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The survival of megafauna after the end-Pleistocene impact: a lesson from the Cretaceous/Tertiary boundary

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Abstract

Survival of Pleistocene megafauna after the hypothesized impact of a bolide during the latest Pleistocene seems to be partly island-centered, whereas the survival of dinosaurs and ammonites after the comparable catastrophe at the Cretaceous/Tertiary boundary seems to have occurred in a fairly haphazard way within the areas affected by the impact. This poses some new questions about the possible mechanism behind the end-Pleistocene extinction, although it does not disprove an impact as a plausible cause.

Keywords: impact, survival, megafauna, Pleistocene, Cretaceous/Tertiary boundary

Introduction

The end-Pleistocene biotic crisis devastated megafaunal communities in North and South America as well as on the other continents (Martin, 2005). Several dozens of genera were swept away, including *Megatherium*, *Eremotherium*, *Mammut*, *Mammuthus*, *Camelops*, *Smilodon*, *Castoroides* (for detailed lists of extinct taxa, see Martin, 2005). The explanations for this extinction include human impact (overkill or hyperdisease), climatic changes, eustatic fluctuations, and volcanism (Grayson & Meltzer, 2002; Martin, 2005; Wroe et al., 2006; Haynes, 2007; Louys et al., 2007; Ruban, in press). Firestone et al. (2007) and Kennett et al. (2009) hypothesized the impact of a comet at ~ 12.9 ka, that would have triggered massive wildfires on ice-free areas, including periglacial zones, and disruption of the terrestrial ecosystems in entire North America, and possibly in northern Europe as well. Available data (Firestone et al., 2007, Kennett et al., 2009) suggest that biomass burning was more intense than that expected from the background wildfire frequency during the Bølling-Allerød interstadial, which were characterized by a stepwise cooling (Hoek, 2009), and the cool Younger Dryas. An impact-triggered scenario for a significant extinction event is not unique for Earth's history. A comparison with the consequences of earlier impacts on our planet seems therefore worthwhile.

Considering the (possible) end-Pleistocene impact, it is challenging to compare its biotic effect with that of the famous Chicxulub impact in what is now the Yucatán peninsula at the Cretaceous/Tertiary (K/T) boundary. The latter had, beyond any doubt, much more dra-

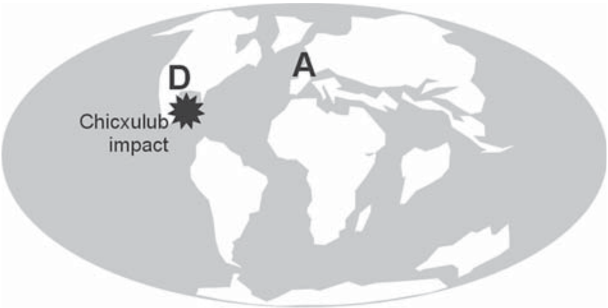

Fig. 1. K/T impact and the recorded localities of Danian survival of dinosaurs (D) and ammonites (A). Plate-tectonic reconstruction after Scotese (2004).

matic consequences for biodiversity and, particularly, it provoked the death of all dinosaurs on land and ammonites in the sea, apart from a few species that seem to have survived, though only at a few places and during a geologically short time-span (Fig. 1). Remains of Paleocene dinosaurs, particularly, a right hadrosaurid femur bone, have been discovered in the San Juan Basin of New Mexico (Fassett, 2001, 2009; Fassett et al., 2002), and post-Cretaceous ammonites of the genus *Hoploscaphites* have been found at Stevns Klint in Denmark (Machalski & Heinberg, 2005; Machalski et al., 2009).

In both cases, it seems appropriate to judge the survivals as "dead clades walking" following the terminology of Jablonski (2004). As mass extinctions use to produce some more or less definite geographic patterns of "dead clades walking" distribution (Jablonski, 2004), it must be emphasised that both above-mentioned discoveries were made in regions where the K/T mass extinction should have been as strong as anywhere else on our planet. Moreover, Danish sections are commonly used as reference sections to document the signatures of the K/T mass extinction. If so, the main lesson from the K/T event is that survival of "dead clades walking" was somewhat occasional, perhaps described best by the bottleneck effect, i.e., a temporal persistence of a small number of representatives of the affected clade until its further complete termination by any, if even mild, environmental perturbation (sensu Jablonski, 2004), although he does not judge this effect as a main explanation of "dead clade walking"). It should be noted, however, that Paleocene dinosaurs from the San Juan Basin have been questioned (Sullivan et al., 2003).

Survival pattern of the Pleistocene megafauna

It is hypothesized that the end-Pleistocene impact occurred somewhere in northern North America, perhaps in the continental ice sheet (Firestone et al., 2007). Some large Pleistocene animals survived, in both a number of places located within the territory that was affected by the impact and in the "periphery" of this territory (Guthrie, 2004; Drummond et al., 2005; Martin, 2005). Some of these refugia were large and acted as such for a long time. It should be realized, however, that a comparison of the survival patterns after the K/T and the end-Pleistocene events does not make much sense, because the resolution and completeness of the fossil record of both events are incomparable.

The most important difference is probably that the survival of megafauna after the end-Pleistocene catastrophe was at least partly island-centered, whereas this is not known for the K/T event. This requires an additional examination of the end-Pleistocene impact hypothesis. The Pleistocene fauna might have persisted on Madagascar (giant lemurs) and in New Zealand (giant birds) because these islands were far from North America, where the impact occurred hypothetically (Firestone et al., 2007). Although nothing like such a survival in remote places is known from the K/T transition, the end-Pleistocene impact must have been significantly smaller and it must have had a much more local effect. The impact-triggered scenario for the end-Pleistocene event lacks, however, an explanation why megafauna persisted also on some Arctic and Caribbean islands, which were fairly close to the impact site.

One should note, however, that some animals that persisted on islands were smaller than the continental representatives of megafauna that became extinct, whereas the end-Pleistocene catastrophe as a whole was selective by animal size (Martin, 2005). Moreover, a survival on the North American continent affected by the end-Pleistocene impact (Firestone et al., 2007) is also evident if the *Bison* populations are considered (Drummond et al., 2005).

This is similar to patterns of survival of "dead clade walking" after the K/T impact (Fig. 1). Additionally, it is sensible to hypothesize that the survival on islands close to North America was also haphazard. In other words, it might not be linked with the persistence of megafauna on "peripheral" islands like Madagascar or New Zealand.

Conclusion

Any rule that may be observed in the megafaunal survival after the end-Pleistocene event (e.g., island-centered survival), differs from what is known for the K/T event, thus suggesting that something additional to an impact governed the end-Pleistocene biotic crisis. The dispersal of humans provides an appropriate explanation (Martin, 2005), but the role of a comet's impact cannot be rejected on the mere basis of a comparison with other catastrophes.

All extinction events were complex with cascading, but spatially varying ecological effects initiated by a main trigger. We cannot reject a coincidence of several disasters (cf. Firestone et al., 2007). The effect of the impact of an extraterrestrial body may have triggered the final decline of the Pleistocene megafauna that had already been provoked by human overkill. Global climate warming and an intensification of volcanism together may have weakened the megafauna sufficiently to prevent its recovery.

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