g or above for the cratering event they describe. If it is assumed that an anhydrite bed lies 1,000m below the surface in this hemisphere, and is 500m thick, 300 cu. km of anhydrite would be heated to 1800 K or above and would decompose with the evolution of 4.0×10^{17} g of SO_2. Most of the high temperature material would be ejected above 30 km in the form of vapor and melt[6].

Sigurdsson[7] has correlated mean global surface-temperature decrease observed after historic volcanic eruptions with estimates of the minimum mass of S released. If the correlation is extrapolated for S released by the Chicxulub event, a cooling of about 11° C is obtained, which would be lethal for many species. There are several reports[8] of a short term cooling of 2.5-8° C across the K-T boundary. Gerstl and Zardecki report that a stratospheric aerosol mass of $1\text{-}4 \times 10^{16}$ g is sufficient to reduce photosynthesis to 10^{-3} of normal because of backscattering of incoming solar radiation[9].

Stratospheric sulfate aerosols from volcanic eruptions play an important role in stratospheric ozone depletion[10]. A large event, such as the one at Chicxulub, that involves sulfate aerosols would remove significant ozone.

The 200 billion tonnes of H_2SO_4 in the stratosphere would eventually return to earth. Such a quantity corresponds to about 1.2 kg H_2SO_4 per sq. m. of the earth. If the release of H_2SO_4 were gradual over many years, the effects on organisms might not be very great, but the cooling effects would persist over a long period. If, on the other hand, release took place over a shorter period, say 2 or 3 years, because of the self-limiting effects of huge releases of SO_2 into the stratosphere[11] the effects on biota could be large. Lake and river life would be devastated in catchment areas free of limestone, because 1-2 kg of H_2SO_4 per sq. m. would lower the pH of a lake 10m deep to below 3. All modern lacustrine life is wiped out at a pH of just below 4; many species cannot survive a pH of 5. Land flora and fauna also would be affected severely.

The effects of large amounts of acid precipitation on near-surface marine life would be severe if acid precipitation took place over several years or less. If one assumes a wave mixing layer of 100m., above which mixing is rapid, and below which mixing takes years, a pH of less than 5 would be achieved by sulfuric acid precipitation. One might anticipate that plankton would be killed, and because they lie at the beginning of the food chain, other fauna would also be damaged. Benthic fauna largely survived the K-T event whereas most planktic fauna were devastated.

Hsu et al.[8] suggest that the world's oceans were temporarily more acid after the K-T event. Martin and Macdougall reported an abrupt increase in $^{87}Sr/^{86}Sr$ in seawater across the K-T boundary. They stated that the probable cause is enhanced continental weathering associated with acid rain on a global scale[12].

Other large impact structures are reported on earth, albeit none as large as the Chicxulub Crater. None of these has been demonstrated to have had such an effect on the biosphere as the Chicxulub event apparently did. I suggest this effect is due to the unique presence of anhydrite as a target rock at Chicxulub. References 1. A.R. Hildebrand et al., Geology 19, 867 (1991). 2. W.C. Ward, A.E. Weidie, and W. Back, Geology and hydrogeology of the Yucatan and Quaternary geology of the northeastern Yucatan Peninsula. New Orleans Geol. Soc., New Orleans, (1985). 3. J.J. Rowe, G.W. Morey, and C.C. Silber, J. Inor. and Nucl. Chem. 29, 925 (1967). 4. R.A. Robie, B.S. Hemingway, and J.R. Fisher, U.S. Geol. Surv. Bull. 1452 (1979). 5. H. Sigurdsson et al., Nature353, 839 (1991). 6. D.J. Roddy et al., Int. J. Impact Eng.50, 525 (1987). 7. H. Sigurdsson, Geol. Soc. Amer. Spec. Paper 247, 99, (1990). 8. R.G. Douglas and S.M. Savin, Initial Repts. of Deep Sea Drilling Project XXXII, 509. Nat. Sci. Found., Washington, (1975). K.J. Hsu, J.A. McKenzie, and O.X. He, Geol. Soc. Amer. Spec. Paper190, 317, (1982). K. Perch-Nielsen, J. McKenzie, and Q. He, ibid, 353. J.A. Wolfe, Nature352, 420 (1991). 9. S.A.W. Gerstl and A. Zardecki, Geol. Soc. Amer. Spec. Paper190, 201, (1982). 10. D.J. Hofmann and S. Solomon, J. Geophys. Res. 94, 5029 (1989). 11. J.P. Pinto, R.P. Turco, and O.B. Toon, J. Geophys. Res.94 11,165, (1989). 12. E.E. Martin and J.D. Macdougall, Earth Planet. Sci. Lett. 104, 166, (1991).