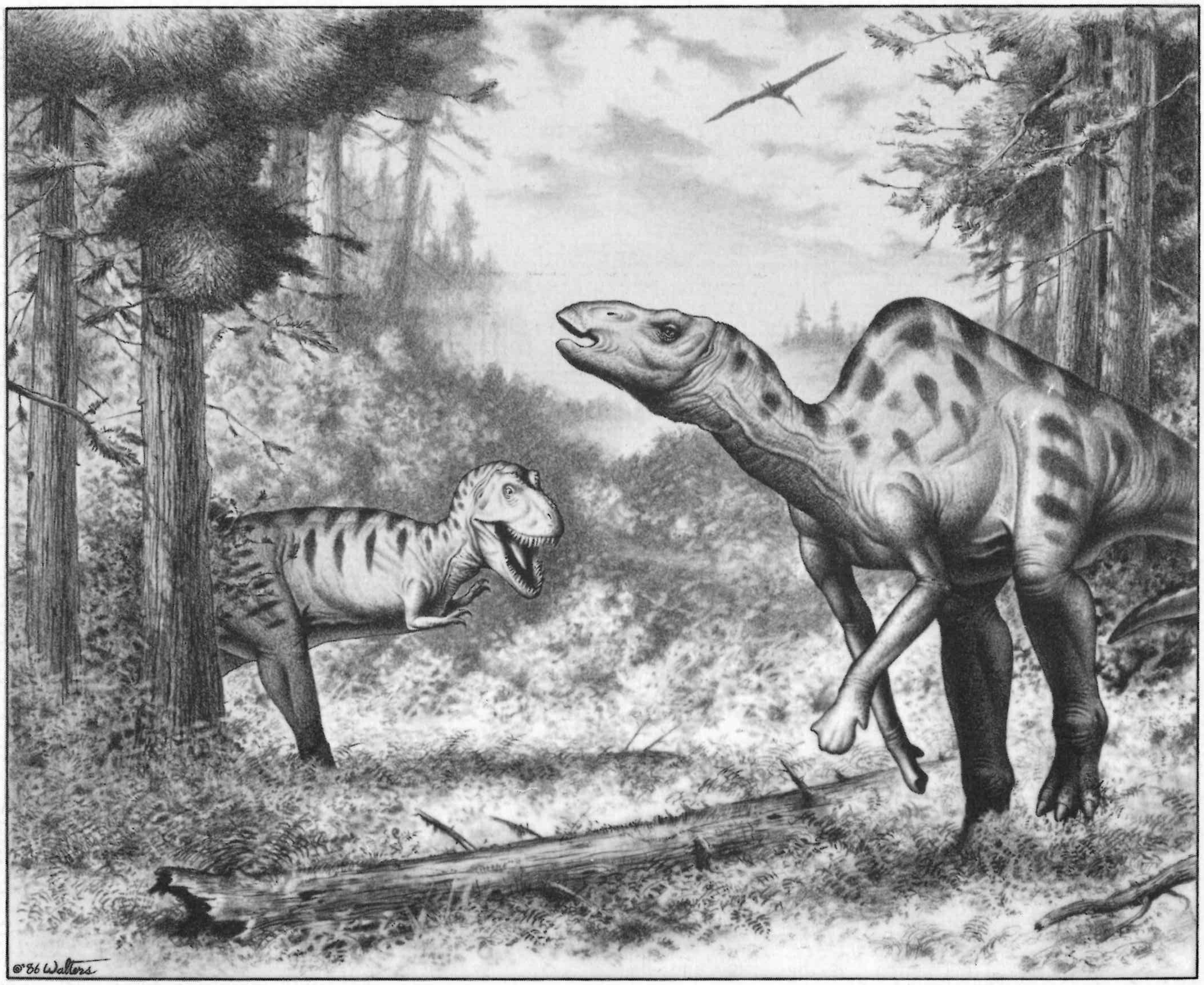
THE MOSASAUR



THE JOURNAL OF THE DELAWARE VALLEY PALEONTOLOGICAL SOCIETY

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EDITOR'S NOTE

This volume of *The Mosasaur* was prepared to coincide with the 46th Annual Meeting of the Society of Vertebrate Paleontology, November 4-8, 1986, in Philadelphia. Two themes are apparent in the papers in this volume: one is historical, detailing the development of American paleontology in its birthplace; the other leitmotif involves the current research on the scrap faunas of the Atlantic Coastal Plain. Even though we may not have the benefits of extensive exposure and fund-generating publicity, research in vertebrate paleontology is alive and well in the Delaware Valley area. The various scrap fauna sites of the East offer us a taphonomic enigma, but an enigma that is close to being resolved. Our mixed nearshore faunas seem ideally suited for working out some interesting problems in paleoecology, land-to-sea correlations, paleoceanography, and the faunistics of the Cretaceous-Tertiary transition.

Our cover illustration by Bob Walters depicts a general East Coast scrap fauna association. In the foreground is *Edmontosaurus* ("*Hadrosaurus*") *minor*, while stalking in the vegetated distance is *Dryptosaurus* ("*Laelaps*") *aquilunguis*, our poorly known eastern tyrannosaurid. The setting is a coastal forest of *Metasequoia* and *Platanus*, quite near an estuary or lagoon.

We welcome our visitors and we hope that their stay here will be informative and pleasant. Those of us who live and work here are proud of the rich traditions and the recent resurgence of paleontology in the Delaware Valley region.

PALEONTOLOGY, BIOSTRATIGRAPHY, AND DEPOSITIONAL ENVIRONMENTS OF THE CRETACEOUS–TERTIARY TRANSITION IN THE NEW JERSEY COASTAL PLAIN

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Introduction

Welcome to Philadelphia, the birthplace of American paleontology. Many of the earliest Philadelphia-based paleontologists cut their teeth on the fossils found in the Upper Cretaceous and Lower Tertiary strata of the New Jersey Coastal Plain. Various Nineteenth-Century luminaries of British paleontology, such as Owen, Lyell, and Huxley, studied and published on specimens found in these deposits. It is this stratigraphic interval that we will visit on this field trip. The New Jersey K–T section is the classic column against which other deposits of this age in the Atlantic Coastal Plain are compared. Moreover, this sequence can be considered a critical correlative link between the thick K–T deposits of the American Western Interior and the classic K–T sections in Western Europe.

We will visit four localities that are being actively worked by the New Jersey State Museum, and thus this field trip reflects some of the current research interests at NJSM. Our specific concerns are faunistics, stratigraphy, taphonomy, and paleoenvironments. Although much of the Coastal Plain is covered by vegetation (and what is not is obscured by deposits of the Technozoic), the relative abundance of fossils in the few extant exposures is tantalizing, as are the old collections from the once-extensive glauconite-mining industry.

We should emphasize that the total New Jersey K–T section is thin, particularly in comparison to the thick Western sequences of similar age. This is largely due to the constrasting tectonic settings. While the Western Interior deposits are the product of extensive erosion of actively uplifting areas with concomitant copious clastic shedding and thick deposition, the Atlantic Coastal Plain deposits, especially the glauconites, were laid down in sediment-starved environments along a passive continental margin. The exposures, limited and intermittent, are generally of unconsolidated sediments that do not produce much in the way of topographic relief. Despite this, the condensed section, composed mostly of an unusual mineralogy (glauconite), affords us an interesting

The Mosasaur, 3:1–35

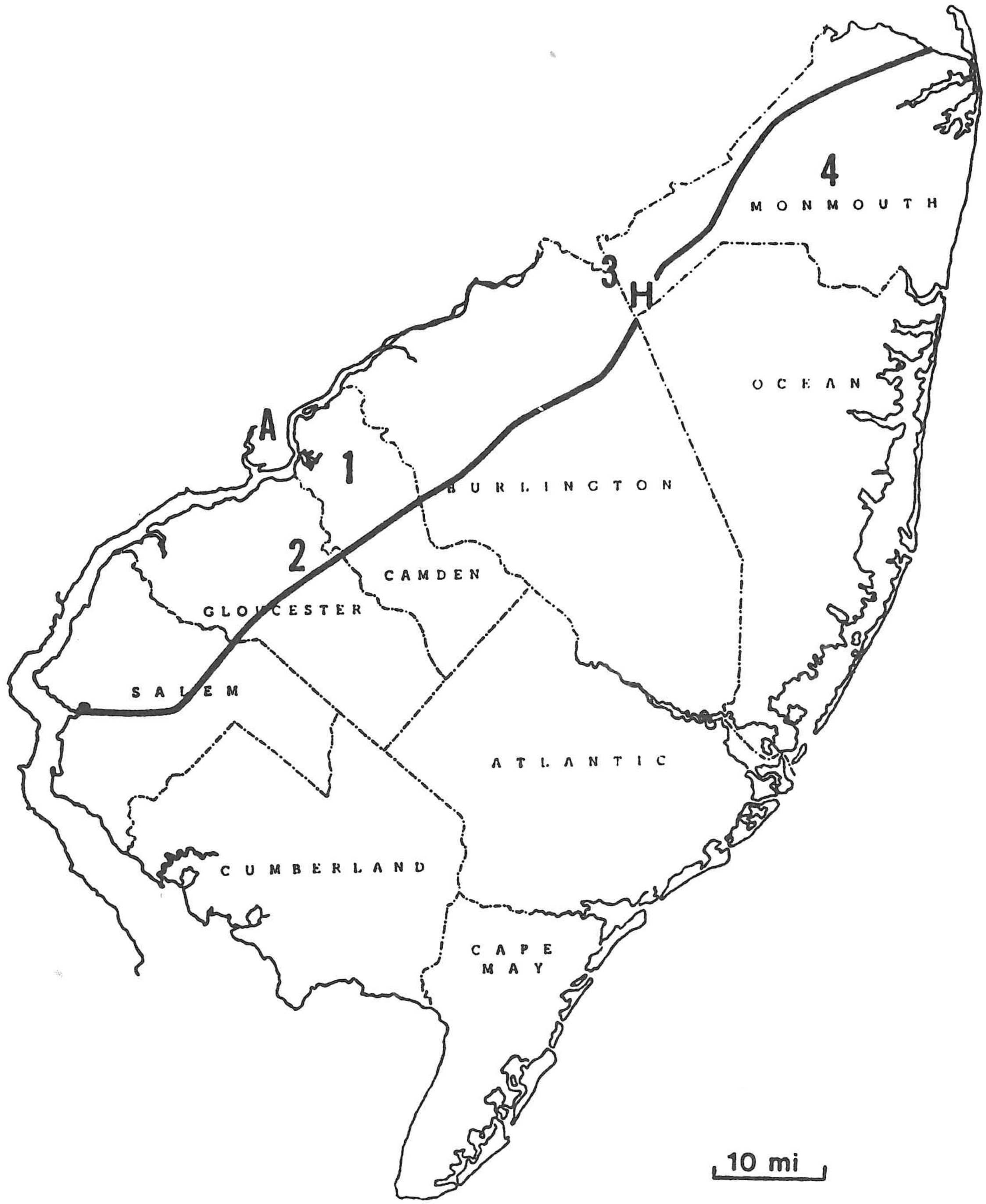

Figure 1. Location map of southern New Jersey: Line indicates division into inner and outer Coastal Plain physiographic provinces and approximates the Cretaceous–Tertiary boundary in much of the area. Numbers correspond to stops on the field trip. A is the Academy of Natural Sciences, Philadelphia. Historic collecting area of Hornerstown–Cream Ridge indicated by H.

Chronostratigraphic Units			Lithostratigraphic Units			STOP
Period	Epoch	Stage	Group	Formation		
Tertiary	Eocene	Ypresian		Manasquan		
				Shark River		
	Paleocene	Danian	Rancocas	Vincentown		
				Hornerstown		
Cretaceous		Maastrichtian	Monmouth	Tinton	New Egypt	
				Redbank		2
				Navesink		
				Mount Laurel		4
				Wenonah		
		Campanian	Matawan	Marshalltown		3
				Englishtown		
				Woodbury		1
		Conacian-Santonian		Merchantville		
				Magothy		
		Cenomanian		Raritan		

Stratigraphic Notes:

1. The Navesink, Redbank, Tinton, and Hornerstown Formations are correlatives to the New Egypt Formation (see Stratigraphic Note in Stop 2 of road log). The Redbank and Tinton Formations are missing at Stop 2.

2. The Wenonah Formation is not recognized in this report (see Stop 4 of road log); it equals the Mount Laurel Formation.

Stops:

1 Haddonfield, Camden County

2 Inversand Company, Sewell, Mantua Township, Gloucester County

3 Ellisdale, Upper Freehold Township, Monmouth County

4 Big Brook, Monmouth County

Figure 2. Generalized stratigraphic succession at the Cretaceous–Tertiary transition in the New Jersey Coastal Plain. Numbers correspond to stops on field trip.

opportunity to study nearshore and shelf sedimentation and taphonomy during an interval of geologic history that has recently been the center of some attention. Changes in sea level at the end of the Cretaceous and the beginning of the Tertiary are reflected in the transgressive and regressive cycles of glauconite, clay, and sand; coupled with ongoing continental margin subsidence and shifting axes of deposition, these cycles produced a complex of facies ranging from terrestrial-fluvial (Raritan Formation) to outer continental shelf (Hornerstown Formation).

The localities on this trip encompass the Campanian-to-Danian chronostratigraphic interval and span the range of continental margin environments from estuarine lagoonal to outer continental shelf. We present faunal lists for each locality and include occasionally non-traditional interpretations of stratigraphy, depositional environment, and taphonomy. We hope you enjoy the trip, and we invite your discussion and comment.

Field Trip

This field trip follows a 171-mile route (round-trip) from Philadelphia through four localities on the New Jersey Coastal Plain. These localities were selected primarily for their content of vertebrate fossils at the Cretaceous-Tertiary transition. Although sometimes of transient interest, notes on regional history and culture are included in this guide. We hope their inclusion enlightens your trip, and we hope that they help dispell unjust reputations that Philadelphia and New Jersey are mute entities of political geography.

All the localities are wet and very muddy. Please dress accordingly.

Mileages in the two columns are cumulative on the left and intervals on the right. Slight variations may occur in actual cumulative mileages due to odometer differences.

Abbreviations of repositories mentioned in the faunal lists are:

ANSP	Academy of Natural Sciences of Philadelphia
NJSM	New Jersey State Museum (Trenton, N.J.)
PU	Princeton University (transferred to the Peabody Museum, Yale University)

Collection numbers for some very common species are those for typical specimens.

Begin field trip at
The Academy of Natural Sciences of Philadelphia

The Academy of Natural Sciences of Philadelphia was founded in 1812. It is the oldest continuously operating museum in America.

Standing in front of the Academy is a statue of Joseph Leidy (1823-1891), Father of American Vertebrate Paleontology; he also was a president of the Academy. He holds in his hand a cast jaw of the Pleistocene felid, *Felis atrox* Leidy, 1853, from near Natchez, Mississippi (D. Baird, personal communication, 1986); the original specimen, the holotype, is in the Academy collections (ANSP 12546).

In 1858, Dr. Leidy described *Hadrosaurus foulkii*, the world's first reasonably complete dinosaur skeleton (ANSP 10005, Holotype), which is on display in the Academy.

Dr. Leidy taught comparative anatomy at the University of Pennsylvania; the campus is about a mile west of the Academy. Several generations of paleontology students can trace their academic roots through Philadelphia. Beginning with Dr. Leidy, this genealogy includes Edward Drinker Cope, who greatly advanced the science of vertebrate paleontology while working both at the Academy and the University. Some of today's practitioners and students of paleontology are sixth- and seventh-generation academic descendents of Dr. Leidy (Stephen Farrington, personal studies).

The Academy's research collections contain material that reflects our American heritage. These collections of paleontological, geological, zoological, and botanical specimens include items collected by Thomas Jefferson, Lewis and Clark, John James Audubon, and numerous other luminaries of diverse scientific specialities.

Within the treasure trove of fossils in the Academy are specimens from the collections of Thomas Jefferson, including the holotype of Jefferson's Ground Sloth, *Megalonyx jeffersonii* Desmarest, 1822. The holotype is represented by the "bones of the left forefoot," from a cave in Greenbrier County, West Virginia (ANSP 12507, 12508; Gillette & Colbert, 1976, p. 32) (originally Greenbriar County in western Virginia). This historic specimen was first identified by Jefferson (1799) as belonging to "an animal of the clawed kind" (see also Wistar, 1799). Kurtén & Anderson (1980, p. 137) remarked:

> "Jefferson called it *Megalonyx* ('great claw') and at first thought (and hoped) that the bones were those of a giant carnivore three times the size of a lion. When he came across a drawing of a recently discovered South American megathere, however, he realized that *Megalonyx* was related to the 'bradypus, dasypus, and pangolin' and was not a carnivore, possessing a 'phosphorous eye' and 'leonine roar' (Jefferson, 1799). Jefferson's talk to the American Philosophical Society in 1797 about *Megalonyx* marked the beginning of vertebrate paleontology in North America, and it is fitting that *Megalonyx jeffersonii* was named for him."

Megalonyx is known from one of the stops on this field trip (Stop 4). A specimen, *Megalonyx* sp., was found in Pleistocene deposits at Big Brook, Monmouth County, New Jersey (Parris, 1983).

The Academy came to hold the Jefferson collection through its close ties with the American Philosophical Society, an organization founded by Benjamin Franklin in 1743 and which was the first scientific organization in Colonial America. Franklin's society was reorganized under its present name in 1769, and the Society still functions in Philadelphia from a building next to Independence Hall; Jefferson and George Washington also were in its original membership. In 1849, the Academy, "which worked so closely and harmoniously with the American Philosophical Society," received the Society's entire collection of fossils, including the Jefferson material (Howard, 1975, p. 124). Other specimens from the Jefferson collection include vertebrate material collected by Meriwether Lewis from Big Bone Lick, Kentucky, an expedition that prepared Captain Lewis for his great Louisiana Purchase expedition with Capt. William Clark. The Jefferson collection also contains a broken Neogene(?) tooth of the shark *Procarcharodon megalodon* (Charlesworth), thought to have been collected by Jefferson himself, from the tidewater region of Virginia.

Other fossils in the Academy collections were collected or described by Leidy, Cope, and many other notable paleontologists of the Nineteenth and Twentieth Centuries. Still more special items of paleontology, not widely known to be held by the Academy, are

Gideon Mantell's specimens of *Iguanodon*, a collection of invertebrates from the Middle Cambrian Stephen Formation of British Columbia (part of which antedates Charles D. Walcott's collections of Burgess Shale material), and the Horace G. Richards collection of Neogene molluscs, to mention but a few of the treasures. And the Academy's library has been called one of the greatest natural science libraries of the western hemisphere; its collections of rare volumes and archival material are particularly outstanding.

At the Academy, we are virtually at the inner edge of the Atlantic Coastal Plain. Several blocks to the northwest, behind the Philadelphia Museum of Art, are large outcrops of the Wissahickon Formation, largely schist (metamorphic age of ?Ordovician in this area). These outcrops delineate the boundary between the Coastal Plain and Piedmont physiographic provinces. Behind the Art Museum, a dam across the Schuylkill River (pronounced "*Skoo*-k'l") sits atop the natural fall line. The dam was built to pond water for a city reservoir that occupied the site of the Art Museum. The associated steam-powered Fairmount Water Works is a National Civil Engineering Landmark and is presently being restored.

The traffic circle in front of the Academy sits in the original Logan Square, the northwest of four corner squares in William Penn's original plan for Philadelphia. The bounding park areas comprise the remnants of Logan Square. The four corner squares, and a central square now occupied by City Hall, were public areas where trade was conducted and citizens' livestock grazed. Other squares are Franklin (northeast, which we shall pass on the way to New Jersey), Rittenhouse (southwest), Washington (southeast), and Center or Market Square (City Hall). Only the central square no longer exists as public parkland, and all five squares are on the National Register of Historic Sites. Franklin and Washington Squares were also used as civil and church cemeteries during the Eighteenth and Nineteenth Centuries. During the Revolutionary War, some of the dead were interred at these sites, and the Tomb of the Unknown Soldier of the Revolution (erected much later) is in Washington Square. Many remains in these squares never were exhumed for reburial as land use practices changed; at times, tombstones have been found in place beneath the present ground surface.

LEG 1. Philadelphia to Haddonfield, N.J.
Driving distance: 9.0 miles. Approximate travel time: 20 min.

0.0		**Academy of Natural Sciences, 19th & Race Streets, on the Benjamin Franklin Parkway. Proceed east on Race St. toward the Ben Franklin Bridge.**
0.3	0.3	Race Street Friends Meeting House on right. The Friends are better known as Quakers, refugees from England and Germany who first sought religious freedom in the New World in the Seventeenth Century. ~~This building~~ originally stood about six blocks away, on South 12th St. It was dismantled and moved to this site around 1970 to make way for a high-rise office building. No. That bldg. went elsewhere
0.5	0.2	Broad Street, one of the longest straight city streets in the world. The view to the south (right) is toward City Hall. Atop the tower is a statue of William Penn (1644-1719), a Quaker, who founded Philadelphia in 1684. Quakers were prominent not only in the history

of Pennsylvania ("Penn's Woodland"), but also in the development of Gloucester County, New Jersey, where there are many notable fossil localities. Penn, the son of an admiral, was imprisoned many times for his preaching (once in the Tower of London). He eventually was elected to the Royal Society and in 1681 he received the charter for Pennsylvania from King Charles II. Quaker vertebrate paleontologists of the Philadelphia area include Joseph Leidy, Edward Drinker Cope and, more recently, Dr. Donald Baird.

0.8 0.3 "Chinatown", Philadelphia's Chinese American community. Great food!

1.0 0.2 Franklin Square to the left. This is the northeast square of William Penn's original Philadelphia.

1.2 0.2 **Bear left at approach to Ben Franklin Bridge.**

"Bolt of Lightning" (Isamu Noguchi, dedicated 1984) atop plaza to the left. This 101.5-foot-high, 36-ton stainless steel work represents a lightning bolt dashing between a kite and key. Several decades in planning, the design and execution of this sculpture was an interesting engineering problem.

The Philadelphia portal to this bridge is just two blocks north of southeast Benjamin Franklin's grave at the ~~southwest~~ corner of 5th and Arch Streets. Designed by renowned bridge engineer Ralph Modjeski and built 1922-1926, this bridge was originally called the Delaware River Bridge. It was an engineering marvel of its time, the world's longest single-span suspension bridge. The span is 1,750 feet and rises 135 feet above mean high water; the overall length of the bridge is 8,291 feet and the total weight of steel and masonry is 720,000 tons. Total construction costs were $55 million. The bridge was rededicated the Benjamin Franklin Bridge in 1956 when the near-by Walt Whitman Bridge was being built.

The two 383-foot-high towers of the Ben Franklin Bridge sit on bedrock of the Wissahickon Formation. The deepest foundation is 105 feet below mean high water. Each of the 30-inch-diameter cables is made of 18,666 wires and has an ultimate strength of 125,000 tons.

As we pass over the bridge, the view to the south (right) takes in the Philadelphia waterfront, Camden, N.J., and, some three miles downriver, the Walt Whitman Bridge. A 40-foot-deep ship channel is kept open on the Philadelphia side of the river.

Visible on the Philadelphia side are I-95 (Maine to Florida) and, to the south, Penn's Landing, a multipurpose city park built near where William Penn first landed to found his "greene Country Towne." Penn's Landing is home to a variety of vintage sailing vessels and the cruiser *U.S.S. Olympia*, flagship of Admiral (then Commodore) George Dewey at the Battle of Manila Bay. The *Olympia* is the sole survivor of the late Nineteenth Century shipbuilding program that produced the Great White Fleet of wholly steel naval vessels. It was on the bridge of this ship, on the morning of May 1, 1898, that the historic words were spoken by Dewey, "You may fire when you are ready, Gridley".

On the New Jersey side, the view to the south takes in the city of Camden. The prominent white tower is the Camden City Hall. Rutgers University occupies the area immediately adjacent to the bridge as you approach the bottom. The large red brick building next to the bridge is the university's Victor Hall, original headquarters of RCA and where the RCA Victor recording studios were housed. The complex of industrial buildings to the south is RCA manufacturing facilities (where many components for our lunar-landing and unnmanned space programs have been developed) and the headquarters for Campbell Soup.

Camden was settled originally as Cooper's Ferry, in 1681; Camden County was created from part of Gloucester County in 1844 and was named for Charles Pratt, Earl of Camden. This city, once noted for its therapeutic artesian water (with which Camden Lager was brewed), was the home of the great naturalist-artist John James Audubon. A few blocks south of RCA stands the last home of the American poet Walt Whitman.

3.0 1.8 **Pay toll.** (Story has it, as told by some long-time residents, that after the bridge was built toll would be charged only until the construction costs were met.)

Proceed east on US 30. Admiral Wilson Boulevard. US 30 spans the continent, from Atlantic City to San Francisco, over 3000 miles. (Amongst local residents, no one seems to recall who Admiral Wilson was.)

5.0 2.0 **Bear left, go up ramp. At top of ramp, bear left to NJ 70 East.**

5.6 0.6 **Bear right onto NJ 70 East.**

7.2 1.6 Garden State Racetrack at 11 o'clock. The glass clubhouse was built in 1984 after the original, largely wooden, historical structure was destroyed in a huge 1977 fire.

8.0 0.8 **Race Track traffic circle. Bear right (1/4 the way around the circle) onto Grove St. Follow the sign for Haddonfield.** [Note: The New Jersey Department of Transportation is planning to remove this circle. Later followers of this road log may encounter an intersection.]

8.8 0.8 **Maple Ave. Turn left (east) at traffic light.**

9.0 0.2 **Park at the end of the road, before entering property of the Haddonfield Department of Public Works Disposal Plant.**

⚒ S T O P 1 A ⚒

HADROSAURUS FOULKII SITE

Please remove hats. Through the trees beyond the memorial plaque here is a tributary of the Cooper River, incised in the Woodbury Clay (Campanian) of the Matawan Group. The overgrown pit area in front of you is the remnant of a Nineteenth-Century marl pit; it is the former grave of the type specimen of ***Hadrosaurus foulkii*** Leidy, 1858. The bones of *H. foulkii*, as area paleontologists never tire to relate, were the first reasonably complete dinosaur skeleton to be found anywhere in the world, and they were among the first dinosaur remains to be found in America. The mounted specimen at the Academy of Natural Sciences is a cast of the holotype material; some of the original material is also on display elsewhere in the exhibit hall.

The memorial plaque is mounted on a slab of Stockton Arkose, from the Triassic portion of the Newark Supergroup.

Text of Commemorative Plaque

"In a marl pit on the John E. Hopkins farm in October 1858, the world's first nearly complete dinosaur skeleton was unearthed by William Parker Foulke. The find was adjacent to this point. This was also the first dinosaur skeleton to ever be mounted. The bones represented a 25 foot, 7–8 ton, herbivorous hadrosaurus [*sic*] (reptile). Its height probably ranged from 6–10 feet at the hips. Some 55 of an estimated 80 bones were discovered. This creature lived 70–80 million years ago during the Cretaceous Period at the end of the dinosaur age.

"This site was developed in 1984 as an Eagle Scout Project by Christopher Brees, Troop 65. Major project funding by the Academy of Natural Sciences, Philadelphia, PA."

		Turn around, return to Grove St.
9.3	0.3	**Turn left onto Grove St. Go south one block.**
9.4	0.1	**Turn left onto Hawthorne Ave.**
9.5	0.1	**Turn left into American Legion Post 38 parking lot. Park vehicle.**

⚒ S T O P 1 B ⚒

HADDONFIELD LOCALITY

Walk north toward the creek. Proceed carefully down the stream bank to the stream bed. Turn left and walk upstream about 30 m to an exposure of 1.2 m of Woodbury Clay, which here is grayish-black (N 2) on a clean surface. This is a somewhat variegated micaceous clay containing abundant very fragile molluscan fossils, primarily ammonites and pelecypods. The only vertebrate specimens known from this locality are the type skeleton of *Hadrosaurus foulkii*, found in the marl pit area downstream, and, recently collected from the cliff here, two associated fragments of a toxochelyine turtle, referred by Parris *et al.* (1986) to *Dollochelys*. The streambank exposures continue westward (upstream); feel free to collect samples and fossils.

When returning to the vehicle, please do not go up the nice (and very convenient) path if you come upon it; it goes to someone's back yard.

Depositional Environment

The Campanian Woodbury Formation demonstrates the difficulties of interpreting stratigraphy in an area of limited outcrop. Owens & Minard (1969) and Owens *et al.* (1970) have interpreted the Woodbury as pinching out along strike to the southeast, and indeed typical Woodbury lithology is not observed at the "Deep Cut" section of the Chesapeake and Delaware Canal in Delaware (Gallagher, personal observation; Pickett, 1972). Petters (1976) showed that the overlying Englishtown Sand disappears downdip, replaced in well sections by a thicker Woodbury interval. Petters suggested that the Woodbury intertongues with the Englishtown Formation in a facies change along strike. Traditionally, following Weller's (1907) interpretation, the Woodbury has been regarded as a depositional environment shallower than the glauconitic units of the Atlantic Coastal Plain, *e.g.*, the Merchantville, Marshalltown, Navesink, and Hornerstown Formations. The generally gradational relationship the Woodbury has with the subjacent Merchantville and superjacent Englishtown mark it as a transitional regressive unit between deeper-water mid-shelf deposition and the regressive beach sands of the Englishtown.

The Woodbury Formation probably represents some kind of embayment. Fossils of scaphopods and corals suggest full-marine salinity in this embayment. The relative completeness of the *Hadrosaurus foulkii* type specimen (in comparison to the fragmentary remains of other New Jersey dinosaurs) argues for a near-shore origin for this unit. Furthermore, hadrosaurs seem to have been coastal inhabitants who perhaps frequented estuaries and similar environments with high biomass productivity. Supporting this interpretation is Horner's (1979) observation that hadrosaurs are the most frequently found dinosaur fossils in marine deposits.

Faunal List
(Updated from Gallagher, 1984)

INVERTEBRATA

Coelenterata

Astrangia cretacea (Bolsche)
Micrabacia cribraria Stephenson

Pelecypoda

Gervilliopsis ensiformis (Conrad)
Trigonia eufaulensis Gabb
Cyprimeria depressa Conrad
Cardium ripleyanum Conrad
Vetericardia crenilata (Conrad)
Linearia metastriata Conrad
Corbula crassiplica Gabb

Scaphopoda

Dentalium subarcuatum Conrad

Cephalopoda

Placenticeras placenta (DeKay)

VERTEBRATA

Reptilia

Toxochelyinae, cf. *Dollochelys* sp.	NJSM 12757
Hadrosaurus foulkii Leidy	ANSP 10005 (Holotype)

LEG 2. Haddonfield to Sewell
Driving distance: 15.6 miles. Approximate travel time: 30 minutes.

		Drive from parking lot, return to Grove St.
9.8	0.3	**Turn left (south) onto Grove St.**
10.0	0.2	Hopkins Farm site to your left. The house behind Hopkins Pond was the home of John Hopkins, the man who informed William Parker Foulke of the existence of the dinosaur bones that Foulke eventually brought to Dr. Leidy.
10.3	0.3	**Turn right (west) onto NJ 41 Temporary (Kings Highway).** This is downtown Haddonfield. Kings Highway is a road laid out in Colonial times, running from Salem, in southern New Jersey, northeastward across the state to Freehold. (We will be in Freehold later in this trip.)
10.4	0.1	Indian King Tavern on the right (built 1750). (Sorry, no beer or ale; it's a museum now.) The New Jersey legislature met at this tavern in 1777 and there formally declared New Jersey to be a State. British forces passed the Indian King when they retreated from Colonial forces at Red Bank northward along Kings Highway. (Don't confuse that Red Bank with the other Red Bank in northeastern New Jersey; the latter gives its name to the later-Maastrichtian Redbank Sand.) The British retreat toward Trenton eventually set the stage for Washington's famous crossing of the Delaware, and victory, on Christmas, 1776.

10.7	0.3	**Go over small railroad bridge.**
10.8	0.1	**Turn left at the first traffic light, onto Warwick Rd.**
12.0	1.2	**Turn right onto Copely Rd. (in a residential section).**
12.4	0.4	**Bear right onto I–295 South.**
15.2	2.8	**Bear right to continue on I–295 South.** interchange re-engineered
15.7	0.5	Highway turns left nearly 180 degrees. (This is the infamous "Al-Jo Turn," named after the former Al-Jo's tavern, the stucture visible to your right after emerging from the underpass.)
16.2	0.5	**Bear left to follow NJ 42 South. Follow signs for Atlantic City.**
17.0	0.8	Bellmawr Dump on right. This landfill site is composed of fossiliferous mixed spoil from several Campanian formations; it is now strictly off limits. Well-preserved decapods (from the Woodbury Clay) and numerous scraps of vertebrate material have been collected here.
17.4	0.4	**Cross over New Jersey Turnpike and Big Timber Creek; enter Deptford Township, Gloucester County.** The New Jersey Turnpike is the world's most heavily travelled highway. Deptford is the landing site of the first flight in America, when on January 9, 1793, two balloonists ascended from Philadelphia and shortly reached this area. Gloucester County was created in 1686 and was originally settled by Swedes; it was named for Gloucestershire, England. Billingsport, in this county, contains the first piece of land to be acquired by the new United States, in July 1776. Gloucester County was reduced in size in 1844 and 1873 when Camden and Atlantic Counties, respectively, were created.
17.8	0.4	**Take exit from Rt. 42 onto NJ 55 South.** This road cut (now covered) yielded many Cretaceous shark teeth from the Marshalltown Fm.
21.3	3.5	Kinsley Landfill at 10 o'clock. Landfills have been a major industry in Gloucester County for many years, in part because of old marl excavating. This landfill, now about to close (by legislation and legal litigation), was once heavily used by Philadelphia and local communities.
24.9	3.6	**Exit onto County Rt. 553 North.**
25.0	0.1	**At top of ramp, turn right onto paved road, then turn left onto gravel road.** INVERSAND COMPANY.
25.2	0.2	**Bear left through gate to pit.**
25.3	0.1	**Park vehicle on right.**

⚒ STOP 2 ⚒

INVERSAND COMPANY

no longer in business

The Inversand marl pit in Sewell, Mantua Township, N.J., is one of the most productive localities ever found for Cretaceous and Tertiary fossils. Invertebrate fossils are the most abundant, but vertebrates are common, and plants are represented by wood, amber, and seeds. The Main Fossiliferous Layer (MFL) contains fossils of latest Maastrichtian age and is within the basal part of the Hornerstown Formation ("Green Marl" of the miners). Concentrations of fossils also are found in the Navesink Formation and in the upper Hornerstown Formation.

This is the only remaining company of the glauconite industry. Widely mined a century ago for agricultural "marl," the industry now consists of a major operation for the production of water softener. Agricultural use persists, but it is of little economic significance.

The Inversand Company was owned by Churchill Hungerford, Jr., a man whose generosity to science can scarcely be overestimated. For decades he allowed fossil collectors from the New Jersey State Museum to recover specimens from the pit, and countless thousands of fossils have thus been available for scientific and educational purposes. His death on 15 March 1982 was a sad day for those of us who work in the field of paleontology. His company has continued commercial operations and its relationship with the Museum, and we are its guests for this field trip. His wife, Mabel Hungerford, remains one of our museum's greatest friends.

You may collect fossils as much as you wish, but highly significant specimens may be found. The Company asks that you offer these to the Museum, which will list the collector as donor. The eight Maastrichtian bird fossils from the pit are a good example of how precious such specimens can be.

Depositional Environments

The Navesink Formation or "Chocolate Marl" at the base of the exposure here is an inner continental shelf deposit consisting of clayey glauconitic sand with a typical Upper Cretaceous marine fauna. Noteworthy are the taphonomically mature hadrosaur specimens that are found in the pit from time to time. The terrestrial faunal input and the less purely glauconitic sand indicate a nearer-shore environment; also suggestive are the callianassid-style burrows in the Navesink. By contrast, the Hornerstown Formation, an almost pure glauconite sand, is probably deeper-water, mid- to outer-shelf deposition (Van Houten & Purucker, 1984). This environment would appear to be well below normal wave base, with slow, gentle sedimentation producing a condensed section in a sediment-starved basin under generally low-oxygen conditions. So the Navesink-Hornerstown transition represents a sea-level rise.

The Hornerstown Formation itself may be an example of a deposit that is lithostratigraphically condensed but biostratigraphically relatively complete (Behrensmeyer & Kidwell, 1985). The preservation of bird remains and the completeness of some reptiles (*e.g.*, cheloniids) argues against reworking in the MFL from the subjacent Navesink. An intriguing association of reptile remains with infaunal suspension feeders such as *Cucullaea*

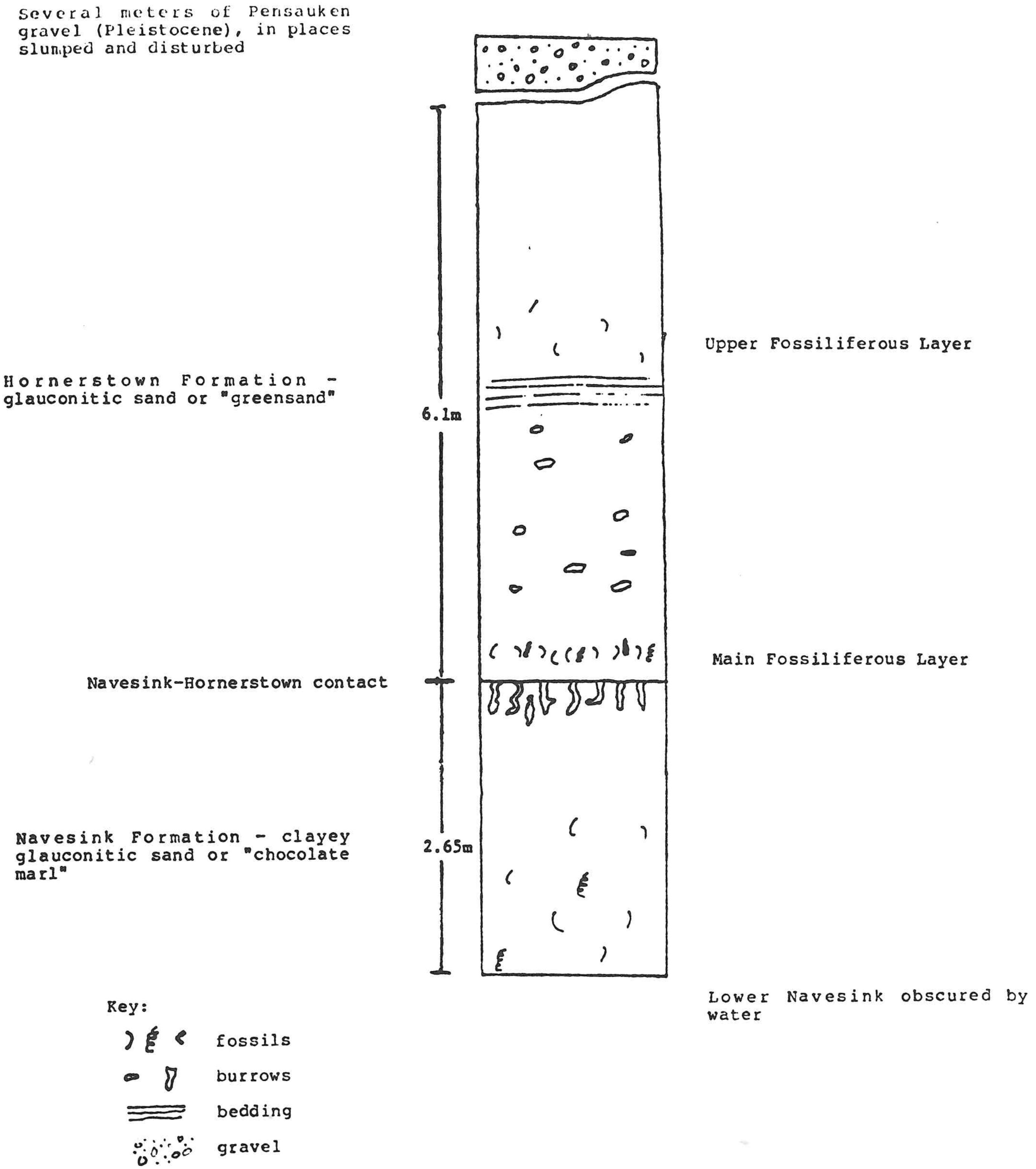

Figure 3. Stratigraphic section at the Inversand Company pit, Sewell, Manutua Township, New Jersey.

vulgaris and *Turitella vertebroides* suggests that post-mortem decay of the reptilian carcasses produced trophic resources for the infaunal benthos, probably in the form of increased micro-planktonic and bacterial concentrations.

The yellowish-orange gravel that unconformably overlies the Hornerstown greensand is the Pensauken Formation, a Pleistocene outwash deposit containing fossiliferous chert pebbles derived from Paleozoic strata in the Appalachians.

Stratigraphic Note. Some workers in the New Jersey Coastal Plain refer to the Navesink Formation here as the New Egypt Formation. The Navesink, Redbank, Tinton, and Hornerstown Formations all are correlatives to the New Egypt (see Olsson, 1963, fig. 3). We prefer that the formational name "New Egypt" be used only when referring to down-dip facies of the Navesink, Redbank, Tinton, and Hornerstown Formations or to the exposures along Crosswicks Creek in the New Egypt type section area in southern Monmouth County.

Biostratigraphic Succession

A detailed biostratigraphic list has been prepared for this section that indicates the Cretaceous-Tertiary boundary is present in the lower part of the Hornerstown Formation. A fauna of nektonic reptiles, Cretaceous birds, ammonites, fish, and infaunal benthos is replaced by a Tertiary assemblage dominated by epifaunal suspension feeders. Burrowing decreases upward in the section until, 3 meters above the Navesink-Hornerstown contact, there is faint layering in an otherwise massive glauconitic sand. Above this the Tertiary fauna is numerically dominated by brachiopods (*Terebratulina manasquani*), sponges (*Peronidella dichotoma*), and coral (*Flabellum mortoni*). This "Paleozoic" aspect can be attributed to a major environmental disturbance that decimated the infaunal benthos and allowed the opportunistic epifaunal generalists to become dominant species. This is an excellent example of "resetting" of the evolutionary-ecological clock by a major mass extinction event. Corroboration of this pattern is seen in the differential survival of "primitive" reptilian types (crocodilians, sea-turtles) and nautiloid cephalopods that replace such typical Mesozoic types as mosasaurs and ammonites (among the nekton), also seen in this sequence.

Faunal List
(Updated from Gallagher & Parris, 1985)

Navesink Formation

INVERTEBRATA

Porifera

Cliona cretacea Fenton & Fenton	NJSM 12932

Brachiopoda

Choristothyris plicata (Say)	NJSM 12925

Pelecypoda

Pycnodonte mutabilis Morton	NJSM 12886
Gryphaeostrea vomer Morton	NJSM 12882
Exogyra costata Say	NJSM unnumbered
Cucullaea neglecta Gabb	NJSM 12863
C. antrosa Morton	NJSM 12898
C. vulgaris Morton	NJSM 12978
C. tippana Conrad	NJSM 12301
Trigonia mortoni Whitfield	NJSM 12867
Crassatellites vadosus (Morton)	NJSM 12874
Liopistha cf. *protexta* (Conrad)	NJSM 12875
Spondylus sp.	NJSM 12873
Dianchora echinata (Morton)	NJSM 12880
Cardium (*Pachycardium*) *spillmani* Conrad	NJSM 12881
Agerostrea nasuta (Morton)	NJSM 12927
Solyma cf. *lineolatus* Conrad	NJSM 12946
Lithophaga ripleyana Gabb	NJSM 12949

Gastropoda

Pyrifusus macfarlandi Whitfield	NJSM 12865
Turbinopsis curta Whitfield	NJSM 12866
Volutomorpha ponderosa Whitfield	NJSM 12870
Gyrodes abyssinus (Morton)	NJSM 12872
Lunatia halli Gabb	NJSM 12950
Anchura cf. *abrupta* Conrad	NJSM 12307
A. pennata (Morton)	NJSM 12900
Turritella sp.	NJSM 12887

Nautiloidea

Eutrephoceras dekayi Morton	NJSM 12876

Ammonoidea

Baculites cf. *ovatus* Say	NJSM 12931
Indeterminate coiled ammonite	

VERTEBRATA

Chondrichthyes

Squalicorax pristodontus Morton	NJSM 12939
Scapanorhynchus texanus (Roemer)	NJSM 12944

Osteichthyes

Enchodus ferox Leidy	NJSM 12186, 12187

Chelonia

Peretresius ornatus Leidy	NJSM 11051
Cheloniidae	NJSM 11884

Lacertilia

Mosasaurus maximus Cope	NJSM 11053
Mosasaurus sp.	NJSM 11052, 12146
cf. *Platycarpus*	NJSM 12259
Prognathodon rapax (Hay)	NJSM 9827

Ornithischia

Edmontosaurus minor (Marsh)	ANSP 15202, NJSM 11880
Lambeosaurinae, n.gen. [*fide* D. Baird]	NJSM 11961

Main Fossiliferous Layer
Basal Hornerstown Formation

INVERTEBRATA

Brachiopoda

Terebratulina atlantica Morton	NJSM 12152

Gastropoda

Gyrodes abyssinus Morton	NJSM 11301
Acteon cretacea Gabb	NJSM 11311
Anchura abrupta Conrad	NJSM 11337
Turbinella parva Gabb	NJSM 11327
Lunatia halli Gabb	NJSM 11326
Pyropsis trochiformis (Tuomey)	NJSM 11283
Volutoderma ovata Whitfield	NJSM 11318
Turbinella subconica Gabb	NJSM 11331
Turritella vertebroides Morton	NJSM 11282

Pelecypoda

Cardium tenuistriatum Whitfield	NJSM 11317
Glycymeris mortoni (Conrad)	NJSM 11312
Gryphaea convexa (Say)	NJSM 11320
Gervilliopsis ensiformis (Conrad)	NJSM 11313
Gryphaeostrea vomer Morton	NJSM 11316
Panopea decisa Conrad	NJSM 11310
Veniella conradi Morton	NJSM 11319
Crassatella vadosa Morton	NJSM 11324
Cucullaea vulgaris Morton	NJSM 11322
Lithophaga ripleyana Gabb	NJSM 11325
Xylophagella irregularis (Gabb)	NJSM 12151
Nuculana stephensoni Richards	NJSM 11336
Etea delawarensis (Gabb)	NJSM 11314

Nautiloidea

Eutrephoceras dekayi (Morton)

Ammonoidea

Baculites ovatus Say	NJSM 11321
Sphenodiscus lobatus (Tuomey)	NJSM 11328
Pachydiscus (*Neodesmoceras*) sp.	NJSM 11284

Crustacea

cf. *Hoploparia* sp.	NJSM 11360

VERTEBRATA

Chondrichthyes

Lamna appendiculata (Agassiz)	NJSM 11291
Odontaspis cuspidata (Agassiz)	NJSM 11276
Squalicorax pristodontus (Morton)	NJSM 11273
Hexanchus sp.	NJSM 11899
Edaphodon stenobyrus (Cope)	NJSM 11301–L
E. mirificus Leidy	NJSM 11301–X
Ischyodus cf. *thurmanni* Pictet & Campiche	NJSM 11301–M
Squatina sp.	NJSM 12150
Myliobatis cf. *leidyi* Hay	NJSM 11339, 11898
Ischyrhiza mira Leidy	NJSM 12148
Rhinoptera sp.	NJSM 12149
cf. *Rhombodus levis* Capetta & Case	NJSM 12112

Osteichthyes

Enchodus cf. *ferox* Leidy	NJSM 11304
Enchodus cf. *serrulatus* Fowler	NJSM 11308
Paralbula casei Estes	NJSM 11855

Chelonia

Adocus beatus Leidy	ANSP 15356
Agomphus sp.	NJSM 13753
Osteopygis emarginatus Cope	ANSP 15335, NJSM 11872
Peritresius cf. *ornatus* Leidy	NJSM 13735
Taphrospys molops Cope	NJSM 11306
T. sulcatus Leidy	ANSP 15358; NJSM 11340; PU 18706, 18707
?*Dollochelys atlantica* (Zangerl)	NJSM 12295
cf. *Dollochelys* sp.	NJSM 11307

Crocodilia

cf. *Procaimanoidea* sp.	NJSM 11305, 11886
Hyposaurus rogersii Owen	NJSM 11882
Thoracosaurus sp.	NJSM 11885
Bottosaurus harlani Meyer	NJSM 11265
Diplocynodon sp.	NJSM 11902, 11903

Lacertilia

Mosasaurus sp.	NJSM 11299, 11332, 11895
Plioplatecarpus sp.	NJSM 11070

Aves

Eight specimens of birds, including an articulated wing (Olson & Parris, in press)

Upper Hornerstown Fossiliferous Layer

INVERTEBRATA

Porifera

Peronidella dichotoma Gabb	NJSM 12188

Coelenterata

Flabellum mortoni Vaughan	NJSM 11323

Brachiopoda

Terebratulina manasquani Stenzel	NJSM 12189

Pelecypoda

Cucullaea macrodonta Whitfield	NJSM 10863
Ostrea glandiformis Whitfield	NJSM 10860
Crassatellites cf. *littoralis* Conrad	NJSM 10857
Caryatis veta Whitfield	NJSM 11315

Gastropoda

cf. *Volutocorbis* sp.	NJSM 10566

Nautiloidea

cf. *Aturia* sp.	NJSM 10859

VERTEBRATA

Chondrichthyes

Odontaspis sp.	NJSM 12212
Lamna cf. *obliqua* (Agassiz)	NJSM 10858
Edaphodon agassizi (Buckland)	NJSM 11335

Chelonia

Dollochelys sp.	NJSM 11254

Crocodilia

Hyposaurus rogersii Owen	NJSM 11069

LEG 3. Sewell to Ellisdale, New Jersey.
Driving distance: 48.6 miles. Approximate travel time: 1 hour.

		Return to I–295 North:
		Leave Inversand Company, return to Rt. 55.
25.6	0.3	**Turn left onto Rt. 553 South.**
25.7	0.1	**Turn left onto Rt. 55 North.**
32.8	7.1	**NJ 55 feeds into NJ 42 North.**
34.3	1.5	**Bear right onto I–295 North.**
		Travel northeastward on the Inner Coastal Plain, the physiographic expression of the Cretaceous and Tertiary Systems.
48.9	14.6	Fake destroyer bridge at 9 o'clock. This is part of a naval missile guidance engineering facility in Moorestown, N.J. Hot dogs will *not* cook in the air if held out the vehicle window, contrary to local rumors.
		The generally high lie of the land around here is part of the discontinuous westward-facing cuesta-like physiographic feature that delineates the belt of outcropping Upper Cretaceous-Lower Tertiary strata which we are visiting on this trip. This feature, the margin of the inner coastal plain, runs from the southwestern to the northeastern part of the state.
		British forces occupied a camp in Moorestown in June 1778.
51.0	2.1	Rancocas Creek. This river is said to have been a major pre-Colonial American Indian thorofare, and numerous archaeological sites dot its banks. Slumpage causes spectacular apparent sedimentation rates on the banks of such streams. A Colonial-period horse was found at a depth of 15 m when this Westhampton-Rancocas bridge was built. The New Jersey Turnpike also crosses the Rancocas here.
63.9	12.9	**Exit onto US 130 North.** Exposures of (?)Merchantville Clay (Campanian) can be seen on the right at the bottom of the ramp. Better exposures are to the left, just out of sight.
65.1	1.2	**Turn right onto County Rt. 528 East.** Burlington County, New Jersey's largest in area, was created in 1681 and named for a town of the same name. "Bog iron" furnaces in this county provided much of the metal used by Colonials.
66.3	1.2	**Cross over New Jersey Turnpike.**
69.1	2.8	**Bear left in "downtown" Chesterfield.**

70.3 1.2 **Bear left onto Rt. 664.**

71.2 0.9 **Go straight onto Stewart Rd. (on maps this is Crosswicks–Ellisdale Rd.).**

72.8 1.6 **Turn left (north) onto Provinceline Rd.** (Bus Trips: See important note below.)

Monmouth County is on the right side of Provinceline Road; Burlington County is on the left. Monmouth County, created in 1675, was one of the counties of East Jersey and was reduced in 1850 by the creation of Ocean County; it was named for Monmouthshire, Wales.

This boundary, the Keith Line, was surveyed in 1687 and was the boundary between the Colonial provinces of East Jersey and West Jersey and which still exist as minor landholdings. The division of East and West Jersey was deeded by Sir George Carteret in 1676. Carteret retained East Jersey and deeded West Jersey to William Penn and others who were acting as trustees for Edward Byllynge. Penn and the others bought East Jersey in 1682 after the death of Sir George. In 1687, George Keith, Surveyor-General of East Jersey, ran this province line but never completed the survey. The proprietorship of Penn and others grew and, in 1701, they gave up their claims to Queen Anne. In 1702, the Queen reunited the two Jerseys and reinstated the Royal Province of New Jersey under the governorship of Lord Cornbury.

Just before reaching Crosswicks Creek, and Stop 3 of this trip, the road will jog to the right a little to descend to the creek. The Keith Line, however, continues straight northwestward into the woods. The Stop 3 locality is just barely within Monmouth County, by a few meters.

73.6 0.8 **Intersection with Crosswicks–Ellisdale Rd.** Bus trips pause here.

IMPORTANT NOTE: The bridge over Crosswicks Creek has an overhead obstruction and a 5-ton weight limit. Groups traveling by bus should stop at the intersection in Ellisdale, and the passengers should proceed on foot about one-half mile north along Provinceline Road. There is no place for the bus to turn around near the bridge. While the passengers visit the locality, the bus can be driven around to the other side of the creek. When leaving the site, the group will have to continue on foot north about one-half mile along Provinceline Road to where the bus is able to wait.

BUS ROUTE: 0.0 mi.: turn left and proceed west on Crosswicks-Ellisdale Rd. 2.2: bear right. 4.1: bear right; town of Crosswicks. 4.2: cross Crosswicks Creek. 4.4: turn right onto Old York Rd. 4.8: turn right onto Crosswicks-Extonville Rd. 7.1: turn right onto Extonville Rd. 7.6: turn left onto Ellisdale Rd. 8.0: T-intersection with Provinceline Rd. coming in from right; wait here.

74.2 0.6 **Park on right just before small bridge over Crosswicks Cr.**

STOP 3

ELLISDALE LOCALITY

Cross the road and follow the small path through the woods westward (downstream) along Crosswicks Creek. About 60 m from the road, note the small concrete boundary marker with a metal pin in its top; this is seen just before descending into the first small tributary on the south bank of Crosswicks Creek. The marker sits on the Keith Line which, judging by the materials used in the marker, was resurveyed here in much more recent time; you will cross from Monmouth into Burlington County. To your right, on the other side of Crosswicks Creek, the Keith Line separates Monmouth and Mercer Counties.

Descend into the tributary and follow it upstream to the locality; in the process you will cross back into Monmouth County. (The Allentown, N.J., topographic sheet indicates that this small drainage just barely lies entirely within Monmouth County; this resolution is in error, but the error would not have been noticed if the boundary marker were not in place.)

The Ellisdale Project

The excavations you see here are the result of an ongoing research project of the New Jersey State Museum, funded by a grant from the National Geographic Society. This is, to the best of our knowledge, the first major excavation in New Jersey purely for Mesozoic vertebrates since William Parker Foulke assembled a team of marl-diggers at Haddonfield in 1858 (see Foulke, 1858, and Stop 1A of this guide).

The discovery of the Ellisdale site is also an excellent example of the cooperation between amateur and professional paleontologists. Previously unknown in the literature, the locality was discovered in 1980 by Robert Denton, a chemist with college training and field experience in paleontology. Mr. Denton started a cooperative arrangement with the New Jersey State Museum, donating his finds as they were collected. His diligence in collecting from the streambed after each heavy rain led to the discoveries that convinced the State Museum to actively excavate this site. He and a friend, Robert O'Neill, continue to participate in the Ellisdale project.

Depositional Environment

An unusual facies of the Marshalltown Formation (later Campanian) is exposed at the Ellisdale locality. Near the contact with the underlying Englishtown Formation (also later Campanian), the glauconitic clay of the Marshalltown is flaser-bedded and burrowed. Fossil remains include abundant wood, either lignitic or replaced by limonite. Some of the wood shows borings by *Teredo*-type bivalves, indicating a minimum level of salinity. Higher up in the Marshalltown, sand lenses occur, some of which are cross-bedded. These sandier beds incorporate clay rip-up clasts probably derived from thinner intercalated clay beds. In some areas there are siderite concretions that are diagenetic in origin. The sedimentary features, along with the high wood content and mixture of marine and terrestrial faunas, indicate an estuarine lagoon-tidal channel-barrier island complex.

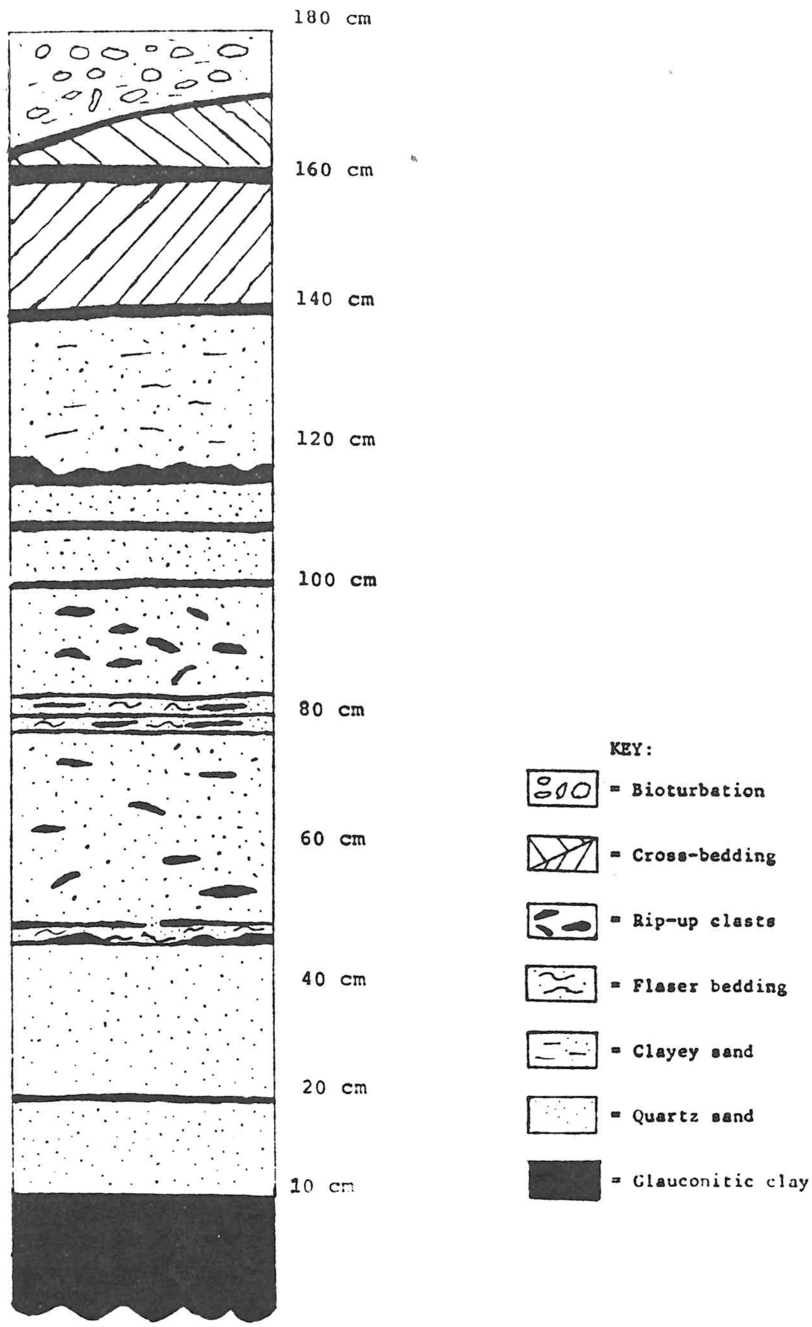

Figure 4. Stratigraphic section of Marshalltown Formation at Ellisdale, Monmouth County, New Jersey.

Nearshore Taphonomy at Ellisdale

The Ellisdale site shows an intriguing resemblance to the Phoebus Landing locality in Bladen County, North Carolina. This exposure of the Black Creek Formation along the Cape Fear River yielded Cope's type of the sauropod(?) *Hypsibema crassicauda*, and over the years a varied fauna of terrestrial, aquatic, and marine species has been collected there. The same mixed near-shore taphonomic pattern is evident at Ellisdale. Widely separated sites in time and space also reflect this same assemblage of plants, marine invertebrates, and marine, aquatic, and terrestrial vertebrates. In addition to the Campanian of North Carolina and New Jersey, the Bone Valley Formation (Hemphillian) of Florida and the Calvert Formation (Barstovian) of the Chesapeake Bay area exhibit a similar mix. Other scrap faunas demonstrate a corresponding pattern, with varying degrees of terrestrial input according to position along the paleobathymetric gradient.

We propose (after Gallagher) a general hypothesis for mixed scrap assemblages. Fluvial systems transport taphonomically mature terrestrial biota into river mouths, embayments, and estuaries, where bones and plant material are trapped. Typically marine animals come into estuaries to feed and breed; environmental stresses cause mortality of these animals. Additionally, death associated with reproduction (*e.g.*, sea turtles) plays a part. Episodic redeposition and mixing is accomplished by major storm events such as seasonal hurricanes, nor'easters, or monsoons. In the case of the Upper Cretaceous deposits, these storms may have been generated by a Tethyan climatic regime; for Miocene-Pliocene time, the initiation of Gulf Stream circulation may have set up modern hurricane patterns. Storm surges over barrier beaches and increased flow through tidal channels are specific mixing mechanisms. Seasonal storms are "killing seasons" when many different populations suffer higher mortality rates. Transgressive phases are optimum times for mixed-assemblage deposition. Mixed scrap faunas became possible in the Mesozoic and Cenozoic when large terrestrial vertebrates became relatively common, and when passive margins were widespread due to the break-up of Pangaea.

As studies of material retrieved by the Ellisdale project continue, the following faunal list is liable to frequent revision.

Faunal List
(Updated from Denton & Parris, 1985)

INVERTEBRATA

Pelecypoda

cf. *Lithophaga* sp.	NJSM 12721
Xylophagella kummeli (Weller)	NJSM 13770
pelecypod fragments	NJSM 12142

Gastropoda

cf. *Anchura* sp.	NJSM 12720

Crustacea

Ophiomorpha nodosa Lundgren (callianassid shrimp burrow)	NJSM 13767

VERTEBRATA

Chondrichthyes

Scapanorhynchus texanus (Roemer)	NJSM 12141
Squalicorax kaupi (Agassiz)	NJSM 12471
Cretolamna appendiculata (Agassiz)	NJSM 12533
Odontaspis samhammeri (Cappetta & Case)	NJSM 12470
Hybodus sp. indet.	NJSM 12732
cf. *Ischyodus* sp.	NJSM 12480

Osteichthyes

Xiphactinus sp., cf. *X. audax*	NJSM 11370, 12465

Chelonia

Bothremys barberi (Schmidt)	NJSM 12704–12707, 12718
Taphrosphys sp. indet.	NJSM 12507
Adocus beatus (Leidy)	NJSM 12711
A. punctatus (Marsh)	NJSM 12437
Adocus sp.	NJSM 12478, 12506, 12483, 12717
Corsochelys sp.	NJSM 12479
Desmatochelys sp.	NJSM 12708, 12709, 12712
Osteopygis sp.	NJSM 12481, 12482
Trionyx sp., cf. *T. halophilus* (Cope)	NJSM 12464

Sauropterygia

Elasmosauridae indet.	NJSM unnumbered

Squamata

cf. *Globidens* sp.	NJSM 12462

Crocodilia

Deinosuchus rugosus (Emmons)	NJSM 10854, 12463
Leidysuchus sp.	NJSM 12137, 12138
Alligatorine, cf. *Brachychampsa*	NJSM 13766

Saurischia

Dryptosaurus aquilunguis (Cope)	NJSM 12436
Hypsibema crassicauda (Cope)	NJSM 12702

Ornithischia

Hadrosaurus sp., cf. *H. notabilis*	NJSM 12703, 12133
Edmontosaurus sp., cf. *E. regalis*	NJSM 12132

PLANTAE

Gymnospermae	
conifer twig with needles	**NJSM 12469**
Angiospermae	
possible fructification	**NJSM unnumbered**
Pyritized and carbonized wood	**NJSM 13769**
Amber droplets	**NJSM unnumbered**

LEG 4. Ellisdale to Big Brook.
Driving distance: 28.8 miles. Approximate travel time: 40 minutes.

74.3	0.1	Bridge over Crosswicks Creek.
74.6	0.3	**Turn right onto Ellisdale Rd.**
74.7	0.1	**Turn left onto continuation of Ellisdale Rd. (noted on some maps as Ellisdale–Allentown Rd.).**
76.7	2.0	**Turn right on S. Main St.**
77.5	0.8	**Allentown, N.J. Continue straight onto combined County Rts. 524 East/539 North.**
78.2	0.7	**Turn right onto I–195 East.**
86.3	8.1	**Exit onto County Rt. 537.**
86.4	0.1	**Bear left onto Rt. 537 East toward Freehold.**
		This is a continuation of the Colonial route we drove along in Haddonfield, there called Kings Highway. Ocean County, created in 1850 and named for the Atlantic Ocean, is on the right side of the road; Monmouth County is on the left.
94.9	8.5	Moore's Inn (1793) on right, fortunately surviving without ye aide of recent restoration.
96.2	1.3	Cross over NJ 9. "Sprung from cages on Highway 9" (Springsteen, 1974).
96.4	0.2	Intersection with NJ 33.
97.0	0.6	Downtown Freehold. Birthplace of Bruce Springsteen, "The Boss", unofficial poet laureate of Twentieth Century New Jersey ("My Hometown", "Born in the U.S.A.").

97.2	0.2	**Bear left onto NJ 79 North.**
100.7	3.5	Cross over NJ 18. Enter Marlboro, named for the greensand marl that was mined here in the Nineteenth Century.
101.2	0.5	**Turn right (east) onto Vanderburg Rd. (Monmouth County Rt. 4).**
102.6	1.4	**Turn left (north) onto Boundary Rd.**
103.0	0.4	Bridge over Big Brook.
103.1	0.1	**Park on right side of road. Leave vehicle, walk back to Big Brook.**

⚒ STOP 4 ⚒

BIG BROOK

At the bridge, descend on the left side to the creek. This slope is very steep and usually muddy. Please exercise caution.

Exposures of the Navesink Formation, capped by the Redbank Formation, occur to the east (downstream), on the south bank. Vertebrate material is common in the creek bed upstream from the bridge.

This is a superb example of the baffling Monmouth brook localities which produce fossils by the thousands. These localities are much-loved by amateur collectors and have produced the majority of specimens in many private collections, notably for shark tooth fanciers. However, the depth of interest in these localities goes far beyond curio interest. These localities are a major source of scrappy specimens of Pleistocene megafauna (Parris, 1983) as well as Cretaceous reptiles, and even one Cretaceous mammal (Krause & Baird, 1979). Significant archaeological resources have also been reported from some of the sites (Kraft & Cavallo, 1974).

Unfortunately, few fossils are found *in situ* in these sites. Typically the stratigraphy consists of a Cretaceous (usually Maastrichtian) unconsolidated sediment overlain by Pleistocene deposits (of which there are various episodes of deposition). Probably most of the latter are Wisconsinan sediments, the fluviatile equivalents of the Cape May Formation. Fossils from the Pleistocene sediments include the ground sloth *Megalonyx* sp. (NJSM 11871, from Big Brook; Parris, 1983, p. 6, fig. 2). These sediments, however, also often yield fossils reworked and redeposited from the Cretaceous. As if that isn't bad enough, the loose mammalian specimens include obvious Colonial domestic mammal teeth, many of them quite permineralized.

Although many Maastrichtian fossils have been collected in place at this locality, the majority of vertebrates are recovered by screening the brook sediment. [A separate paper by Edward M. Lauginiger, "An Upper Cretaceous vertebrate assemblage from Big Brook, New Jersey," appears elsewhere in this volume of *The Mosasaur*. —Ed.]

Stratigraphy and Depositional Environments

Several Upper Cretaceous formations are exposed in the banks of Big Brook, and these again demonstrate the stratigraphic complexity of the Coastal Plain formations. The Wenonah-Mount Laurel Formations have long been mapped together (see Lewis & Kümmel, 1910-1912) and have often been separated merely on the basis of differences in faunal content (Widmer, 1964; Richards *et al.*, 1958). This is confusing biostratigraphy with lithostratigraphy, a basic but common enough mistake; a non-mappable contact and a faunal distinction are not criteria with which to define a lithostratigraphic unit.

At this exposure, the Wenonah-Mount Laurel can be best seen in a series of outcrops upstream (eastward) from the Boundary Road Bridge. The streambank exposures show a massive micaceous unctuous black (N 1) clay that contains thin beds of very micaceous greenish-black (5 G 2/1) silty clay with laminae of black comminuted organic matter, probably lignitic. The thin silty beds show wavy layering and are occasionally cross-stratified. Overlying the black clays is the massive micaceous greenish-black glauconitic clay of the Navesink Formation. The Navesink is very fossiliferous in certain horizons, where concentrations of the oysters *Exogyra*, *Pycnodonte*, and *Agerostrea* are found, sometimes with both valves still articulated. The larger oysters are frequently riddled by borings of the sponge *Cliona cretacea.* Hybodont sharks, batoids, shell-crushing osteichthyans, and crustaceans are duraphagous predators and may have fed on the abundant trophic resources of the oyster bank ecosystem; this predation would have been facilitated by the structural weakening of the shells due to extensive boring. Above the Navesink is the yellowish-orange Redbank Sand, a relatively unfossiliferous unit.

The whole stratigraphic sequence of the Wenonah/Mount Laurel-Navesink-Redbank is a regressive-transgressive-regressive cycle, with maximum water depths and full marine salinity occurring in the Navesink. Reptilian remains represent either nektonic forms such as the mosasaurs, plesiosaurs, marine crocodilians, and sea turtles, or else the infrequently found terrestrial dinosaurs (nodosaur, *Hadrosaurus*, ?*Dryptosaurus*, and *Ornithomimus*) perhaps washed in by storm events or as floating carcasses.

We propose that the distinction between the Wenonah and Mount Laurel Formations be disregarded; they should be united into a single lithostratigraphic unit, a coarsening-upward deposit of clay, silt, and pebbly sand. We retain the formational name Mount Laurel for this unit (by priority in the literature; *cf.* Clark *et al.*, 1897), which we correlate as lower Maastrichtian in age (Petters, 1976), and include it in the Monmouth Group.

Unifying the Wenonah-Mount Laurel as the Mount Laurel Formation eliminates the nomenclatural confusion caused by inability to separately map the two supposedly separable units, heretofore discriminated largely by biostratigraphy. Changes in lithology along strike in this stratigraphic interval are more reasonably explained as facies changes that reflect the natural spatial variations in depositional environments. Such facies changes are expected because they are common features of Coastal Plain deposits (Gallagher, in press; Gallagher & Johnson, in press; Denton & Parris, 1985; Gallagher, 1984; Petters, 1976; Olsson, 1963).

Faunal List
(Compiled by Ralph Johnson,
Monmouth Amateur Paleontologists Society)

Navesink Formation

INVERTEBRATA

Pelecypoda

Exogyra costata Say
Pycnodonte (*Gryphea*) *convexa* (Say)
Agerostrea mesenterica (Morton)
A. monmouthensis (Weller)
Ostrea tecticosta Gabb
Plicatula urticosa Morton
Spondylus (*Dianchora*) *echinata* (Morton)
Meleagrinella abrupta (Conrad)
Dithophaga carolinensis (Conrad)
Pecten whitfieldi Weller
P. venustus Morton
Radiopecten mississippiensis (Conrad)
Lima pelagica Morton

Crustacea

Protocallianassa mortoni (Pilsbry)

Echinoidea

Cidarid spines

Porifera

Cliona microtuberus

Annelida

Longitubus lineatus (Weller)
Serpula pervermiformis Wade
Serpula sp.

Brachiopoda

Choristothyris vanuxemi (Lyell & Forbes)
C. plicata (Say)
Terabratulina cooperi Richards & Shapiro

Bryozoa

unidentified species

VERTEBRATA

Reptilia

Mosasaurus sp.
Cimoliasaurus magnus Leidy
?*Dryptosaurus* sp.
Hadrosaurus sp.
Mosasauridae

Mount Laurel ("Wenonah") Formation

INVERTEBRATA

Pelecypoda

Ostrea subspatulata Forbes
Lima whitfieldi Weller
?*Radiopecten quinquenarius* (Conrad)
Camptonectes sp.
Anatimya lata (Whitfield)
A. anteradiata (Conrad)
Etea sp.
Leptosolen sp.
Cymella bella texana Stephenson
Trachycardium longstreeti (Weller)
Granocardium sp.
Pholadomya roemeri Whitfield
Glycymeris sp.
Inoceramus sp.
Linearea metastriata Conrad
Veniella elevata Conrad
Cyprimeria sp.
Nemodon sp.
Cymbophora appressa (Gabb)
Inoperna carolinensis Conrad
Crassatella transversus (Gabb)
Trigonia cerulia Whitfield
Tellina sp.

Gastropoda

Pyropsis sp.
Xenophora leprosa (Morton)
Gyrodes sp.
Turritella sp.
Arroges (Latiala) *rostrata* (Gabb)
Paladmete cancellaria (Conrad)
Napulus sp.
Striaticostatum sp.

Cephalopoda

Placenticeras syrtale? (Morton)
Menuites complexus (Hall & Meek)
Baculites scotti? Cobban
Nostoceras sp.
Didymoceras sp.
Trachyscaphites pulcherrimus (Roemer)

Echinoidea

Hardouinea mortonis emmonsi (Stephenson)
Hardouinea sp.

Annelida

Longitubus lineatus (Weller)

Crustacea

Hoploparia gabbi Pilsbry
Tetracarcinus subquadratus (Weller)
Linuparus sp.
?*Palaeopagurus* sp.
Cretocoranina sp.
?*Palaeopagurus* sp.
Cretocoranina sp.
Xanthosia elegans Roberts
Protocallianassa mortoni (Pilsbry)
P. praecepta Roberts
Pagurus sp.

VERTEBRATA

Pisces

Anomoeodus phaseolus Hay
Enchodus ferox Leidy
Ischyrhiza mira Leidy
Hybodus sp.
Brachyrhizodus wichitaensis Roemer
Stephanodus sp.
Squatina hassei Lereche
Cylindracanthus ornatus Leidy
Rhombodus levis Cappetta & Case
Parabula casei Estes
Xiphactinus (Portheus) sp.
Ischyodus bifurcatus Case
Squalicorax pristodontis (Morton)
Scapanorhynchus texanus Roemer
Cretolamna arcuata (Woodward)
Odontaspis samhammeri (Cappetta & Case)
O. hardingi (Cappetta & Case)
fish coprolites

Reptilia

Mosasaurus maximus Cope
Mosasaurus sp.
Thoracosaurus sp.
Ornithomimus antiquus (Leidy)
unidentified marine turtle vertebra

LEG 5. Return to Philadelphia.
Driving distance: 68.6 miles. Approximate travel time: 1–1/2 hours.

0.0		Turn around. Return to Rt. 537:
0.6	0.6	Turn right onto Vanderburg Rd.
2.0	1.4	Turn left onto NJ 79 South.
6.0	4.0	Bear right onto Rt. 537.
16.5	10.5	I-195 interchange.

Further down the old Kings Highway, in the type area of the Hornerstown Formation ("H" in Figure 1), one of the more bizzare incidents in local paleontological history took place. We quote in its entirety an item by Florence D. Wood of the American Museum of Natural History, from the *News Bulletin* of the Society of Vertebrate Paleontology (no. 47, June 1956, p. 9). So far as we know, nothing more is known about this curious incident.

> "Some wild excitement occurred for a while when a student brought in a Paleocene mammal from New Jersey, and ostensibly from the Cretaceous (Navesink) at that! More sober reflection and (if we do say so) some neat detective work established that the specimen is an old friend come home to roost. It is actually from the Torrejon of New Mexico, one of the specimens collected for Cope by Baldwin. Along with no fewer than 26 other specimens of *Mioclaenus turgidus* it disappeared from the American Museum sometime between 1930, when Matthew last worked on his San Juan Basin memoir, and 1938, when the collection was again thoroughly checked following publication of that memoir. After due investigation, we have no doubt that the student did, in fact, find the specimen on, or indeed in, a Navesink exposure. Who planted it there? Where was it between 1930 and 1956? And above all, where are the other 26 specimens? We haven't the slightest idea. We would welcome suggestions — and please check your own collections! (We might add, for information and with no implications, that classes from Columbia, Princeton, and Rutgers have long been visiting the spot where this specimen was planted.)"

32.0	15.5	Turn right onto Arena Dr.
32.3	0.3	Turn left onto Hempstead Ave.
32.4	0.1	Turn right onto Broad St.
32.9	0.5	Bear left through White Horse traffic circle onto NJ 206 South.
35.7	2.8	Merge with US 130 South. Stay to right.
36.1	0.4	Bear right onto US 130 South.
37.2	1.1	Turn onto cloverleaf for I–295 South.
38.0	0.8	Enter I–295 South.
53.7	15.7	Exit at NJ 38 West.
54.1	0.4	Enter NJ 38 West.

63.3	9.2	**Bear right onto overpass ramp for US 30 West (Admiral Wilson Blvd.)**
64.6	1.3	**Bear left. Follow signs for Ben Franklin Bridge.**
65.5	0.9	Toll plaza. Ben Franklin Bridge.
67.1	1.6	"Bolt of Lightning" monument to Franklin. All traffic bears right.
67.3	0.2	**Go straight onto Vine Street. Keep to the right.**
67.7	0.4	Broad St.
68.4	0.7	Philadelphia Free Library at one o'clock. Founded by Benjamin Franklin, this is the oldest free libary in America.
		Turn left onto 19th St. Turn right onto Logan Circle; go half way around. The Franklin Institute faces the circle from the right.
68.6	0.2	**Academy of Natural Sciences. Joseph Leidy statue. End of field trip.**

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