

THE TRIASSIC-JURASSIC BOUNDARY IN EASTERN NORTH AMERICA;
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Rift basins of the Atlantic passive margin in eastern North America are filled with thousands of meters of continental rocks termed the Newark Supergroup which provide an unprecedented opportunity to examine the fine scale structure of the Triassic-Jurassic mass extinction in continental environments. Time control, vital to the understanding of the mechanisms behind mass-extinctions, is provided by lake-level cycles apparently controlled by orbitally induced (Milankovitch-type) climate change (1) allowing resolution at the < 21,000 year level. Correlation with other provinces is provided by a developing high resolution magnetostratigraphy (2) and palynologically-based biostratigraphy (3).

A large number of at least local vertebrate and palynomorph extinctions are concentrated around the boundary with survivors constituting the earliest Jurassic assemblages, apparently without the introduction of new taxa. The palynofloral transition is marked by the dramatic elimination of a relatively high diversity Triassic pollen assemblage with the survivors making up a Jurassic assemblage of very low diversity overwhelmingly dominated by *Corollina*. The extinctions include a large number of species of angiosperm- and gnetalian-like pollen (4), and based on cyclostratigraphy, the transition took place over an interval of less than 40,000 years. Within the Newark the palynoflora never recovered its previous levels of diversity. The terrestrial vertebrate transition is not so well constrained; however, some dominant taxa of the Late Triassic such as phytosaurs and procolophonids, are known from osseous remains from strata dated at about 600,000 years older than the boundary, and ichnofaunules of "typical" Late Triassic aspect are known from strata about 6,000,000 years older than the boundary (5). Rich osseous assemblages from the McCoy Brook Formation of Nova Scotia are characteristically Early Jurassic in aspect and completely lack the dominant "Late Triassic forms"; they date from 100,000 to 200,000 years after than the boundary (6). Ichnofaunules from strata dated as less than 40,000 years after the boundary show the same pattern as the bones. Newly discovered ichnofaunules closer to the boundary should permit much tighter time constraints. Based principally on palynological correlations, the hypothesis that these continental taxonomic transitions were synchronous with the massive Triassic-Jurassic marine extinctions is strongly corroborated. We hypothesize an extremely rapid, perhaps catastrophic, taxonomic turnover at the Triassic-Jurassic boundary, synchronous in continental and marine realms.

As is the case for the Cretaceous-Tertiary boundary, plausible causes for the extinctions include: 1) competitive superiority of newly evolved taxa; 2) climate change; 3) very large-scale volcanic eruptions; and 4) giant bolide impacts. Hypotheses explaining the extinctions as a result of competitive replacement are not supported by the observed pattern of taxonomic change because the surviving taxa coexisted with those that went extinct for millions of years before the boundary. Jurassic sediments do seem to indicate changes in climate at many places in the world, but these changes seem neither synchronous with each other or with the large-scale faunal and floral changes. Massive tholeiitic extrusives characterize Early Jurassic age sequences in the Newark Supergroup, rift basins in western Africa, and basins in southern Africa. The oldest of these are the extrusives of the Newark Supergroup which post-date the Triassic-Jurassic boundary and the associated extinctions by about $60,000 \pm 20,000$ years, which is close in time but hard to understand as a causative agent. To us the most plausible cause is the great bolide impact which produced the Manicouagan structure of Quebec (6). This hypothesis is supported by the discovery by Nazarov and others (7) of a shocked quartz horizon in the marine Triassic-Jurassic boundary in Austria. However, the best available dates from Manicouagan range from 206 ± 6 to 215 ± 4 million years (6), compared to 201 ± 2 million years for the boundary (8), and we attribute this discrepancy to excess Ar. Systematic, multiple-system re-dating of Manicouagan is underway as is a search for an impact ejecta layer in the Newark Supergroup.

No interval of comparable taxonomic turnover is apparent in Newark Supergroup strata dated by palynostratigraphy as straddling the Carnian-Norian boundary, either in vertebrates or palynomorphs. A large faunal turnover is seen, however, within Newark Middle Carnian age

strata. This departs from literature tabulations (9) which suggest a marine mass extinction at the Carnian-Norian boundary. Either Newark strata are misdated or the marine and terrestrial extinctions were not synchronous. Parenthetically, Sepkoski (9) suggests the apparent marine Carnian-Norian mass extinction could be an artifact of very high ammonite evolution rates during this time. Therefore, evidence from the Newark Supergroup does not suggest a mass extinction event at the Carnian-Norian boundary or anywhere in the Triassic or Early Jurassic, except at the Triassic-Jurassic boundary.

The Triassic-Jurassic faunal and floral extinctions stand in dramatic contrast to the background taxonomic turnover rates during the Triassic and Early Jurassic as seen in the Newark Supergroup (3). In addition, they seem to have occurred during an interval of overall increasing diversity (8). The extraordinarily fine time scale provided by the orbitally controlled lake level cycles will provide the basis for rigorous tests of the timing of faunal and floral change across the Triassic-Jurassic boundary and its association with the Manicouagan impact.

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