Precambrian era. Also, the amount of cometary volatile material that has been deposited on Earth may be more than is found at present, since some of the volatile material may have been removed by impact erosion. In addition, the UV absorption cross sections of cometary H_2O and NH_3 may be larger than the values measured in the laboratory, since in comets they could be in the form of cluster molecules [8]. Finally, the continuous introduction of H_2O and NH_3 at the top of the atmosphere would not only supress O_3 production by UV absorption, but the photolyzed products would catalytically destroy O_3 by the well-known reactions at work in the stratosphere at present [9].

Since suppression of the O_3 atmosphere by comets in the inner solar system appears to be possible, it is of interest to note that the same mechanism would resolve two other current problems involving the history of Earth and Mars. The likelihood of NH_3 in the Precambrian atmosphere was suggested [10] in order to provide the necessary greenhouse effect when solar luminosity was less than its present value, and thus reconcile calculated ocean temperatures with the observation that the oceans had not frozen. However, calculation of NH_3 photolysis [11] indicated a lifetime for NH_3 in the atmosphere that was significantly less than that which was required. The presence of NH_3 and H_2O in the inner solar system according to the scenario presented here could reduce the rate of NH_3 photolysis in the Earth's atmosphere to a level that would permit the small amount of NH_3 that had been suggested [10]. In a similar way the efficient greenhouse nature of NH_3, in conjunction with its shielding from solar UV radiation by cometary outgassing in the inner solar system, could account for the warmer temperatures on Mars that are needed to explain the fluvial features that have been observed there.

To summarize the main suggestion proposed here: Discontinuities in the history of Earth's biota can be explained by the single unifying suggestion that low levels of O_3 production are controlled by cometary activity. Precambrian biological activity is explained along with mass extinctions. Where mass extinctions since the Cambrian are concerned, comet showers from the remnants of the nebular disk lasting for thousands to millions of years provide a model consistent with the paleontological record, which shows biological degradation lasting for similar periods and becoming increasingly destructive with time until the event suddenly ends. Since the model proposed here appears to answer some outstanding questions it should be investigated further.

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THE CRASH OF P/SHOEMAKER-LEVY 9 INTO JUPITER AND ITS IMPLICATIONS FOR COMET BOMBARDMENT ON EARTH. E. M. Shoemaker and C. S. Shoemaker, Lowell Observatory, 1400 West Mars Hill Road, Flagstaff AZ 86001, USA.

Periodic Comet Shoemaker/Levy 9 will impact Jupiter in late July 1994 [1,2]. The comet, which broke into more than 20 telescopically detectable fragments [3] when it passed within the Roche lobe of Jupiter on July 8, 1992, is captured in a highly eccentric orbit about Jupiter. The 21 recognized nuclei will be spread out in a train of the order 7×10^6 km long at the time of impact, and the impacts will be spread in time over about 5 1/2 days centered on about July 21.2 UT [4]. In addition to the train of recognized bright nuclei, the comet consists of "wings" of unresolved bodies that are the source of a very broad composite dust tail. The linear extent of the wings is about an order of magnitude greater than that of the train of recognized discrete nuclei. Collision of the wings will be spread in time over several months. Thus the impact of P/S-L 9 with Jupiter will be an event of appreciable duration.

Sizes of the recognized nuclear fragments of P/S-L 9 are not yet firmly established. Photometry from high-resolution images acquired by the Hubble Space Telescope suggests that the 11 largest nuclear fragments range from 2.5 to about 4.3 km in diameter, and that the precursor body, before breakup, was about 8 km in diameter or larger [5]. A preliminary dynamical solution for the development of the observed train of nuclei by Scotti and Melosh [6] suggests that the precursor body was only about 2 km in diameter. However, a later solution by Chodas and Yeomans [4], based on orbits of the individual nuclei, indicates that the precursor body was about 9 km in diameter. We conclude that the precursor of P/S-L 9 was of the order 9 km diameter and that the total impact energy will be of the order 10^8 megatons TNT.

Observations of comets discovered shortly after escape from jovicentric orbit, plus the discovery of P/S-L 9, indicate that the frequency of collision of objects orbiting Jupiter with the estimated impact energy of P/S-L 9 is of the order once per millenium [7]. Collisions with Jupiter of comets on free heliocentric orbits are several times more frequent. These collision rates are an order of magnitude higher than those predicted with the use of Opik's equations, which fail for very-low-velocity encounters with Jupiter.

The development of a train of cometary debris by tidal breakup leading to multiple impacts on a planet has direct relevance to the impact history of Earth. Both periodic and long-period Sun-grazing comets are subject to tidal disruption. A catastrophically disrupted periodic comet on a free heliocentric orbit can be expected to form a compact debris stream somewhat similar to but much narrower than an ordinary meteoroid stream. If such a stream intersects Earth's orbit at one of the nodes, Earth will be subject to repeated impacts as a result of its annual passage through the stream [8–10]. High-inclination periodic comets tend to be driven to Sun-grazing orbits [11], and the formation of compact debris streams should occur fairly frequently. Breakup of very large (several hundred kilometers in diameter) periodic comet nuclei should have occurred occasionally during the last 0.5 Ga, leading to comet showers with durations of the order of 10^5 yr. If one such breakup occurred when the distance to a node was near 1 AU, an intense pulse of bombardment lasting a few decades may have occurred. We postulate that just such an event happened at K/T boundary time.

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CRYSTALS, LITHICS, AND GLASSY EJECTA AT THE KT BOUNDARY: IMPLICATIONS FOR LITHOLOGY OF THE CRUST AT THE IMPACT SITE. H. Sigurdsson[1], S. Smith[1], S. D'Hondt[1], S. Carey[1], and J.-M. Espindola[2], [1]Graduate School of Oceanography, University of Rhode Island, Narragansett RI 02882, USA, [2]Instituto de Geofísica, Universidad Nacional Autónoma de México, Cd. Universitaria, Mexico City 04510, Mexico.

Ejecta from bolide impact may contain melt quenched to glass droplets as well as rock fragments and fractured mineral grains from the impact terrane. In distal sections of the ejecta deposit, an impact origin for glass and shocked minerals may generally be established, whereas the origin of lithics and unshocked crystal fragments found in association with impact glass is uncertain, due to possible contamination from other sources. In addition to 1–8-mm-diameter glassy ejecta spherules, the 0.5–1-m-thick KT boundary impact ejecta layer in the Beloc pelagic carbonate sediment formation in Haiti contains silicate mineral fragments and rock fragments that may provide clues about the nature of the Earth's crust at the impact site. Because of the monotonous and relatively pure lithology of the enclosing upper Createceous and lower Tertiary carbonate sediments, the Haiti exposures of the KT boundary layer provide an opportunity to detect mineral ejecta present in only trace amounts,

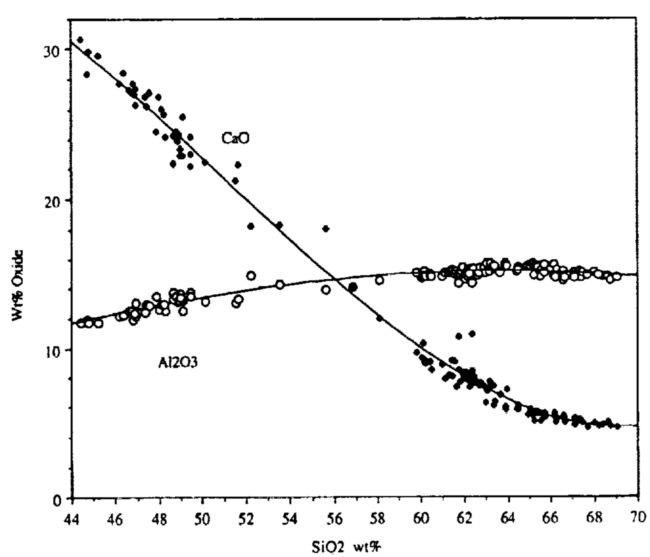

Fig. 1. Compositional trends in KT boundary glassy ejecta spherules, illustrating the smooth compositional trends of Al_2O_3 and CaO, from high-Ca yellow glasses to the more abundant high-silica glasses. In total, the dataset represents analyses of 140 spherules. The compositional range from 44–62 wt% SiO_2 can be modeled as a simple binary mixing trend [1], whereas the high-silica glasses reflect a more heterogenous source. Curves define best-fit regression lines through the data, with correlation coefficient of 0.992 for CaO and 0.91 for Al_2O_3.

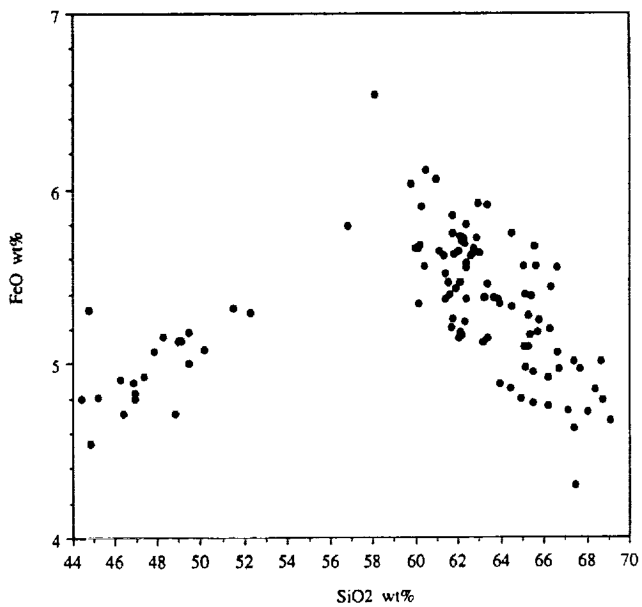

Fig. 2. Two distinct trends of FeO content in KT boundary impact glasses. The trend of decreasing Fe content with increasing silica in the high-silica glasses may reflect heterogeneity in the source region, whereas the trend between high-Ca glasses (44–54 wt% SiO_2) and high-silica glasses can be modeled as a mixing trend.

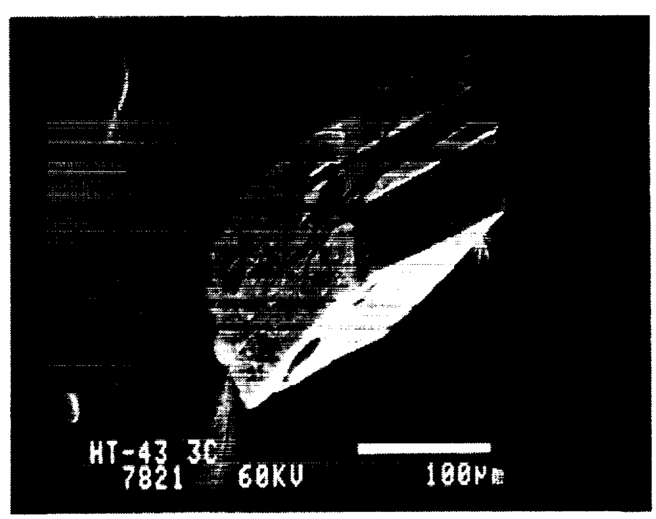

Fig. 3. Scanning electron micrograph of a crystal of amphibole from the KT boundary ejecta layer. The 400-μm euhedral crystal is entirely defined by {110} cleavage planes and formed by breakage. Mineral chemistry is consistent with derivation from 9–12 km depth in the crust.