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# Commentary on the note by Vincent Courtillot and Paul R. Renne, *On the ages of flood basalt events* [C. R. Geoscience 335 (2003) 113–140] ☆

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In their paper on the ages of flood basalt events, Courtillot and Renne discuss the end-Triassic mass extinction and use our discoveries of giant sauropod dinosaurs in the Upper Triassic of Thailand [2] as evidence against the hypothesis put forward by Olsen et al. [3], which involves a possible terminal Triassic meteorite impact. As presented by Courtillot and Renne, however, the palaeontological evidence bearing on this question is somewhat misleading, and I would like to offer a few comments on the dinosaur record at the Triassic–Jurassic boundary.

First, Olsen et al. did not claim that "theropod dinosaurs appeared less than 10 ka after the T/J boundary". What they noted, on the basis of ichnological evidence from eastern North America, is that *large* theropods appeared a very short time after the boundary. Theropod dinosaurs are well represented in the Late Triassic, but mostly by small forms. Large theropods appear to develop after the T/J boundary.

Olsen et al. did mention that their evolutionary hypothesis "could be falsified by the discovery of large theropod bones" in the Triassic, which would indeed lead to a revision of their interpretation, but would not in itself invalidate possible evidence for a meteorite impact.

In any case, our discovery of very large *sauropod* dinosaurs in the Upper Triassic of northeastern Thailand [2] does not in any way falsify the hypothesis put forward by Olsen et al., for the simple reason that the latter is based only on theropod dinosaurs. The fossil evidence does suggest that theropods (carnivorous dinosaurs) remained small during the Triassic, and increased in size in the Jurassic, but it also clearly shows that large herbivorous dinosaurs (prosauropods and, as shown by the Thai finds, sauropods [1]) had already evolved in the Late Triassic. The recently discovered large sauropods from Thailand, which may have been 15 m in length) illustrate this point, but it has been known for a long time that some Late Triassic prosauropods (such as *Plateosaurus*, *Lufengosaurus* and *Riojasaurus*) reached a large size (up to 9 m in length). Whatever happened at the end of the Triassic had no significant effect on large *herbivorous* dinosaurs, since both prosauropods and sauropods crossed the boundary (prosauropods, however, became extinct in the Early Jurassic). On the other hand, the point made by Olsen et al. remains valid: Triassic *carnivorous* dinosaurs (theropods) were mostly small forms (although *Liliensternus* could reach a length of 5 m [4]), and large theropods expanded only after the T/J boundary.

Whether the changes in land vertebrate communities at the T/J boundary can be linked to a meteorite impact, or to any other kind of catastrophic event, is another matter. However that may be, it should be noted that the pattern of land vertebrate extinction at the T/J boundary differs significantly from that ob-

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served at the K/T boundary – when the influence of a meteorite impact is no longer in doubt. One of the main differences is that, at least among terrestrial vertebrates, size was not an important factor of extinction or survival at the T/J boundary, whereas it clearly was at the K/T boundary. No terrestrial vertebrates weighing more than about 25 kg survived the K/T boundary, and Early Palaeocene vertebrate assemblages consisted of small forms, in sharp contrast with terminal Cretaceous faunas dominated by large dinosaurs. The pattern at the T/J boundary is very different. Some large non-dinosaurian vertebrates did disappear, including rauisuchid pseudosuchians, which were the largest predators in the Late Triassic (and their demise may have facilitated the rise of large theropod dinosaurs). However, as mentioned above, large herbivorous dinosaurs (prosauropods and sauropods) do not seem to have been significantly affected.

What these different patterns mean in terms of causal mechanisms is unclear. If a meteorite impact was involved at the T/J boundary, its effects on terrestrial vertebrates were quite different from those of the Chicxulub impact at the K/T boundary – but the problem remains if one assumes that in both cases flood basalt volcanism was the main cause of extinction.

In conclusion, I would like to stress the need for a better knowledge of *patterns* of mass extinction at times of major biotic crises. Simple compilations of taxa which survive or become extinct are useful to reveal the occurrence of a mass extinction event, but the search for patterns (which, for instance, may indicate that some food webs or some habitats were more affected than others) is crucial to an understanding of extinction processes, and hence of possible causes.

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