Olsen, P. E., 1986, Discovery of earliest Jurassic reptile assemblage from Nova Scotia implies catastrophic end to Triassic: Lamont (Newsletter), v. 12, p. 1-3.

Discovery of Earliest Jurassic Reptile Assemblages from Nova Scotia: Imply Catastrophic End to the Triassic

Late Triassic and Early Jurassic sediments record a crucial period in the evolution of the Earth's biota. Not only does this interval witness the origination of the dinosaurs, pterosaurs, mammals, turtles, lizards, crocodiles, and teleost fishes, but the Triassic-Jurassic boundary itself is the third most significant of the thirteen or so mass extinctions that punctuate the Phanerozoic record. Unfortunately, despite its crucial position, the Triassic-Jurassic transition has remained one of the most poorly documented successions of the Phanerozoic, especially for terrestrial vertebrates. In particular, the time-stratigraphic framework for continental rocks of Late Triassic and Early Jurassic age has been especially problematic, with well dated earliest Jurassic terrestrial skeletal assemblages being essentially unknown. A direct consequence of these stratigraphic difficulties is a proliferation of conflicting hypotheses on the nature of the faunal transition: from those suggesting a dramatic, catastrophic turnover, to those suggesting none.

Late Triassic and Early Jurassic continental sediments are well represented in eastern North America, where they comprise the Newark Supergroup (Fig. 1). These are the remnants of the basin fill of the rifting episode of the present Atlantic passive margin. Fossils, especially those of terrestrial vertebrates, have traditionally been regarded as very rare in the Newark Supergroup. Last summer, however, in collaboration with a team headed by developmental biologist Neil H. Shubin of Harvard and funded by the National Geographic Society, Lamont paleontologist Paul E. Olsen discovered a series of rich assemblages of well-preserved reptiles in the earliest Jurassic part of the Fundy Group of the Newark Supergroup. These assemblages apparently just postdate the mass extinction event, and thus they shed considerable light on what may prove to be one of the great biological catastrophes that helped shape the modern world.

The animal remains occur within the upper part of the early Mesozoic Fundy Group of the Newark Supergroup, a 1000-m-thick continental sequence consisting of red clastics, minor carbonates, and extrusive tholeiitic basalts (Fig. 3). Five formations spanning from the Anisian-Ladinian (Middle Triassic) to Hettangian (earliest Jurassic) are recognized (Table I). The new assemblages occur in basal beds of the youngest formation of the Fundy Group, the McCoy Brook Formation at Wasson's Bluff near Parrsboro, Nova Scotia. The upper flows of the underlying extrusive North Mountain Basalt are discontinuous in this area and the basal, bone-producing portions of the McCoy Brook Formation fill the highly irregular basalt topography where the two formations intertongue (Fig. 4).

So far, roughly three tons of bone-bearing matrix have been collected, containing perhaps 100,000 bones. Long-legged, fully terrestrial crocodiles and crocodile relatives are by far the most common animals, with at least 50 skulls and jaws uncovered. Second in abundance are small lizard-like sphenodontid rhynchocephalians represented by about 30 jaws and one nearly complete skull (Fig. 5). Third, and perhaps the most precious of all, are remains of highly advanced mammal-like reptiles. These are the trithelodonts, the reptile group thought to most closely relate to mammals. Over 13 trithelodont skulls and jaws have been recovered, with several forms being represented — including the *Pachygenelus* and *Diarthrognathus.* This is the first definitive record of these genera outside South Africa, and the first record of the reptile group closest to mammals in North America. Least common is a suite of ornithischian, theropod, and prosauropod dinosaur remains. This includes a partial prosauropod dinosaur skeleton (collected in collaboration with Donald Baird of Princeton). There is a massive residuum of unidentified material that remains to be sorted through. A faunal list is given in Table II.

The faunal assemblages occur in three distinct facies of the McCoy Brook Formation: 1) a brown fluvial sandstone dominated by sphenodontids, and crocodilomorphs (this is also the unit which produced the prosauropod dinosaur skeleton); 2) a basalt-bearing basalt agglomerate, a probable lahar, dominated by crocodilomorphs and the trithelodont mammal-like reptiles: and 3) a lacustrine muddy limestone and interbedded basalt agglomerate dominated by semionotid fishes and ornithischian dinosaurs.

The real value of these assemblages is that it

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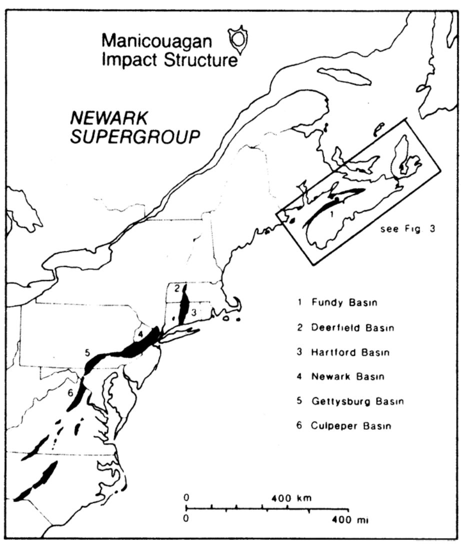

Fig. 1: Just prior to the Middle Jurassic separation of the North American and African continental plate, a series of elongate rift basins formed around the incipient rifting axis. In eastern North America, these basins parallel the grain of the Appalachian Orogen and were filled with thousands of meters of continental sediments and minor tholeiitic igneous rocks. The faulted, tilted, and deeply eroded remnants are exposed from Nova Scotia to South Carolina and are termed the Newark Supergroup. The Manicouagan impact structure, which dates from 210 ± 4 ma, very close to the Triassic-Jurassic boundary, and according to impact theory may have been responsible for a mass extinction event at the boundary.

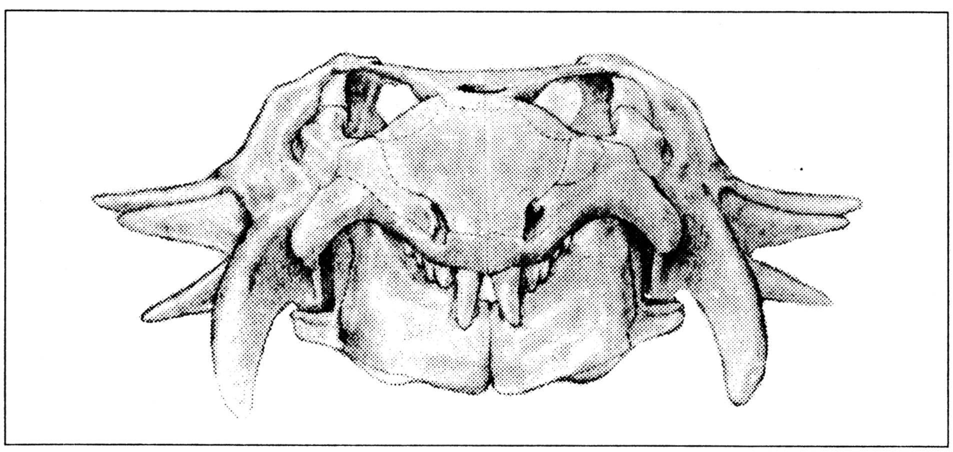

Fig. 2: Skull of the common primitive reptile Hypsognathus *found in latest Triassic Newark Supergroup red sandstones from the Fundy Basin in Nova Scotia, Hartford Basin, and Newark Basin. In Clifton, New Jersey, a skeleton has been found 100 m (<500,000 years) below the Triassic-Jurassic boundary.* Hypsognathus *represents one of the 13 families of terrestrial reptiles that went extinct at or near the boundary. (Drawing by Paul Olsen, twice actual size).*

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is possible to place the bone-bearing units in a developing, high-resolution litho- and chronostratigraphy in a way that has not been possible for Early Jurassic terrestrial vertebrate assemblages outside the Newark Supergroup. The age of the lower McCoy Brook faunules is constrained by three separate lines of age-correlative data: First, pollen and spore assemblages from the upper 5 m of the Blomidon Formation, the Scots Bay Formation and the middle McCoy Brook Formation, are dominated by *Corollina meyeriana,* strongly suggesting a maximum of an Hettangian age. Second, reptile footprint faunules from the basal McCoy Brook Formation and Scots Bay Formation are of "Connecticut Valley" aspect, which indicates an Early Jurassic age. Third, conventional K-Ar, and K-Ar isochron dates from the North Mountain Basalt are consistent with an Early Jurassic age.

Detailed correlation with the rest of the Newark Supergroup is afforded by the whole rock and trace element geochemistry of the underlying North Mountain Basalt, by pollen and spore data, and by lacustrine cycles. According to the regional magma evolution model of John Puffer of Rutgers and Tony Philpotts of University of Connecticut at Storrs, the North Mountain Basalt correlates with the oldest of the high Fe_2O_3-high TiO_2 tholeiites of the more southern Newark basins. The Triassic-Jurassic boundary is palynologically fixed at about 30 m below the oldest basalt (Orange Mountain) in the Newark Basin and all of the interbeds of the southern extrusive units bear Hettangian aspect microfloras. The hierarchy of lacustrine cycles that occurs interbedded with and underlying the basalt flows in the Newark Basin can be used to estimate the total length of the Newark extrusive episode and to infer the duration of the interval between the new reptile assemblages and the Triassic-Jurassic boundary. The lacustrine cycles have been interpreted as responses to climate changes governed by the precession cycle of 21,000 years and the eccentricity cycles of roughly 100,000 and 400,000 years following the Milankovitch theory of climate change. By counting the lake-level cycles caused by the precession cycles and looking at the phase relationships of the longer-term eccentricity cycles, the entire Newark extrusive episode seems to involve less than 500,000 years. This agrees with times for igneous cooling and fractionation of the basalts, worked out by Philpotts. Because the North Mountain Basalt seems to correlate with the oldest of the flows of the southern basins, and the Triassic-Jurassic boundary seems to be 100,000 years older than the oldest basalts (again based on climate cycles), the new reptile assemblages should be less than 200,000-300,000 years younger than the boundary.

Late Triassic continental faunas were dominated by diverse quadrupedal archosauromorph reptiles, large labyrinthodont amphibians, and various mammal-like reptiles, and remains of these are found in Nova Scotia in formations below the locally-defined Triassic-Jurassic boundary and in correlative strata in more southern Newark basins. By the Early Jurassic, dinosaurs, diverse crocodilomorphs, mammals, and essentially modern small reptiles (including sphenodontids) and amphibians were dominant and the terrestrial fauna attained the basic composition it would retain for the next 140 million years.

The Late Triassic-Early Jurassic age assemblages from the Newark Supergroup, especially the new McCoy Brook assemblages shed considerable light on two previous hypotheses proposed for the pattern of extinctions around the Triassic boundary. These are: 1) that the transition was abrupt and of a scale rivaling the mass extinction at the Cretaceous-Tertiary boundary; and 2) that the large number of extinctions at the boundary is an artifact of miscorrelation of strata. At the time the first hypothesis was formulated, virtually

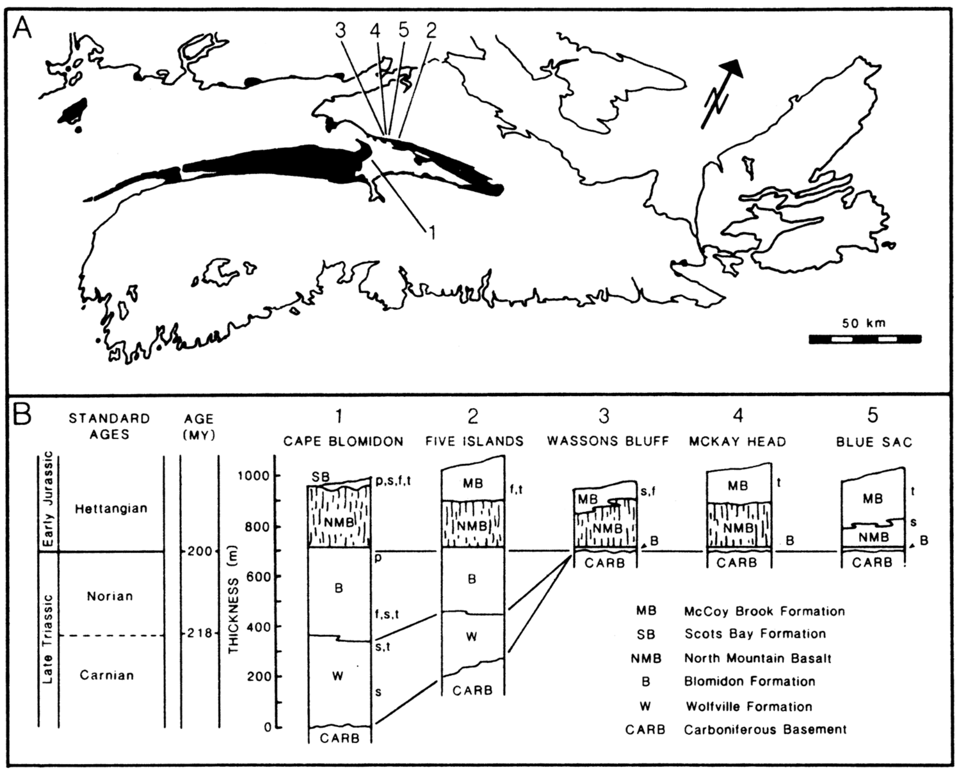

Fig. 3: ***(A)*** *The Fundy Basin (shown here in black) is unique in the Newark Supergroup in having an extensive continuation offshore (not shown), below the Bay of Fundy and Gulf of Maine. Numerals 1-4 show positions of sections shown in B.* ***(B)*** *Sections measured on the north side of the Fundy Basin in Nova Scotia (2-5) show a marked thinning compared to the south side (1) due to onlap on the faulted margin of the Fundy Basin. New assemblage of Early Jurassic skeletal remains is at Wassons Bluff at "s,f." Major fault zone on the north side of the Fundy Basin is the so-called Glooscap Geofracture. Abbreviations for fossils as follows: f, fish; p, pollen and spores; s, reptile bones; t, reptile footprints.*

Table I: **Formations of Fundy Group in Nova Scotia, Canada**

McCoy Brook Formation (+200 m)
Red and brown coarse to fine fluvial and deltaic clastics with locally developed eolian sandstones and minor purple, green, and white lacustrine limestone and clastics and basalt agglomerate (lateral equivalent of Scots Bay Fm.).

Scots Bay Formation (<30 m)
White, green, and red lacustrine limestone and chert with minor brown fluvial and eolian sandstone (lateral equivalent of McCoy Brook Fm.).

North Mountain Basalt (maximum of 270 m)
Bluish gray to green and red tholeiitic extrusive basalt flows.

Blomidon Formation (maximum of 300 m)
Red and brown and green, cyclic lacustrine and deltaic fine claystone to sandstone with locally developed brown eolian sandstone and purple conglomerate.

Wolfville Formation (maximum of 400 m)
Brown and red fluvial sandstone and conglomerate and subordinate mudstone with locally developed red and brown deltaic and lacustrine clastics and thick brown eolian sandstone.

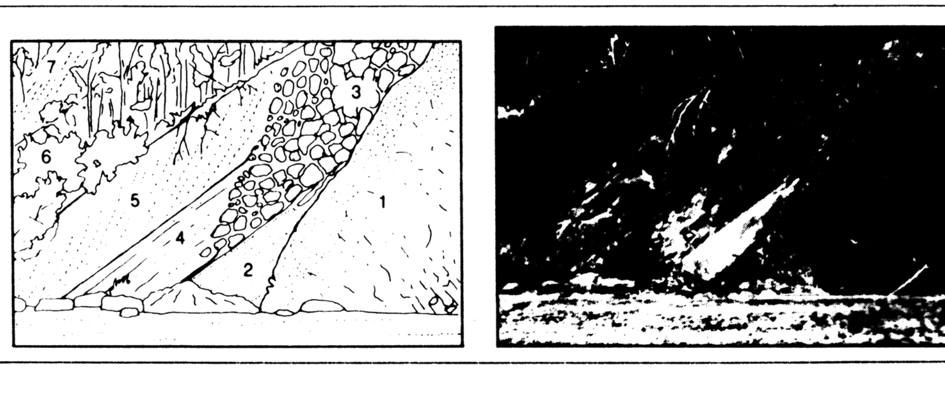

Fig. 4: Example of intertonguing relationship between McCoy Brook Formation and North Mountain Basalt at Wassons Bluff, Nova Scotia, Canada. Center panel is key to photograph: (1) massive and vesicular flow of North Mountain Basalt; (2) lacustrine limestone, sandstone, and siltstone lapping onto sloping basalt surface; (3) basalt agglomerate intimately mixed with lacustrine siltstone containing abundant semionotid and palaeonisciform fish scales, hybodont shark teeth, and ornithischian dinosaur bones — pinches out to lower left; (4) red siltstone and nodular limestone; (5) large-scale cross bedded eolian sandstone; (6) lacustrine red and brown-purple claystone and thin channel sandstones bearing abundant reptile bones (mostly covered); (7) large-scale cross bedded eolian sandstone.

all the strata dated here as Early Jurassic were considered to be Triassic in age. Their reassignment to the Jurassic at first markedly decreased the number of families thought to have gone extinct at the boundary, thus leading to the second hypothesis, first proposed by Olsen and Peter Galton in 1977, that most extinctions occurred gradually through the Late Triassic and Early Jurassic.

Subsequent fossil discoveries, however, brought most of the Triassic extinctions back to near the boundary, yet still extended the range of many families far into the Jurassic and Early Cretaceous. As a consequence, extinctions once again appear concentrated in the latest Triassic (Norian Age). Moreover the high Norian extinction rate is matched with a zero origination rate through the Hettangian. A global tabulation of the stage-level faunal transition of the Norian-Hettangian boundary reveals that 43% of all continental tetrapod families disappear in or at the end of the Norian. While this bespeaks an extinction event, it tells little as to whether it is gradual or catastrophic. Utilizing families present only at the latest Norian, at least 50% of those families are extinct by the Hettangian. In the Newark Basin, typical late Triassic taxa such as the procolophonid reptile *Hypsognathus* (Fig. 2) and phytosaurs occur within 100 m of the estimated position of the Triassic-Jurassic boundary. Again, using lacustrine cycles this places their extinction within the 500,000 years prior to the boundary. Although by no means conclusive, this is suggestive of a very large, catastrophic extinction.

Earliest Jurassic faunas are thus characterized only by the absence of "typical" Triassic families; there are no new families. This is exactly the kind of transition that would be expected of a catastrophic extinction event such as that proposed for the Cretaceous-Tertiary boundary. One would not expect the immediate aftermath (within 200,000-300,000 years) of a catastrophe to see the origination of new families, rather the "day after" communities should be composed of survivors — exactly the pattern seen in the early Hettangian McCoy Brook faunules. Such a pattern of survivors has already been described for the Cretaceous-Tertiary boundary.

It has long been recognized that the Triassic-Jurassic boundary was marked by a major extinction event affecting dominant marine invertebrates. As Anthony Hallam of Oxford has shown, all conodonts, nearly half of the bivalve genera and nearly all bivalve species, almost all nautiloid and ammonite families, and most brachiopods, disappeared at the Triassic-Jurassic boundary. The redating of many supposedly Late Triassic continental rocks at first suggested that the terrestrial vertebrate extinctions were not correlative with those of the invertebrates. The McCoy Brook assemblages and the new interpretations of the global pattern of extinctions strongly suggests that the tetrapod and invertebrate extinctions were in fact contemporaneous.

Fig. 5: Survivor of the Triassic-Jurassic extinction event; the same form occurs in Connecticut below the Triassic-Jurassic boundary: a skull of a sphenodontid reptile from the Early Jurassic McCoy Brook Formation of Nova Scotia. The skull is 1.5 cm across.

The hypothesis of a sudden and dramatic extinction event at the Triassic-Jurassic boundary, affecting both marine and terrestrial assemblages, is supported by the McCoy Brook Formation discoveries. An advantage of this hypothesis is that it is easily falsified by either the discovery of "typical" Triassic families or the discovery of uniquely Jurassic families in the McCoy Brook Formation of correlative strata.

Further corroboration of this catastrophic extinction hypothesis is needed. Planned efforts include additional collection of the Nova Scotian Early Jurassic localities and an intense collection effort directly around the Triassic-Jurassic boundary in the Culpeper, Gettysburg, Newark, and Hartford, Deerfield, and Fundy basins of the Newark Supergroup. Actual osseous remains will probably never be found in sufficient abundance to examine rates of extinction across the boundary rigorously. Reptile footprints, however, are very abundant in the strata around the boundary in several basins. Because these are good for recognizing the presence of many ecologically dominant reptile families they can provide the statistically robust data needed to examine the abruptness of the vertebrate transition where actual osseous remains are lacking. Coupled with studies of the floral transition in the same beds and with the use of lacustrine cycles and a developing paleomagnetic stratigraphy, the Triassic-Jurassic boundary can be examined in the Newark Supergroup at a less than 10,000 year level of resolution. Only when data are available at this level of resolution can a true catastrophic extinction be distinguished from a more gradual one.

Table II: **Taxa Found in McCoy Brook Formation**
(*indicates taxon is a footprint)

Class Chondrichthyes (sharks and rays); Subclass Elasmobranchii; Order Hybodontiformes:
- aff. ***Hybodus*** sp.

Class Osteiichthyes (bony fishes); Subclass Actinopterygii; Order Paleonisciformes: unidentified scales and skull bones.
order Semionotiformes:
- ***Semionotus*** sp.

Class Reptilia; subclass Therapsida; Order Ictidosauria:
- ***Pachygenelus*** sp.; ***Diarthrognathus*** sp.

Subclass Lepidosauromorpha; Order Rynchocephalia (tuatarids):
- 3 new sphenodontids

Subclass Archosauromorpha; Order Crocodilomorpha (crocodile-like reptiles):
- Cf. ***Stegomosuchus*** sp.; new sphenosuchid; ***Batrachopus*** spp.*; ***Otozoum moodii**.**

Order Saurichia (lizard-hipped dinosaurs):
- ***Ammosaurus*** sp.; cf. ***Syntarsus*** sp.; ***Grallator*** spp.*

Order Ornithischia (bird-hipped dinosaurs):
- New fabrosaurid; ***Anomoepus*** spp.*