edited by Jennifer Sills

Cretaceous Extinctions: Multiple Causes

IN THE REVIEW "THE CHICXULUB ASTEROID IMPACT AND MASS EXTINCTION AT THE CRETACEOUS-Paleogene boundary" (P. Schulte *et al.*, 5 March, p. 1214), the terminal Cretaceous extinctions were confidently attributed to a single event, the environmental consequences of the impact of an extraterrestrial body. The list of 41 authors, although suggesting a consensus, conspicuously lacked the names of researchers in the fields of terrestrial vertebrates, including dinosaurs, as well as freshwater vertebrates and invertebrates. Although we the undersigned differ over the specifics, we have little doubt that an impact played some role in these extinctions. Nevertheless, the simplistic extinction scenario presented in the Review has not stood up to the countless studies of how vertebrates and other terrestrial and marine organisms fared at the end of the Cretaceous (*1*–*4*).

Deccan plateau basalts. Lava from Deccan volcanism formed distinct layering.

Patterns of extinction and survival were varied, pointing to multiple causes at this time—including impact, marine regression, volcanic activity, and changes in global and regional climatic patterns (*5*). It is telling that in all other instances of mass extinction in the past 600 million years, no signature of an extraterrestrial impact has ever been reliably detected, despite extensive searches. Moreover, there are many other known instances of large impacts in the geologic record, with no associated extinctions (*6*). The general importance of impacts to extinction is called into question, as well as the importance of the Cretaceous-Paleogene impact as a single cause (*7*). By contrast, all of the five widely accepted mass extinctions occur during or shortly after times of global marine regression (*8*) and at least three occur during intervals of massive volcanism (*9*).

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Cretaceous Extinctions: The Volcanic Hypothesis

IN THEIR REVIEW "THE CHICXULUB ASTEROID impact and mass extinction at the Cretaceous-Paleogene boundary" (5 March, p. 1214), P. Schulte *et al.* conclude that "the Chicxulub impact triggered the mass extinction." However, the Review does not give sufficient and accurate consideration to the volcanic hypothesis. The authors claim that for Chicxulub, "the extremely rapid injection rate of dust and climate-forcing gases would have magnified the environmental consequences compared with more-prolonged volcanic eruptions." As evidence, they cite our paper (*1*), saying, "the injection of ~100 to 500 Gt of sulfur into the atmosphere within minutes after the Chicxulub impact contrasts with volcanic injection rates of 0.05 to 0.5 Gt of sulfur per year during the ~1-million-year-long main phase of Deccan flood basalt volcanism." This contains a substantial error and a fundamental misrepresentation of our paper. Half a Gt per year of sulfur for 1 million years amounts to 500,000 Gt of sulfur, which in any