South American Reptiles Found in Virginia: Second Triassic Extinction Constrained in North America

Debate on the causes of mass extinctions is now focusing on resolving the precise pattern of taxonomic turnover and correlated physical events at each of the thirteen extinction episodes which punctuate the last 600 million years of the history of life. The marine record shows three apparent mass extinctions in the Triassic period, with the largest of all extinctions, the Permian-Triassic event (245 Ma), ushering in the period, and another great event, the Triassic-Jurassic mass extinction (201 Ma) closing it (Fig.1). In between is the poorly known Carnian-Norian event (218 Ma). The latter two events are recorded in spectacular detail in the continental fill of the early Mesozoic rift basins of the Atlantic passive margin, called the Newark Supergroup (Fig. 2, 3), currently under multidisciplinary study by a team headed by Paul Olsen at Lamont.

Newark's temporal control

Time control is vital to the understanding of the mechanisms behind mass-extinctions, but it is usually very difficult to establish at the appropriate scale in ancient rocks. For example an error in dating of ±1,000,000 years for rocks 200,000,000 years old is considered quite good using radiometric techniques, such as K-Ar, $^{40}Ar/^{39}Ar$ or Rb-Sr, but unsuitable for trying to resolve whether faunal or floral change is gradual or unusually abrupt. In the continental rocks of the Newark Supergroup, however, Olsen found that very fine temporal control is provided by sedimentary cycles produced by the rise and fall of large lakes, controlled by orbitally induced (Milankovitch-type) climate change, with a period of around 21,000 years (Lamont Newsletter 13, 1986). These lake level cycles, called Van Houten cycles, allow time resolution at the less than 21,000 year level. Correlation with areas outside of the Newark Supergroup is provided by a high-resolution magnetostratigraphy being developed by Dennis Kent, William K. Witte (Lamont) along with Paul Olsen and palynologically-based biostratigraphy being refined by Bruce Cornet and Sarah J. Fowell (Lamont). Such correlation is essential in determining whether the extinctions seen in Newark strata are synchronous with the mass extinctions seen in the marine record.

Rich Carnian assemblage

Because of a lack of fossils, the Carnian episode has been very poorly known, but recently Olsen, Hans-Dieter Sues (Smithsonian), and Noel Boaz (Virginia Museum of Science) discovered a spectacularly rich reptile assemblage near Richmond, Virginia which should shed considerable light on its faunal transition. Unlike all other North American Triassic age assemblages, this assemblage is dominated by mammal-like reptiles and is closely comparable to those known for many years from Southern Africa, Brazil, and Argentina. Most common is an advanced traversodont mammal-like reptile almost identical to *Massetognathus* (Fig. 4A), otherwise known from Argentina. Most of the other reptiles present are unknown from North America but resemble southern hemisphere forms, while others appear to be completely new.

A major discovery is excellent jaw and skull material of what appears to be one of the closest reptilian forms closest to mammals (Fig. 4B). For the first time, it is clear that the differences between early Late Triassic assemblages of Laurasia and Gondwana were due to differences in age rather than geographic isolation.

Gondwana fauna replaced

Based on the new data from Virginia, the Carnian episode of faunal change is characterized by the *replacement* of a Gondwana-like assemblage of terrestrial vertebrates with another of typical North American aspect dominated by the crocodile-like phytosaurs and other archosaurian reptiles. Although still poorly constrained in time, this transition must have taken place over less than 5 million years and involved not only the extinction of many groups of reptiles, but also the origination of many others. According to Cornet, the plant record shows much the same pattern with the replacement of a diverse spore-rich assemblage by a diverse pollen-rich one.

Terrestrial vs. marine record

The marine record shows no obvious anomalous increase in faunal turnover within the Carnian, but an interval of high faunal turnover is reported at the marine Carnian-Norian boundary. However, no such turnover is apparent in the fauna or flora from Newark Supergroup strata at that point. In fact, as shown by extraordinarily abundant and well preserved footprints (Fig. 5), and less abundant bones, no terrestrial reptile extinctions at all are known through this boundary, and the dominant forms continue through. Clearly, either the Newark Carnian episode is misdated, or the marine and terrestrial transitions are not synchronous. In addition, Jack Sepkoski (University of Chicago) has suggested that the apparent marine Carnian-Norian mass extinction could be an artifact, produced by very high ammonite evolution rates. Thus the evidence from the Newark Supergroup suggests rather slow change through the Triassic.

Contrast with Triassic-Jurassic event

Faunal and floral change in the Newark spanning the Triassic-Jurassic boundary shows a very different pattern. 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 replacement by the introduction of new taxa. This is especially well seen in the Newark and Fundy basins, where new finds of vertebrate bones and footprints by the Lamont group are filling in the gap between the well known typically Late Triassic age assemblages and those of the Early Jurassic, allowing tight constraints on the duration of the period of extinctions.

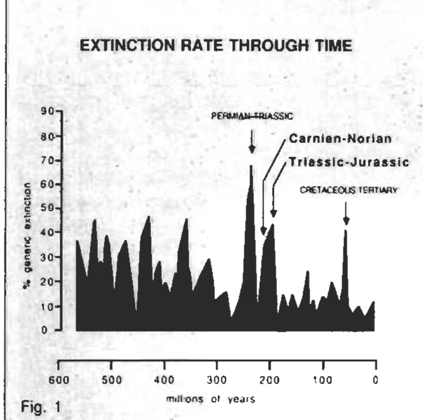


Fig. 1

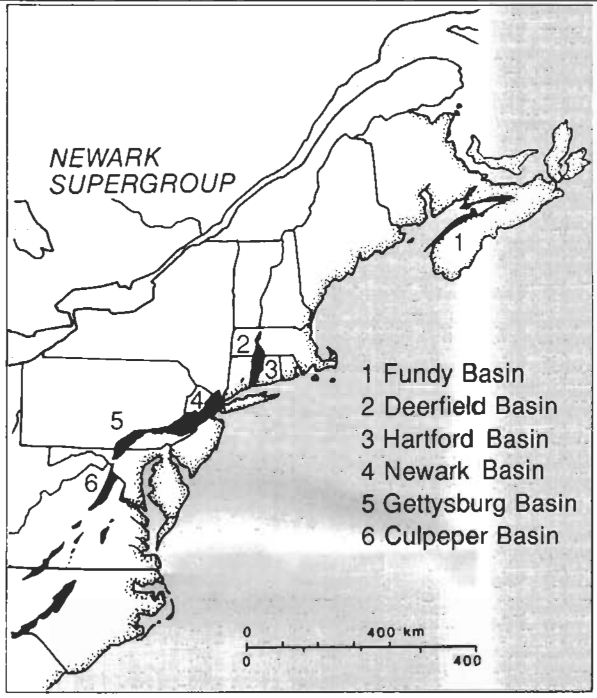


Fig. 2: Newark Supergroup

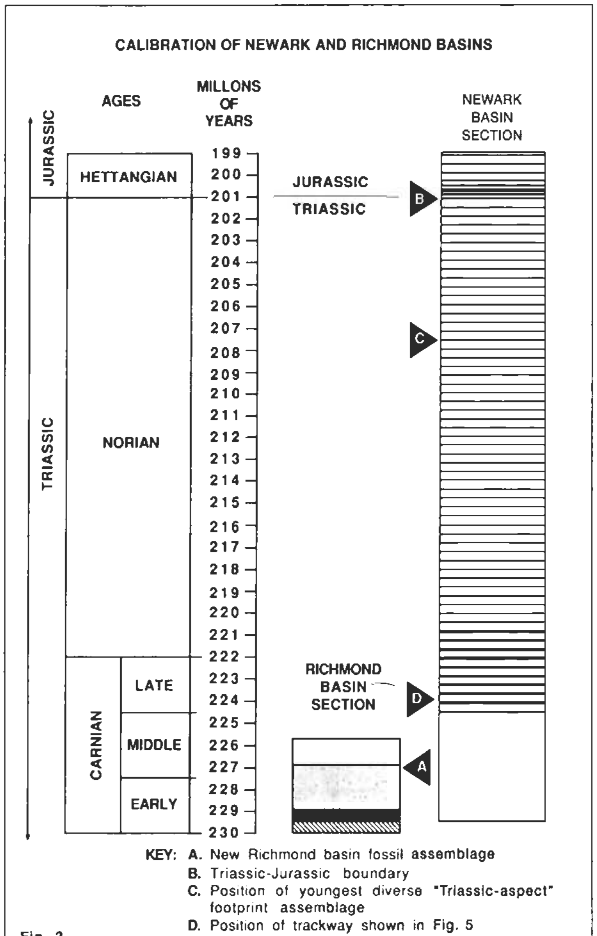


Fig. 3

Fig. 3: Use of lake level cycles has allowed a ***fine-scale time calibration of the stratigraphic sections in the Newark and Richmond basins.*** *Ages are the paleontologically defined time divisions of the Early Mesozoic. Time in millions of years is based on lake level cycles (400,000 year cycle) shown as horizontal bars in the Newark basin section.*

Olsen, P. E., 1989, South American reptiles found in Virginia: second Triassic extinction constrained in North America, Lamont Newsletter, 19, 4-5.

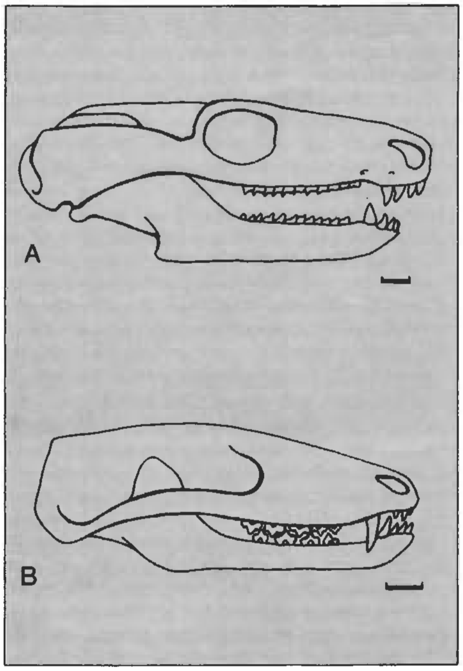


Fig. 4: ***Mammal-like reptiles from the Richmond basin.*** *Reconstruction of Massetognathus* ***(A)*** *a herbivore with a crushing and chopping dentition* ***(B)*** *is a preliminary sketch of the newly discovered form which appears to be very close to the ancestry of mammals.*

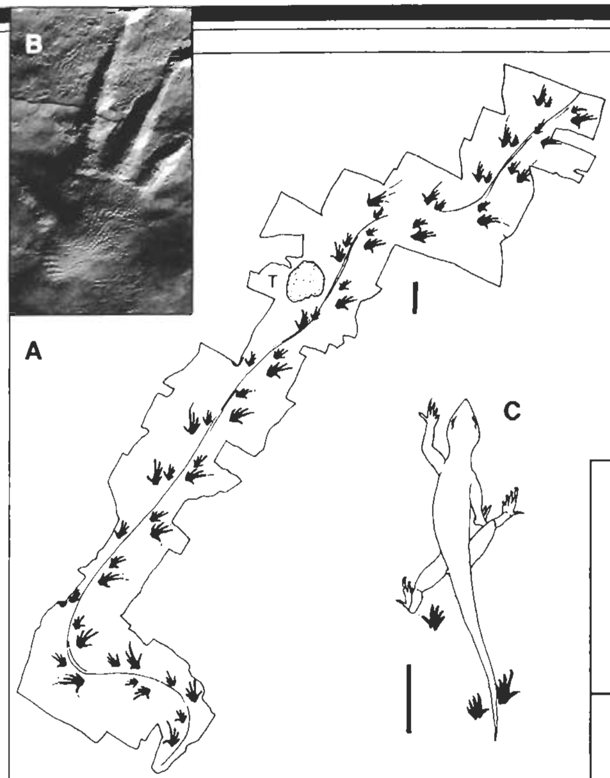
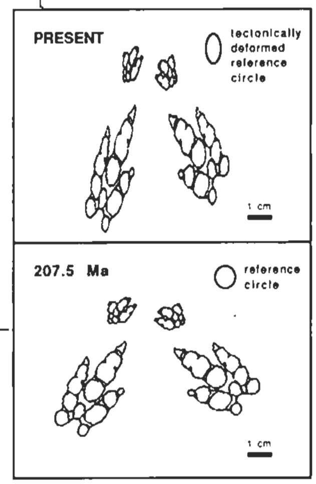


Fig. 5. ***Extraordinarily preserved trackway of* Rhynchosauroides hyperbates** *from Late Carnian age strata of the Newark basin.* ***A****, Complete sinuous trackway with tree stump (T).* ***B****, Enlargement of single left hand impression from trackway.* ***C****, Reconstruction of lizard-like trackmaker. Slab assembly and drawing by SM. Silvestri.*

Fig. 6: A newly completed excavation for ***Norian age reptile footprints from the Newark basin*** *supervised by ShayMaria Silvestri (Rutgers, Newark) produced a very well preserved footprint assemblage showing that there were virtually no extinctions of ecologically dominant reptile groups through the preceding 17 million years. This figure below shows how the footprints from this locality have been tectonically deformed and how the deformation is graphically removed prior to taxonomic analysis.*



Faunal extinction constrained

Thus far the Lamont group has been able to show that the major Triassic-Jurassic faunal shift took place in less than 800,000 years. Strata about 600,000 years older than the boundary have produced bones of the ecologically dominant Triassic reptiles, the phytosaurs and procolophonids. From beds about 100,000 to 200,000 years younger than the boundary have come the rich osseous assemblages from the McCoy Brook Formation of Nova Scotia discovered two years ago (Lamont Newsletter 12, 1986) by Olsen and Neil Shubin (U.C. Berkeley); these are characteristically Early Jurassic in aspect and completely lack the dominant "Late Triassic forms." In addition, reptile footprint assemblages of "typical" Late Triassic aspect (Fig. 6) occur in strata about 6,000,000 years older than the boundary in the Newark basin and show that there were virtually no extinctions of ecologically dominant forms during the preceding 16 million years. Newark basin footprint assemblages from strata dated as less than 40,000 years after the boundary clearly postdate the major extinctions. New exposures of the Triassic-Jurassic boundary now under study have several footprint bearing horizons above and below the boundary, which should permit much tighter time constraints. In dramatic contrast to the Carnian extinctions, those of the Triassic-Jurassic boundary in the Newark Supergroup apparently occurred without the appearance of any new forms; the earliest Jurassic assemblages consist only of survivors from the Triassic.

Microfloral parallel

The microfloral transition studied by Cornet follows the pattern seen in the faunal remains; it 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 pollen resembling the pollen of flowering plants, and, based on lake level cycles, 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 correlation using pollen and spores strongly corroborates the hypothesis that the continental vertebrate extinctions were synchronous with the massive Triassic-Jurassic marine extinctions. The Lamont group hypothesize an extremely rapid, perhaps catastrophic, taxonomic turnover at the Triassic-Jurassic boundary.

Bolide impact hypothesis favored

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. Voluminous tholeiitic lavas were extruded during the Early Jurassic in many parts of the world. However, the oldest of these are the lavas of the Newark Supergroup, which without question *post-date* the Triassic-Jurassic boundary and the associated extinctions by about 60,000 ± 20,000 years, which is close in time but hard to understand as a causative agent (Fig. 3).

Shocked quartz horizon found

To Olsen and his colleagues, the most plausible cause of the Triassic-Jurassic extinctions remains the great bolide impact which produced the Manicouagan structure of Quebec (Fig. 2). This hypothesis is supported by the discovery by D.D. Badjukov, M.A. Nazarov, and others (Moscow State University) of a shocked quartz horizon in the marine Triassic-Jurassic boundary in Austria (Fig. 3). However, the best available dates from Manicouagan range from 206 ± 6 to 215 ± 4 million years, compared to 201 ± 2 million years for the boundary (based on dates from the Newark igneous rocks which just predate the boundary). According to Olsen, this discrepancy may be attributed to excess Argon inherited from the incompletely outgassed 1.6 billion year old basement rocks at Manicouagan. Excess argon appears to be a general problem in dating impacts. Systematic, multiple-system redating of Manicouagan is underway to assess this hypothesis and provide a more robust date. The hypothesis that Manicouagan is the source of the Austrian shocked quartz can be addressed by a new cathodoluminescence technique developed by Mark Anders (newly of Lamont) and M.R. Owen (St. Lawrence University), which allows the provenance of the shocked quartz to be identified. Olsen and Anders are also scouring the later Triassic age portions of the Newark Supergroup for an impact ejecta layer which they hope will correlate with that discovered in Austria. □