BONE BEDS AT THE BOUNDARY: ARE THEY A REALISTIC EXPECTATION?
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Over the past decade and a half an impressive array of evidence has been amassed to support the hypothesis that the Mesozoic Era was brought to a close by the impact of one or more extraterrestrial objects [1–3]. The most convincing lines of evidence have been mineralogic, geologic, and geochemical rather than paleontologic. Indeed, the fossil record remains ambiguous, and paleontologists disagree as to whether the putative impact was in fact responsible for abrupt and widespread extinction of species [4]. The problem is especially acute for the terrestrial record where KT boundary sections are not extensive and the fossil record tends to be fragmentary and facies-dependent [5].

One source of confusion is the absence of a clear picture of what the fossil record of a global catastrophe should look like. Signor and Lipps [6] made an early contribution along these lines by pointing out that the vagaries of preservation would tend to truncate species' apparent ranges below their true level of extinction, with the result that truly abrupt extinction events would appear gradual in the fossil record. In their analysis, however, Signor and Lipps assumed that taphonomic processes remained constant up to and across the extinction boundary, and at least one author [7] has suggested that the scale of mortality implied by an impact should be reflected in the record by widespread bone beds and mass mortality horizons.

Mass mortality horizons associated with local or regional events such as droughts [8], fires [9], and volcanic ash falls [10] can be documented in the vertebrate fossil record. Is it reasonable to expect that mass mortality of large vertebrates on a global scale would leave a recognizable signal in the record? It is obviously too much to expect to find vast horizons of dinosaur carcasses in their final death postures dusted with a layer of It, but it is less obvious whether such an event would produce a detectable elevation in the frequency or scale of bone concentrations (a “bone spike”) at the extinction horizon.

Based on calculations of mortality (turnover) rates of dinosaurs from known relationships of body size to life span [11,12], estimates of the dinosaur-carrying capacity of the late Cretaceous ecosystems (animals/km²) and faunal lists indicating the number of species in coexisting communities of animals >20 kg [13] we infer a range of probable densities of live animals and carcasses on the landscape of the latest Cretaceous. From this we infer the differences between a bone assemblage formed under normal turnover (attributable input of bones) and from a catastrophe that wiped out all large tetrapods over a period of hours to days. In addition to the issue of attritional vs. single-pulse availability of carcasses, longer-term effects of burial and preservation of bone-bearing strata must be taken into account in assessing whether a mass die-off of dinosaurs would leave a detectable signal in the fossil record at the KT Boundary. We conclude that it is unlikely that a single event such as a bolide impact would leave dense, multispecies dinosaur bone beds in the area of greatest mass mortality.

It is possible that ecological stress farther from the impact site, which allowed some species time to congregate around specific areas prior to death (waterholes, remaining patches of forage), would have created more concentrated bone assemblages for particular taxa. Whether any of these were preserved in the long run would depend on whether such zones of variable, “less catastrophic” mortality intersected active areas of deposition at the time. Recovery of a fossil record from these same areas would depend also on later tectonic processes that created outcrops, which we can search today. The complexity of the combined requirements for there to be a record of any major mass mortality event for land animals at the KT boundary makes it unlikely that this will be detectable. The absence of bone beds at the boundary should not be used for or against hypotheses regarding causes of the extinction event.


IMPACTS, EXTINCTIONS, VOLCANISM, GLACIATIONS, AND TECTONICS: MATCHES AND MISMATCHES.
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The debate concerning possible relations between impacts, extinction events, and volcanism has recently taken a new turn. Diamictites and associated sedimentary deposits long regarded by geologists as glaciogenic, have been reinterpreted as impact-related. Going further, the Permo-Carboniferous diamictites that are widespread in the southern continents and India are now put forward as evidence that fragmentation of the Gondwana supercontinent in the Mesozoic was a direct result of meteorite impact. In an abstract at a meeting of the American Geophysical Union, and in an article in the popular press, one member of the earth science community has made a specific claim to identify the site of the supercontinent-destroying bolide on the Falkland/Malvinas Plateau. It is claimed by this scientist that the Cape fold belt in Africa represents a “breaking wave” of deformation resulting from this impact, and that fractures in the clasts of the Dwyka diamictite in southern Africa represent impact-induced cataclasis of the target rock. These hypotheses fly in the face of the well-established tectonic history of the Gondwana supercontinent in several respects.
Permian strata overlie the diamictites everywhere, and were de-morphic, etc.) between modem tillites and deposits such as the formed with them during the Gondwanide folding. The deformation in the Gondwanide fold belt. Glossopteris-bearing behind an active subducting margin of the Pacific Ocean. From the Cape fold belt it extended from ca. 278-230 Ma. It took place the South Pole across the supercontinent in the Devonian, synchronous and track the paleomagnetically determined position of the continent in the Earth. Hence the suggested circle (Chicxulub crater). Thick (~1-km) Late Cretaceous evaporite sequences occur in the region of the Chicxulub KT impact structure [1]. Calcium-rich KT tektites contain high SO\textsubscript{4} concentrations (0.83% [2]; 0.53% [3]; range = 0.20–1.0%). They also exhibit S\textsuperscript{4+}S values typical of evaporites (13.2% [2,4]). Experimental results have duplicated the high-Ca tektite composition by high-temperature melting of evaporite + anodesite [2,5]. Several studies have estimated the amount of SO\textsubscript{2} volatilized from target evaporites by the KT impact. An estimate of 1.3 x 10\textsuperscript{16} was based on the proportion of unaltered high-Ca glass in Haiti and the global thickness of the KT boundary clay. This assumed that 1000 km\textsuperscript{3} of impact glass was created and 2% was high-S glass derived from evaporite source [2,5]. This represents a minimum estimate, since it is limited to SO\textsubscript{2} released by tektite formation and does not include SO\textsubscript{2} released from solid rock by shock, or SO\textsubscript{2} released by initial volatilization of the target. More comprehensive estimates have been derived from reconstruction of Chicxulub geology and assumed shock pressures required for sulfate release. These rely on variable estimates of transient crater diameter (80 to 146 km), stratigraphy of Chicxulub region (0.5 to 1.5 km anhhydrite), and shock pressure of sulfate release (20 to 40 Gpa). Based on such criteria, Sigurdsson et al. [5] estimated that 2.4 x 10\textsuperscript{16} to 8.4 x 10\textsuperscript{16} g of SO\textsubscript{2} was released, Brett [6] estimated that 4 x 10\textsuperscript{17} g SO\textsubscript{2} was released, and Pope et al. [7] estimated that 5.4 x 10\textsuperscript{17} to 1.6 x 10\textsuperscript{18} g of SO\textsubscript{2} was released.

Combined with the great optical depth loading previously estimated to result from the KT impact “dust” cloud, the resultant stratospheric S aerosols may have contributed to a rapid decline in global surface temperatures to near-freezing in about one week [5]. Time-dependent conversion of stratospheric SO\textsubscript{2} to H\textsubscript{2}SO\textsubscript{4} would have prolonged this cooling for several years [5]. These stratospheric sulfate aerosols may also have caused global “blackout,” preventing photosynthesis for months and disrupting it for years [7]. These relatively long-lived effects of the estimated SO\textsubscript{2} release...