Fossils of the Northeastern US:
a brief review

Fossils are found almost exclusively in sediment and sedimentary rocks. Igneous rocks, which form from cooling magma or lava, would not normally be expected to preserve fossil material or be likely to have any. The elevated temperature and pressure necessary to form a metamorphic rock likewise would destroy any fossil material within the rock, unless it is only weakly metamorphosed. Fossils usually are the mineral skeleton of an organism, such as the shell, bones or some kind of impression. Most shells and bones never become fossils, but instead are broken to tiny bits or dissolved. In order to become a fossil, the skeletal material must be buried before it is destroyed. Often, the shells or bones leave fossil impressions or casts of their shape in the sediment in which they are buried. Records of the movement of animals in the rock are also fossils; these are known as ***trace fossils***.

Fossils are especially useful in geology because of where they occur. Particular kinds of rocks are formed as a result of processes that are not unique to time or space. A sandstone formed in the Devonian in the Northeast, for example, may look very similar to a sandstone formed in another time period or another region. Fossils, on the other hand, are unique to particular times and places because the organisms preserved as fossils have evolved through time, and live in specific geologic areas and environments. There are, however, important generalities about the distribution of groups of organisms in the Northeast with respect to age and types of rocks in which they are found.

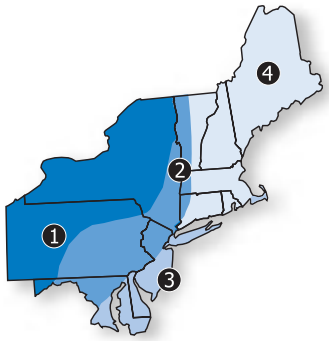
The Northeast preserves an excellent record of:

- *the* **shallow marine realm of the inland ocean** *that existed in the early and mid-Paleozoic. Brachiopods, trilobites, corals and sea lilies are especially numerous.*
- **Devonian, Mississippian** *and* **Pennsylvanian plants** *that accumulated in swampy coastal wetlands bordering the inland ocean.*
- *organisms that lived in the lakes that existed in parts of the* **Triassic/ Jurassic rift basins** *and on the land during the same period.*
- **Cretaceous and Tertiary shallow marine organisms**, *mostly clams and snails, in Coastal Plain sediments.*
- *and* **late Pleistocene land, freshwater, and marine animals** *that lived during the most recent ice age.*

see Rocks, p.5

The soft parts of an organism, including the skin and internal organs, tend to rot away and are not normally preserved in the fossil record. The exceptions to the rule occur when minerals replace soft parts before they rot away, such as petrified wood, or where the oxygen content is low enough that rotting is slowed down to near zero, such as leaves in swamp sediments or insects preserved in amber.

Trace fossils *do not preserve shell or bone material. Rather, they preserve the evidence of the movement of an organism, such as a footprint, burrow, trail or trackway. Trace fossils cannot always be linked to a particular species, but they can often be associated at least with a group of organisms or way of life. The first trace fossils appear a couple hundred million years before the first animal fossils, and burrows through sediment seem to become deeper from the Paleozoic through the Cenozoic.*

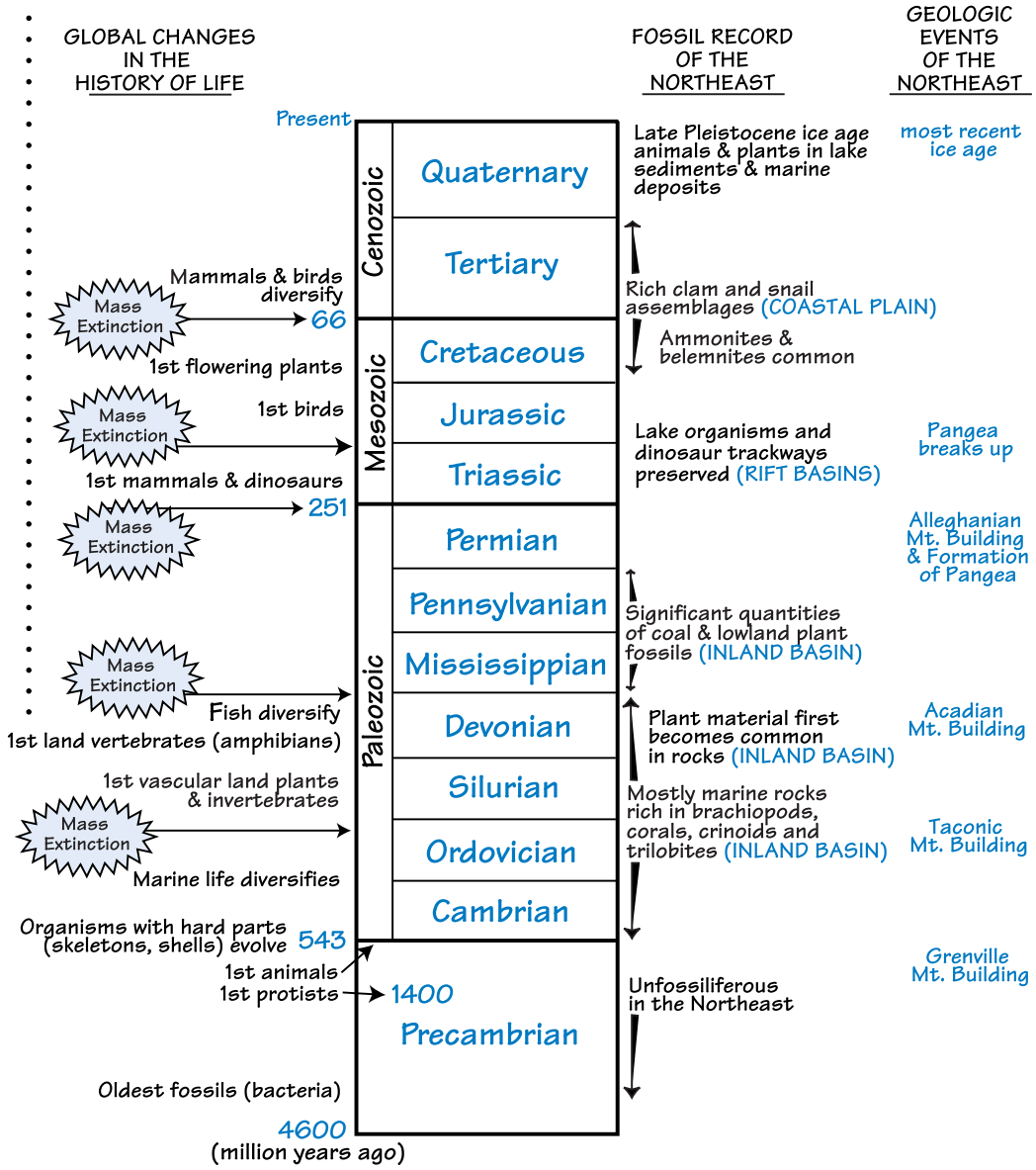


Fossils

Mass Extinctions

Most species have a lifetime of several million years before going extinct; rarely do species live longer than 10 million years. The extinction of a species is a normal event within the history of life. There are, however, intervals of time in which extinction rates (the number of species going extinct within a given time interval) are relatively high, in some cases at a rate 10 or 100 times the normal rate. These intervals are known as 'mass extinctions'. There were five particularly notable mass extinctions in geologic history. These largest mass extinction events, probably due to unusual ecological events, have helped to shape life through time. The largest known extinction occurred at the Permian-Triassic boundary, in which over 90% of the species worldwide became extinct. Trilobites, rugose and tabulate corals, and most other taxonomic groups prevalent in the Paleozoic disappeared. Clams, snails, ammonoids, a new group of corals (scleractinians), crustaceans, and bony fish became the dominant ocean animals during the Mesozoic.

Different plant and animal fossils are found in different places in the Northeast because differently aged rocks occur at the surface in different areas. Further, particular fossil organisms lived only in certain environments and these environments did not exist continuously through time, nor were these environments necessarily preserved in the rock record. Thus the fossil record is very closely tied to the historical geologic events over the last billion years, the rock record formed through those events, and the rocks exposed at the surface today in the Northeast *(Figure 4.1)*.



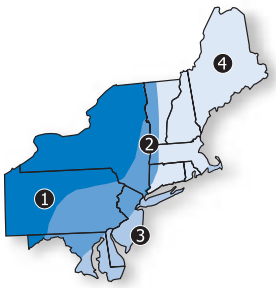


Figure 4.1: The history of life in relation to global and regional geologic events and the fossil record of the Northeast. (Time scale is not to scale.)

The ***history of life*** in the Northeast has been pieced together from fossil records in many different areas. As is evident in the Northeast, a complete record of rocks from every period is not preserved. Not all sediments end up as rocks, and likewise, not all rocks that have formed are still preserved. Many have been weathered and eroded away completely. It is the same with the fossil record. Not all organisms are preserved as fossils and rocks that have contained fossils have not necessarily been preserved (or may be well below the surface, out of sight from ***paleontologists***). The majority of the fossil record in the Northeast is comprised of marine invertebrate organisms such as brachiopods, bivalves and gastropods. There are relatively few fossil remains from dinosaurs and other land-dwelling vertebrate organisms. However, this does not mean that dinosaurs and other vertebrates did not live in the Northeast! They probably did but were simply not preserved. The fossil record is only a small window to the past, reflecting the type and diversity of organisms that once lived and the environments they inhabited. The primary opportunity for sedimentary deposition over a large part of the Northeast has been an inland ocean that existed for many millions of years. Thus it should not be surprising that marine organisms dominate the fossil record of much of the Northeast.

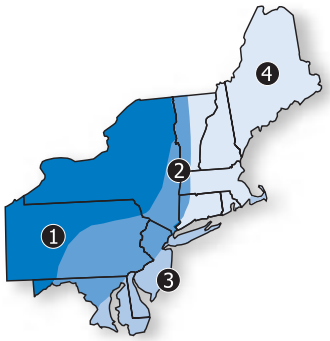
Not only is the **history of life** *recorded in rocks of the Northeast, life has had a direct influence on the type of rocks formed in the Northeast. For example, limestones are formed from an accumulation of skeletons of sea life, which in turn affect soil composition, agriculture and topography. Pennsylvanian-age forests and swampy, wetland vegetation are responsible for the coal and dark-colored, fine grained rocks formed in the Inland Basin and Appalachian/Piedmont regions.*

Paleontology *is the study of fossils. The field of paleontology grew quickly in the 19th and early 20th centuries because fossils could be applied to determine the relative age of a rock and something about the environment in which a sedimentary rock was created. This information was (and is) helpful in tracking down energy resources such as petroleum and coal.*

Determining the environment

The kind of animals and plants living in a particular place depend on the local environment. The fossil record preserves not only a fossil organism, but also elements of the local environment in which the organism lived. By looking at the geological and biological information recorded in a rock that preserves a fossil, you can often determine the type of environment that a fossil organism lived in:

- **Grain size and composition** *of the rock tells you the type of surface the animals and plants lived on (unless they have been transported).*
- **Sedimentary structures** *such as ripples and cross-beds indicate the organism lived in moving water. Mud cracks and wave ripples are characteristic of shoreline environments.*
- **Broken shells** *or* **concentrated layers of shells** *may indicate pounding waves or storms.*
- **Clarity of the water** *in the environment can be determined by the type of rock. Fine grained shales are made of tiny clay particles that easily remain suspended in water. Thus a fossil found in a shale might have lived in muddy water. Filter feeding organisms such as corals and sea lilies are not usually found in muddy water because the suspended clays clog their filters!*
- **Amount of oxygen in the water** *can be determined indirectly from the rock. If there is not enough oxygen in the water, organic material in sediments will not decompose and the rock formed will be dark gray to black in color.*

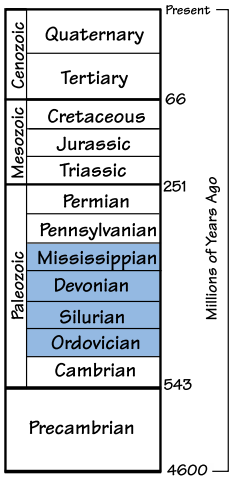


Fossils of the Inland Basin

Region 1

The Inland Basin region primarily contains the story of the evolution of marine and coastal plant life superimposed on the story of mountain-building events, associated sediments deposited in the inland ocean, and changes in relative sea level. The earliest fossils in the Inland Basin region are ***stromatolites***, formed from cyanobacteria in the warm shallow Iapetus Ocean. Stromatolites are preserved in late Cambrian rocks, found to the southwest and southeast of the Adirondacks. Abundant marine fossils are found in Ordovician through Mississippian rocks formed in the inland ocean that existed through most of the Paleozoic. Pennsylvanian-age rocks preserve an excellent record of plant material.

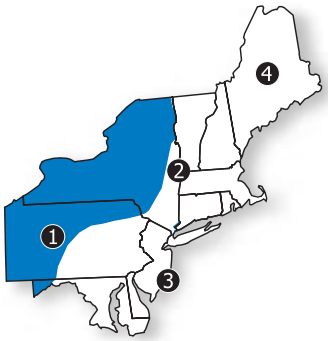
see Fossils, p.91 for more on **stromatolites**



Ordovician to Mississippian

Ordovician, Silurian and Devonian marine fossils of the Inland Basin, especially in New York, are world-famous for their quantity and quality. Ordovician-to-Devonian fossil assemblages are nearly always dominated numerically by brachiopods, and may also contain trilobites, sea lilies, corals, clams and other mollusks, and many other less common organisms. What is perhaps the most striking is the differences in fossil assemblages from different types of paleoenvironments. The type of environment determined the types of organisms that lived there, and thus the fossils that are preserved in the rock.

Clear, shallow marine environments, generally preserved as limestones, often have abundant ***corals*** *(Figure 4.3)*, ***bryozoans*** *(Figure 4.2)* and ***sea lilies*** *(Figure 4.4)*. Corals, bryozoans and sea lilies are all filter feeders, collecting fine particles from the water. These environments form in places and at times when there is little sediment settling in the water. Western New York and Pennsylvania, far from the Taconic and Acadian highlands where sediment was being eroded into the inland ocean, preserve rocks recording this environment. Also, throughout the Inland Basin, and relatively undeformed sections of the Appalachian/Piedmont, rocks formed in-between mountain-building events record clear, shallow marine conditions because there was no highland to erode sediment into the basin.



BRYOZOANS

Many animals that are not easy to study, and in some cases even recognize without the aid of a microscope, have a long and exemplary fossil record. One such group is the bryozoans, colonial marine animals that have evolved a wide variety of skeletal shapes and textures. One of the more common Paleozoic varieties looks like fine mesh cloth with numerous tiny holes in which the individual animals in the colony lived. Small tentacles on the animals captured food particles from the water.

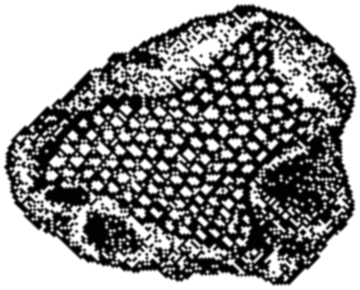
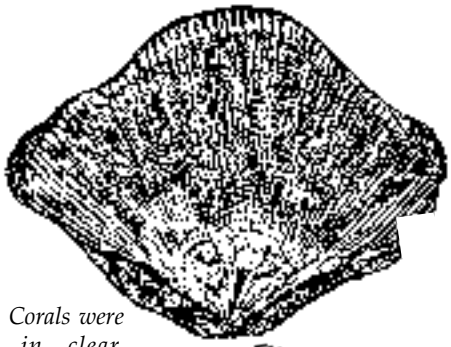


Figure 4.2: Bryozoan, mid-Devonian fenestellid (4 cm wide).

Though functioning somewhat like a coral, and often found in similar environments, bryozoans are more closely related to brachiopods.



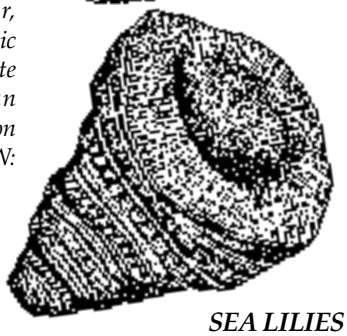


Figure 4.3: Corals were abundant in clear, shallow marine Paleozoic seas. ABOVE: tabulate coral, mid-Devonian Favosites, *cross-section (11.5 cm wide); BELOW: rugose coral, mid-Devonian* Heliophyllum halli *(7 cm long).*

CORALS

Corals have been important and common elements of clear, shallow marine waters since the Ordovician. Ordovician, Silurian and Devonian rocks of the Inland Basin region have numerous examples of reefs or other shallow environments in which colonial 'tabulate' corals are common. Even more abundant in these rocks is the solitary 'rugose' or horn coral. Both tabulate and rugose corals became extinct at the end of the Permian. Soon after, a new type of coral had appeared which are present today: the **scleractinians**. *Though scleractinians look somewhat similar to rugose and tabulate corals, each group possesses distinctive features in the shape of the skeletal cup holding the individual animals.*

Corals have been an important creator of limestone and also, as reef-builders, an important part of building homes for a diverse number of different organisms.

see Fossils, p.93 for more on **scleractinian corals**

SEA LILIES
BLASTOIDS & CYSTOIDS

Several groups of stemmed echinoderms appeared in the early Paleozoic, including crinoids, blastoids and cystoids. All have in common 5-fold symmetry and a head (calyx) held off the sea floor by a stem, where it collected organic particles from the water. The stems, which are the most often preserved part, are made of a series of stacked discs that look like Cheerios. Upon the death of the organism, the stems often fall apart and the individual disks are seen separated in the rock. Feathery arms radiated from the head of crinoids, looking something like a lily flower on a stem. Thus, crinoids are commonly called 'sea lilies', though they are not actually plants.

The head and arms of crinoids are rarely found preserved, while the heads of blastoids and cystoids, on the other hand, are commonly found whole. Though blastoids and cystoids went extinct at the end of the Paleozoic, crinoids still exist today.

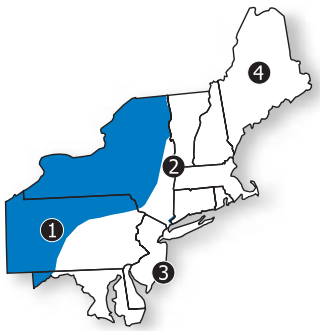
crinoid stems, mid-Devonian (largest is 4 cm long)

crinoid cup, mid-Devonian Dolatocrinus *(4 cm diameter)*

blastoid theca, mid-Devonian Devonoblastus *(2 cm wide)*

cystoid theca, Silurian Caryocrinites ornatus *(5 cm diameter)*

Figure 4.4: Stalked echinoderms, common in clear, shallow marine environments.



Fossils

Rocks that preserve muddy, well-oxygenated environments are especially common in the middle of the Inland Basin, away from the shoreline, such as the late Ordovician and the middle Devonian rocks in central to western New York and western Pennsylvania.

see Fossils, p.94 and 95, to learn about **cephalopods and clams**

Brachiopods *have a special structure formed by tissue with thousands of tiny hair-like tentacles stretched along a coiled piece of internal shell material. These tentacles catch and move small particles towards their mouth. This body plan is very different from that of bivalves, which have a larger fleshy body and collect particles with their gills.*

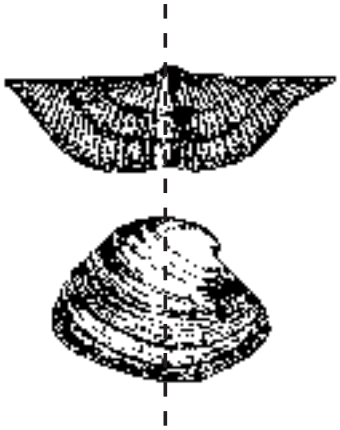
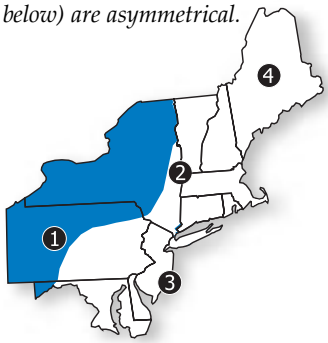


Figure 4.6: Brachiopods (top) are symmetrical and clams (bivalves, below) are asymmetrical.



Muddy, well-oxygenated environments, generally preserved as gray shales, often have abundant **brachiopods**, **trilobites** *(Figure 4.8)*, ***cephalopods*** and small ***clams*** *(Figure 4.7)*. Small or flattened brachiopods that are not likely to sink into the mud, such as *Mucrospirifer*, are common in this environment.

Figure 4.5: LEFT: brachiopod, Mid Devonian Mucrospirifer *(5 cm wide).*
RIGHT: brachiopod, Ordovician Rafinesquina (2.5 cm wide).

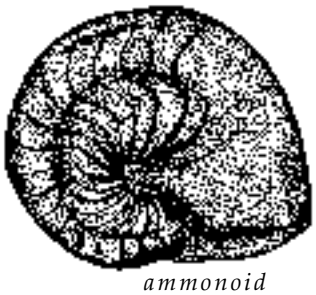
BRACHIOPODS

Brachiopods look somewhat similar to clams you might find at the beach today. However, from the soft parts of modern brachiopods, we know that they are completely unrelated to the animals that make 'shells' that are common today (bivalves); brachiopods are rare today and are unlikely to wash up on shore. Brachiopods are the most common fossil in Paleozoic sedimentary rocks and are therefore very common in the Inland Basin region where these rocks are preserved.

Brachiopod or bivalve?

Brachiopods and bivalves both have a pair of hinged shells ('valves') to protect themselves while feeding. To tell the difference between a brachiopod and a bivalve, look for symmetry on the surface of the shells. Brachiopods are symmetrical across the shell, like your face. Bivalves are asymmetrical (Figure 4.6). The exception would be a deformed brachiopod, which might be found in the relatively more compressed rocks of the Appalachian/Piedmont. The size of the valves also helps to identify to which organism the shell belongs. Bivalve valves are of equal size and mirror image shapes. Brachiopods bottom valves, however, are slightly bigger and often have a different shape.

bivalve (clam)

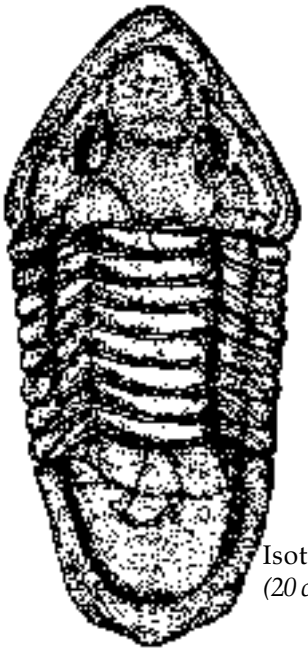


ammonoid (cephalopod)

Figure 4.7: Mollusks found in muddy,well-oxygenated environments: (clockwise) bivalve, mid Devonian Modiomorpha *(5.5 cm); gastropod, mid Devonian,* Platyceras *(4 cm); nautiloid cephalopod, early-mid Devonian (20.5 cm long); ammonoid, mid Devonian,* Tornoceras *(5.5 cm).*

gastropod (snail)

nautiloid (cephalopod)

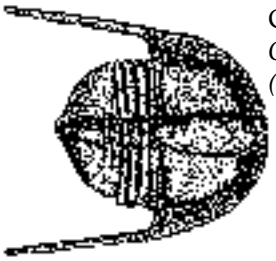


Isotelus, *Ordovician (20 cm long).*

TRILOBITES

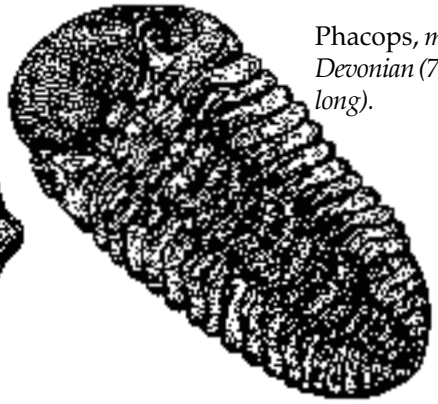
These marine organisms were bottom dwellers, present in a variety of environments and in Paleozoic rocks in the Inland Basin, Appalachian/Piedmont, and a few locations in the Exotic Terrane. Trilobites had a well-defined head, often with large eyes that had multiple lenses usually visible with the naked eye. A primitive arthropod distantly related to horseshoe crabs, trilobites have been extinct since the end of the Paleozoic.

Figure 4.8: Trilobites were abundant in muddy, well-oxygenated environments in the early to mid Paleozoic.



Cryptolithus, *Ordovician (1.5 cm).*

Like crabs and lobsters, **trilobites** *molted their exoskeleton when they grew. Most fossils of trilobites are actually molts, often broken as they were shed off the trilobite. Thus, it is common to find only parts of trilobites, such as the head, mid-section or tail.*



Phacops, *mid-Devonian (7 cm long).*

Dalmanites, *Silurian (6 cm long).*

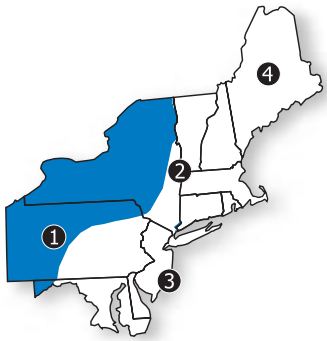
Muddy, oxygen-poor marine environments are preserved as black shales, which often are completely lacking fossils, though plankton such as ***graptolites*** may be found *(Figure 4.9)*. This environment forms in stagnant basins and areas where there is abundant organic material settling to the bottom; sometimes it is apparently associated with basin deepening due to down-warping crust during stages of rapid mountain building.

Inland Basin rocks preserving ***muddy, oxygen-poor environments*** *include especially some late Ordovician and mid Devonian rocks, formed at the beginning of the Taconic and Acadian mountain-building events.*

GRAPTOLITES

Graptolites are a group of extinct, puzzling planktonic organisms found in dark shales. No clear soft parts have been found, though they appear to be related to a minor group of modern colonial invertebrate organisms known as pterobranchs. They are relatively common fossils in the Ordovician rocks of the Inland Basin.

Figure 4.9: graptolites, Ordovician Didymograptus *(2 cm long).*



High energy, **silty or sandy environments** *were common near the eastern shoreline of the inland sea, and are preserved in places such as the mid-Devonian rocks of the Catskills. As the inland basin gradually filled over time, the shoreline moved westward. Thus, fossil-rich siltstones and sandstones are also found in the late Devonian rocks of southern New York and the late Devonian and Mississippian rocks of northern Pennsylvania.*

Silty to sandy marine environments, preserved as siltstone and sandstones, may contain abundant rugose corals, large thick-shelled brachiopods, sea lilies, and bryozoans and lesser amounts of many other organisms such as ***sponges*** *(Figure 4.10)*. These organisms were robust filter feeders.

SPONGES

Technically known as poriferans, sponges come in a variety of shapes and body forms, and have been around at least since the Cambrian. Entire sponges are rarely preserved, but their tiny skeletal pieces, called 'spicules,' are common in sedimentary rocks. Glass sponges (with skeletons made of silica) are a particular group of sponges that existed from the Cambrian to the present. Though now largely found in deep water environments, they were sometimes part of shallow marine environments in the Paleozoic. The best-known glass sponge fossils are from New York Devonian sedimentary rocks of the Inland Basin.

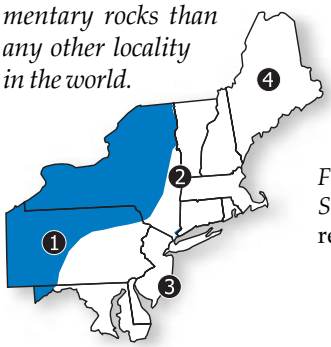
Figure 4.10: Glass sponge, upper Devonian Hydnoceras (16 cm long).

see Rocks, p.35, for more on rocks preserving **hypersaline** *environments.*

Evaporites *are sedimentary rocks created by the precipitation of minerals directly from seawater, including gypsum, carbonate and halite.*

Hypersaline marine environments are preserved as ***evaporite*** deposits. Because ***hypersaline*** environments have higher than normal levels of salt, most organisms cannot survive. Unusually tolerant organisms generally inhabit these environments. ***Eurypterids***, or sea scorpions, were able to withstand the salty water and are well-preserved fossils in rocks of this environment *(Figure 4.11)*.

Rocks preserving hypersaline marine environments are found in the Silurian dolostones of central and western New York, associated with large salt deposits precipitated in the inland ocean. Eurypterids are preserved more commonly in New York Silurian sedimentary rocks than any other locality in the world.



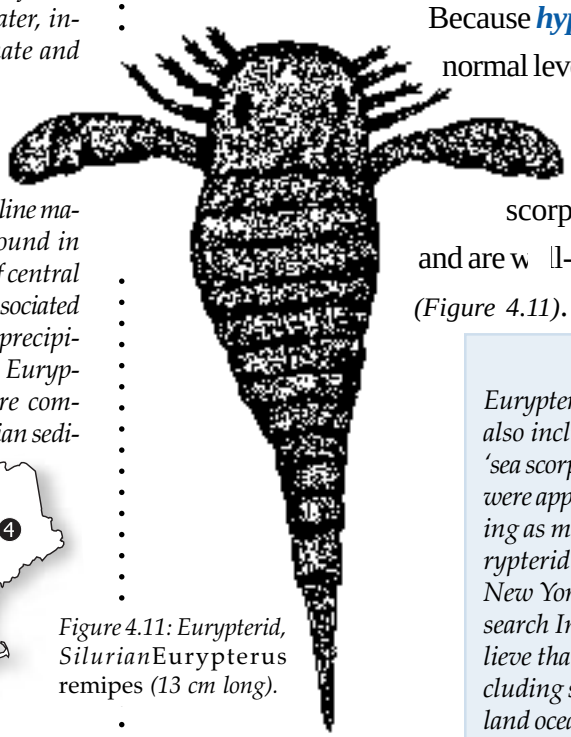


Figure 4.11: Eurypterid, Silurian Eurypterus remipes *(13 cm long).*

EURYPTERIDS

Eurypterids are an extinct group of arthropods, the group that also includes horseshoe crabs. Though known by the name 'sea scorpions', they were not actually scorpions. Eurypterids were apparently one of the great predators of their time, reaching as much as 3 meters in length. The largest complete eurypterid in the world, about 1.3 meters long, was found in New York State and is on display at the Paleontological Research Institution in Ithaca, New York. Paleontologists believe that eurypterids lived in near shore environments, including salty, shallow sea environments like the Silurian inland ocean.

Intertidal and river environments are often preserved as coarse grained sandstones and conglomerates. Rocks preserving these environments commonly contain plant fossils. When land plants first evolved in the Silurian, they were non-vascular, relatively small plants with only very tiny, hair-like roots, if any. Gradually plants began to evolve and diversify. ***Vascular*** plants became more common, leading to taller plants and larger, more extensive root systems. By the Devonian, woody matter from vascular plants is commonly found in the fossil record of the Northeast. The Gilboa forest, in mid-Devonian shales of Scoharie Creek Forest in central New York, contains fossilized tree stumps and is the oldest preserved ***forest***. More commonly, though, Devonian plant material is restricted to thin carbonized sticks.

Early **forests** *were composed of quite different types of plants than today's forests. For example, progymnosperms are a group of plants with spores rather than true seeds; those with two different forms of spores probably were the ancestors to gymnosperms. An important progymnosperm was* Archaeopteris, *a leafy tree of the late Devonian.*

Rocks preserving **intertidal, land,** *or* **river environments** *tend to be found close to the mountain range that existed on the eastern side of the inland ocean or associated with the deltas that formed as sediments eroded off the highlands.*

Vascular *plants have stiffer tissues that help support them and transport nutrients and water to all parts of the plant. This allows vascular plants to grow taller and further from water.*

PROBLEMATICA

There exists a formal Latin name even for enigmatic fossil groups: problematica. Most Problematica are late Precambrian or Paleozoic organisms, all of which have become extinct and so provide no modern organism that would enable us to clarify their anatomy and genetics. Two commonly seen Problematica fossils in the Inland Basin sedimentary rocks are hyolithids (Figure 4.12), conical tubes with a shell covering; and tentaculitids (Figure 4.13), small, cone-shaped, ribbed shells. Both have been considered mollusks in the past, though hyolithids are believed by some to be a distinct phylum.

Figure 4.12: Hyolithid, mid-Ordovician (2 cm).

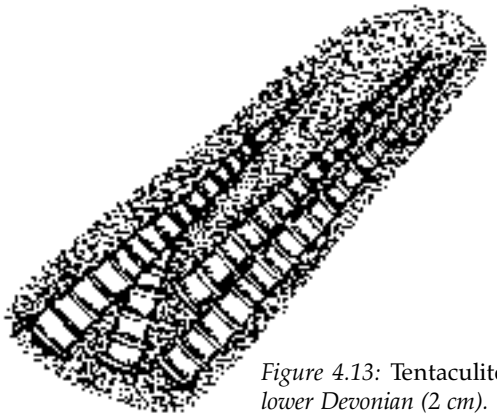
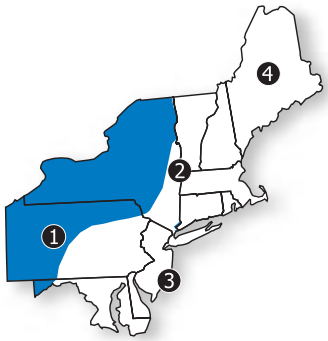
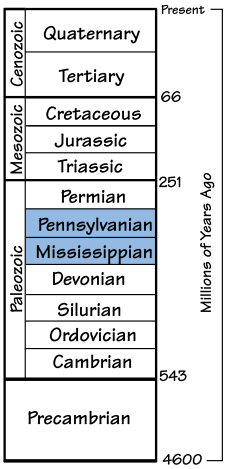


Figure 4.13: Tentaculites *lower Devonian (2 cm).*



Mississippian and Pennsylvanian



Plants can be tricky to reconstruct because their parts (wood, leaves, seeds) tend to break apart and are found separately. Usually each plant part gets its own Latin name. Careful analysis may enable putting a species back together, but there have been many cases in which several plant parts assumed to belong to very different groups of plants turned out to be the same species.

Pennsylvania preserves one of the best-known Pennsylvanian-age plant communities in the world *(Figures 4.14-4.17)*. Large amounts of sediment were being rapidly eroded from the Acadian Mountains to the east, quickly burying plant material in coastal floodplain environments and creating oxygen-poor conditions that prevented the decomposition of organic matter. Plant and other non-marine fossils from the Mississippian and the early Permian are also present in Pennsylvania, but are far less extensive. Common Mississippian and Pennsylvanian plants include horsetails, ferns, seed ferns, and scale trees. These plants formed extensive forests in swampy areas along the edge of the inland ocean that led to the formation of coal deposits found in Pennsylvania and Maryland. Plants are not the only fossils recorded in the Pennsylvanian and Mississippian rocks of the Inland Basin, as the inland ocean still existed in much of the basin at this time. The plant fossils represent typical ferns, seed ferns, and horsetails, while the marine fossils represent typical Inland Basin brachiopods, cephalopods, clams, corals, and snails.

Pennsylvanian-age horsetails reached over 30 meters high. Their stems are known as Calamites *and their leaves are called* Annularia. *The modern horsetail equivalents are known as sphenopsids (Figure 4.14).*

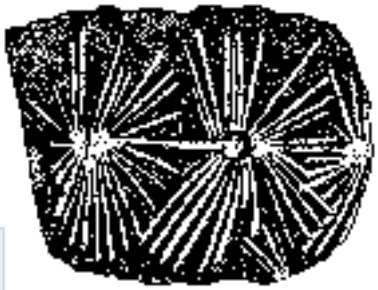
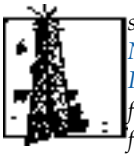


Figure 4.14: Annularia *leaf, Pennsylvanian (specimen 9.5 cm wide).*



see Non-Mineral Resources, *p.156, for more on the formation of* **coal.**

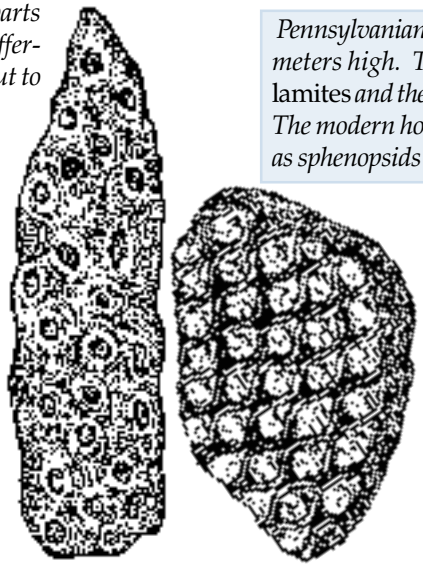


Figure 4.15: LEFT ABOVE: Plant root, Stigmaria, *Pennsylvanian (14 cm long); RIGHT: Lycopod* Lepidodendron, *bark with leaf scars, Pennsylvanian (10.5 cm wide).*

Scale trees (lycopsids) grew up to 45 meters high in Mississippian and Pennsylvanian forests. The roots of a scale tree are called Stigmaria. *The entire tree is known as* Lepidodendron. *The modern scale tree equivalents are known as lubmosses or ground pines (Figure 4.15).*

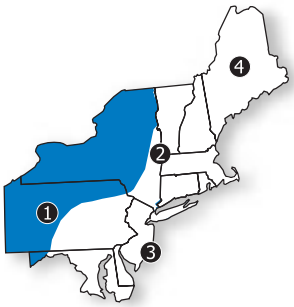


Figure 4.16: Seed fern plant, Neuropteris, *Pennsylvanian (5.5 cm long).*

*Seed ferns (pteridosperms) lived from the Mississippian to the Jurassic. The leaves (*Neuropteris*) resemble ferns, but have seeds instead of spores (Figures 4.16 and 4.17).*

Figure 4.17: Seed fern plant, Alethopteris, *Pennsylvanian (8 cm long).*

Fossils of the Appalachian/Piedmont
Region 2

The Paleozoic fossils in the Appalachian/Piedmont region are generally the same as those of the Inland Basin because the rocks were originally sediments deposited along the same inland ocean. The rocks of the Appalachian/Piedmont, however, are in general more ***deformed*** structurally because they were closer to or part of the Taconic, Acadian and Alleghanian mountain-building events. Because of the deformation, the fossils in this region are less well preserved. The Triassic and Jurassic age Rift Basin fossils, however, are only found in the Appalachian/Piedmont and the Exotic Terrane region.

see Fossils, p.84, for fossils of the Inland Basin.

When fossils are deformed:

- *the carbonate in the shell material may recrystallize, often obliterating the original shape of the shell;*
- *they are often deformed in shape, which can be used by structural geologists to determine the amount and direction of stress;*
- *the sediments surrounding the fossil are sometimes altered so that it is more difficult to discern the type of environment in which the organism lived.*

Cambrian

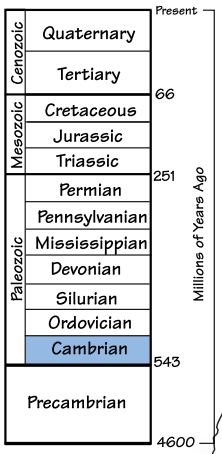
Cambrian rocks in the Appalachian/Piedmont record the erosion of sediment from the Grenville Mountains into the Iapetus Ocean. Early Cambrian fossils near Lancaster, Pennsylvania are among the earliest fossils found in Paleozoic rocks and in the entire Northeast *(See **LAGERSTATTEN** below.)* Western Vermont and northern New Jersey also have early Cambrian shale containing the trilobite *Olenellus*. Late Cambrian ***stromatolites*** are found in Washington County, Maryland and Bucks County, Pennsylvania *(Figure 4.18).*

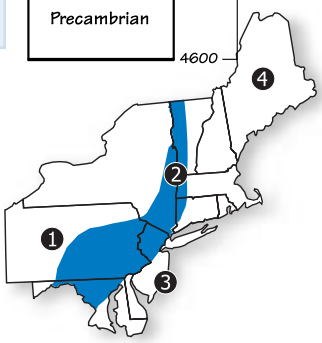
see Geologic History, p. 7, for more on the Cambrian.

Figure 4.18: Stromatolite, Cambrian (14.5 cm long).

STROMATOLITES

Stromatolites are layers of millimeter thick laminations that were once bacterial mats (full of photosynthetic cyanobacteria) at the surface of very shallow water. Cyanobacteria emit a sticky substance that binds settling clay grains and creates a chemical environment leading to the precipitation of calcium carbonate. The calcium carbonate then hardens the underlying layers of bacterial mats, while the living bacteria move upward so that they are not buried. There are still stromatolites today, but they form thick layers only in 'stressful environments', such as very salty water, that exclude animal grazers.





LAGERSTATTE

A locality of Cambrian fossils near Lancaster, Pennsylvania, is an example of a lagerstatten. Lagerstatten are deposits containing animals or plants that are preserved unusually well, sometimes even including the soft organic tissues. Lagerstatten are important for the information they provide about soft-bodied organisms that we otherwise would know nothing about. Lagerstatten form in chemical environments that slow decay of organic tissues or enhance preservation through mineralization. Also, quick burial of the organism leaves no opportunity for disturbance of the fossils.

Ordovician to Devonian

see Fossils, p.85 for more on fossils that lived in **shallow marine environments**

There are some fossil-rich Ordovician and Silurian (and a few Devonian) sites in the Appalachian/Piedmont region, in spite of the deformation of the rocks from the various Paleozoic mountain-building events. For example, eastern Pennsylvania and western Vermont both preserve assemblages of brachiopods, trilobites, corals, bryozoans, clams, and other organisms typical of shallow marine environments.

Triassic to Jurassic

see Fossils, p.97, for more on **rift basin fossils.**

The Appalachian/Piedmont has extensive outcrops of Mesozoic rocks, preserved in the rift basins that formed during the Age of Reptiles, when Pangea was breaking apart *(Figure 4.19)*. The sedimentary rocks preserved in the rift basins record the presence of dinosaurs in the Northeast. In particular, the extensive **dinosaur trackways** found in these rocks have become among the most publicly known fossils in the Northeast. Many of the small three-toed dinosaur footprints are known as *Grallator*, and were probably made by the late Triassic dinosaur known from the southwestern United States as ***Coelophysis***.

Trace fossils receive Latin names independent of the species name of the organism that created them, largely because the species is not known with certainty. Apparent **Coelophysis** *tracks in Nyack, New York, near New York City, are the only dinosaur fossils known from New York State.*

Some areas contain not only footprints, but also abundant freshwater fish, mollusks, and plant fossils such as cycads, ferns, conifers, and ginkos. A locality in Princeton, New Jersey, for example, contained hundreds of coelocanth (known in the fossil record as 'lobe-finned' fish) and small bony fish. In general, however, the Northeast rift valley deposits have relatively few vertebrate bone fossils compared to footprints.

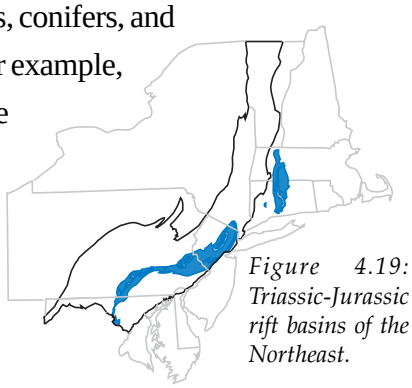
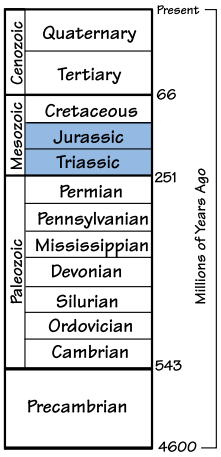
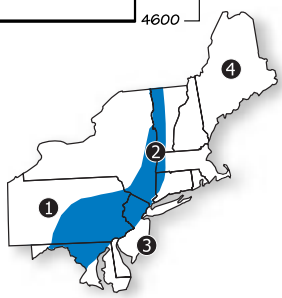


Figure 4.19: Triassic-Jurassic rift basins of the Northeast.





The Age of Reptiles

The Mesozoic Era is commonly known as the Age of Reptiles, a time dominated both on land and in the sea by large reptiles. ***'Dinosaur'*** *technically refers to the group of land reptiles with a common ancestor and thus certain anatomical similarities, including long ankle-bones and erect limbs. At the same time as the dinosaurs, other reptile groups also became important: the pterosaurs, flying reptiles with wingspans up to 15 meters, and plesiosaurs, mosasaurs and ichthyosaurs, marine reptiles that were probably similar in size and habitat to toothed whales, dolphins and large sharks of today. Mammals, evolving from a group known as the 'mammal-like reptiles' that were a dominant land animal in the Permian and Triassic. Mammals appeared at roughly the same time as the dinosaurs in the mid-Triassic. Mammals, however, occupied only rodent-like niches until the dinosaurs went extinct. All the large reptile groups disappeared at or before the mass extinction at the end of the Cretaceous.*

Fossils of the Coastal Plain
Region 3

see Rocks, p.46, for more on Coastal Plain sediments.

see Fossils, p.85, for more on **corals.**

The Coastal Plain is underlain by a wedge of flat-lying Cretaceous and Cenozoic unconsolidated sediments. These sediments preserve striking evidence of how much sea life has changed from the Paleozoic to the Cenozoic. Fossils from the Coastal Plain are very different from the Paleozoic marine fossils found in the Inland Basin and Appalachian/Piedmont regions. The Coastal Plain sediments are especially rich in mollusks (**bivalves** and **gastropods**, and, in Cretaceous sediments, cephalopods). ***Shark teeth***, scleractinian corals *(Figure 4.20)*, barnacles, and sand dollars are also found in the Coastal Plain but are rare or absent in Paleozoic rocks. Brachiopods, so common in Paleozoic sedimentary rocks, are all but absent in the Coastal Plain.

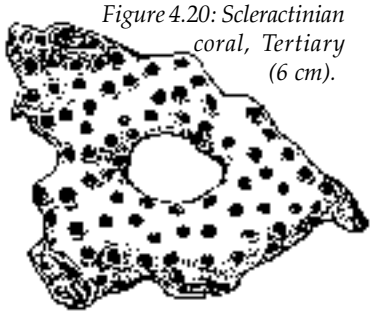


Figure 4.20: Scleractinian coral, Tertiary (6 cm).

Cretaceous

Good outcrops of marine and non-marine Cretaceous fossils are found in New Jersey and famous outcrops along the Chesapeake and Delaware canals in Delaware. Outcrops with clams are common, especially including oysters such as *Gryphaea (Figure 4.21)*, in some cases creating small oyster 'reefs.' Snails, ammonoids, belemnites *(Figure 4.23)*, and claws of the shrimp *Calianassa* are common.

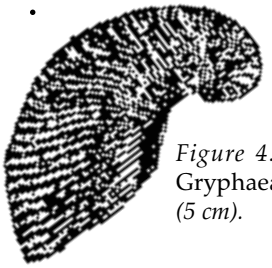
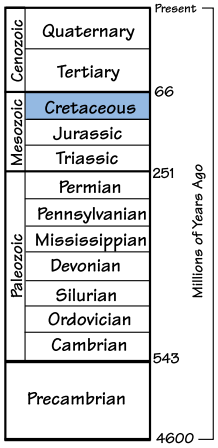


Figure 4.21: Oyster, Gryphaea, *Cretaceous (5 cm).*

Rare remains of dinosaurs and other terrestrial vertebrate organisms have also been found in the Cretaceous sediments of the Coastal Plain. Parts of marine reptiles, such as mosasaurs, giant crocodiles, plesiosaurs, bony fishes, turtles, lizards, snakes, and even a wing and neck bone from a pterosaur have been found in sediments in the Chesapeake and Delaware canals. Perhaps the most celebrated discovery was that of a duck-billed dinosaur known as *Hadrosaurus* in Haddonfield, New Jersey *(Figure 4.22)*. Discovered by John Hopkins in 1835, the bones did not receive much attention until pieces were sent to Joseph Leidy in Philadelphia, who determined that they were from a dinosaur that stood on its hind legs. This was America's first dinosaur skeleton find.



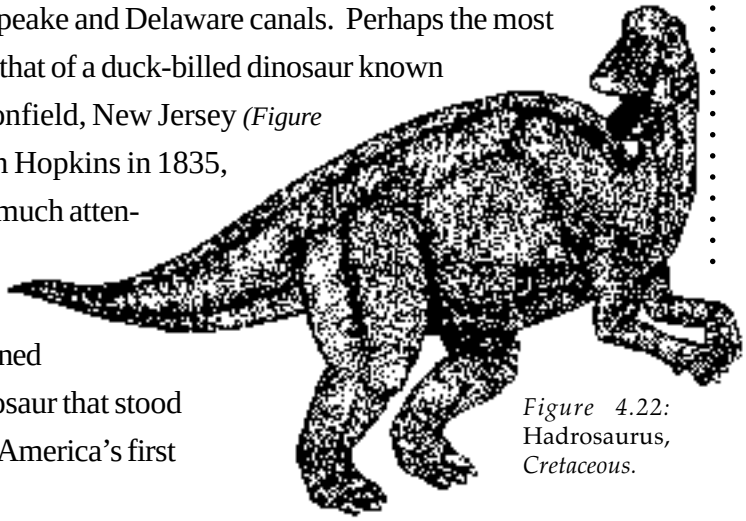


Figure 4.22: Hadrosaurus, *Cretaceous.*

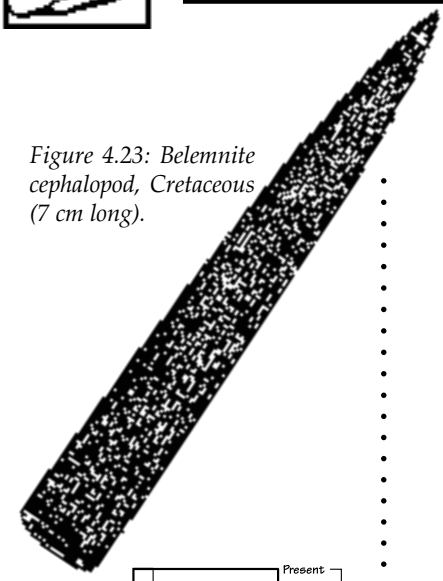
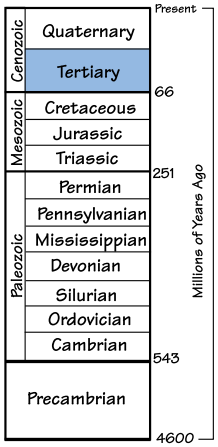


Figure 4.23: Belemnite cephalopod, Cretaceous (7 cm long).

CEPHALOPODS

Cephalopods are swimming predators with tentacles and a beak-shaped mouth that move using a jet of water. The group includes belemnites, nautiloids, ammonoids, squid and octopi. A mass extinction between the Cretaceous and Tertiary eliminated many varieties of cephalopods. The shells of cephalopods range from long straight cones to spirals, but some have internal shells or no significant shell at all, like the octopus. Early to mid-Paleozoic rocks of the Inland Basin preserve cephalopods, mostly nautiloids, but they are generally neither abundant nor well preserved. The Nautilus *is the only living member of this group. Belemnites, bullet-shaped fossils related to squids, were common in the Cretaceous seas. Though belemnites are commonly found in Cretaceous sediments of the Coastal Plain, they did not survive past the Cretaceous. Ammonoids, with somewhat more complex chambering than nautiloids, first appear in Devonian-age rocks. They were especially successful in the Mesozoic, and went extinct at the end of the Cretaceous with the dinosaurs.*

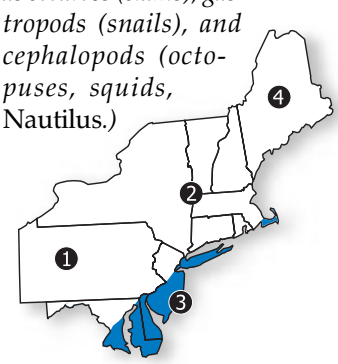


Tertiary

The best-known fossil-rich sections of the Tertiary Coastal Plain deposits in the Northeast are at Calvert Cliffs in Maryland. ***Barnacles*** *(Figures 4.24)*, crab claws, sand dollars and ***bryozoans*** are present in relatively small amounts, in addition to the mollusks that characterize deposits in the Coastal Plain region *(Figures 4.25 and 4.26)*. Among the vertebrates found at Calvert Cliffs have been inner ear bones, teeth, and vertebrae of many species of whales and porpoises, shark teeth *(Figures 4.27)*, ribs, jaws, crocodile teeth, turtle remains, stingray spines and teeth, and skeletal elements of bony fish. There is only one species of ***brachiopod*** at Calvert Cliffs, an organism that had dominated the Paleozoic sea.

see Fossils, p.85, for more on **bryozoans** *and* **brachiopods**

Mollusks are characterized by a muscular foot, calcareous shell, and rough, tongue-like organ called a radula. The group includes creatures as widely varied as bivalves (clams), gastropods (snails), and cephalopods (octopuses, squids, Nautilus.*)*



BARNACLES

Barnacles are filter-feeding crustaceans, something like shrimps living upside down in a box. They are surrounded by calcareous plates and live attached to shells, such as the large Chesapecten *shells found in Tertiary sediments of the Coastal Plain. It is sometimes possible to find them whole, often still attached to other shells.*

Figure 4.24: Barnacles, Balanus, *Tertiary (5 cm wide).*

GASTROPODS

Gastropods are known popularly as 'snails'. Unlike bivalves, gastropods have only one shell. The soft parts of gastropods are anatomically similar to bivalves, but the foot is made to crawl along the surface and the shell is usually coiled. Gastropods are only sometimes found in early and mid-Paleozoic sedimentary rocks of the Inland Basin, but are extremely common in the Cenozoic rocks of the Coastal Plain, and in Late Pleistocene glacial lake deposits and marine deposits in the Northeast.

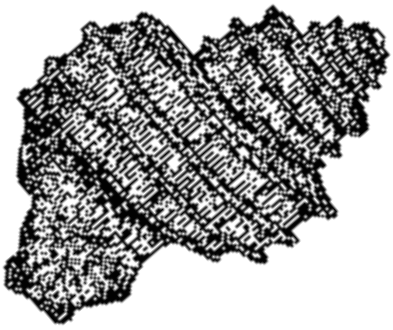


Figure 4.25: Gastropods. ABOVE: Ecphora, *Tertiary (6 cm long); FAR LEFT:* Turritella, *Tertiary (3.5 cm long).*

BIVALVES

Bivalves are often called clams, but they also include scallops, mussels, cockles and oysters. Bivalves have a protective pair of hinged valves and feed off particles in the water by collecting them with their gills. Bivalves are known as 'filter feeders'. During the Paleozoic, bivalves lived mostly on the surface of the ocean floor. In the Mesozoic, bivalves became extremely diverse and some evolved the ability to burrow into ocean floor sediments. Bivalves are the dominant fossils in the Cretaceous and Cenozoic Coastal Plain sediments. They are also common in late Pleistocene marine sediments, for example along the St. Lawrence Seaway and and submerged the coast of Maine and in smaller numbers in Paleozoic rocks of the Inland Basin and freshwater deposits of the Triassic rift basins.

Figure 4.26: Bivalves of the Coastal Plain. BELOW: Chesapecten, *Tertiary (9.5 cm wide); BOTTOM LEFT:* Mercenaria, *Tertiary (7 cm wide).*

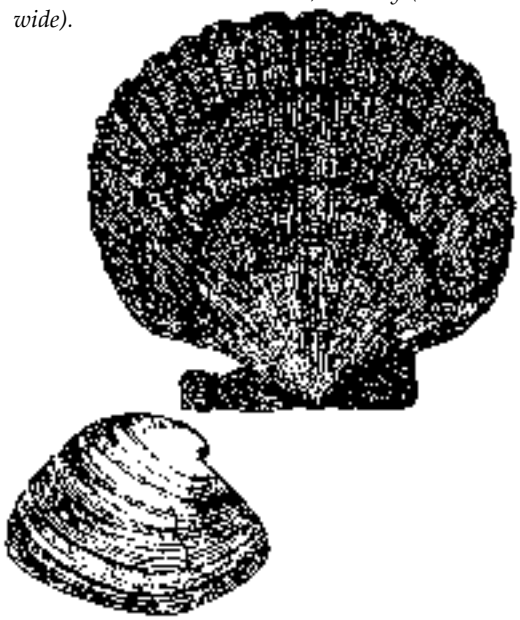


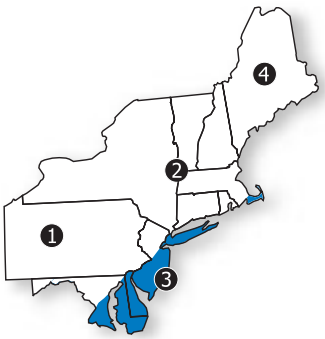
Figure 4.27: Shark teeth from Tertiary sediments at Calvert Cliffs. TOP: Carcharodocles *(7 cm long); BOTTOM: Tiger and sand shark teeth (~3cm long).*

SHARK TEETH

Shark teeth are one of the more common and prized fossils to come from Coastal Plain deposits. A good knowledge of how shark teeth vary both among sharks and in position within the mouth can often aid in identification. Among the shark teeth found in Tertiary Coastal Plain sediments in Maryland are teeth of the requiem, tiger, mako, angel and great white sharks. The fossil great white shark, or Carcharocles megalodon, *is most famous for its enormous size, having teeth over 15 cm long. Since shark skeletons are cartilaginous, except for teeth and vertebrae, there has been considerable debate over the actual body size of* Carcharocles. *Even conservative estimates, though, suggest a body size well over 17 meters long, nearly twice the size of the living great white sharks.*

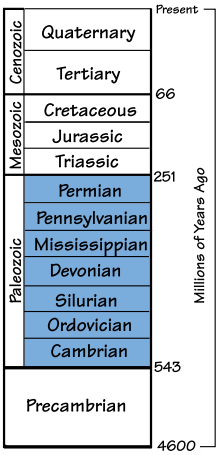
Perfectly round holes of only a few millimeters in size can often be found in Cenozoic shells. Though the holes can be so regular in shape and position that they seem human-made, they are actually predatory bore holes. The most common bores are made by moon snails, which use both acid and their rough, tongue-like organ (radula) to drill their holes. The snails then extend their radula into the hole and suck out the soft tissues of their prey.

Preservation of fossils in Coastal Plain sediments is also very different from that in Paleozoic rocks. The sediments range from well consolidated and cemented Cretaceous layers to unconsolidated sands in the Tertiary. Shells are often very well preserved, and except for the absence of color, look much like modern shells. In some cases, especially for fossils in the late Tertiary, the species are the same as modern species. In fact, along cliff faces near the ocean, modern and ancient shells are often found together. Coastal Plain assemblages of fossils, however, tend to be different than modern shells in the same latitude, because many Cenozoic deposits contain species that lived in relatively warm water.



Fossils of the Exotic Terrane
Region 4

Rocks of the Exotic Terrane region in general do not have preserved fossil communities because either they are metamorphosed sedimentary rocks or they are igneous rocks without fossil communities. Interesting exceptions occur in Paleozoic rocks, which include both fossils from the Ordovician onward, fossils from the accreted terranes, and fossils of organisms that lived in the Iapetus Ocean. Fossils after accretion of the terranes to the Northeast contain organisms that actually lived in the region and were not transported on the terrane.

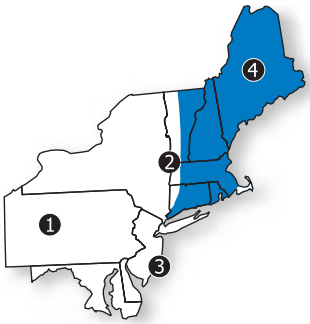


see Geologic History, p.12, for more on the New England basins.

see Rocks, p.49 for more on the Boston Basin

Some species of trilobites (Paradoxides) *found in the Boston Basin rocks of Braintree, Massachusetts are significantly larger than Inland Basin trilobites of the same age, averaging 30 cm long.*

see Fossils, p.5, for more on **these organisms;** *for Bivalves, see p.96.*



Paleozoic

Fossils as old as the Cambrian are known from the eastern Massachusetts ***Boston Basin*** and are preserved in rocks of the exotic terrane Avalonia. These rocks are believed to have originally been part of northern Africa, sutured to the side of North America during the Acadian mountain-building event. The fossil assemblages are like those in northern Africa but different from equivalent-aged fossils in North America. These fossil assemblages were among the earliest evidence for continental plate movement and exotic terranes.

Graptolites have been found in Ordovician rocks in Maine, possibly existing within the Iapetus Ocean. Silurian and Devonian fossils (which also existed in the Paleozoic inland ocean) are found in limestones from Maine and New Hampshire, including ***corals, crinoids, brachiopods, trilobites, bryozoans, bivalves,*** and ***tentaculids***. Devonian fossils in New Hampshire, though badly preserved in schist, include brachiopods. The Devonian plant fossil, *Pertica quadrifaria*, *(Figure: 4.28)* is preserved in parts of northern Maine, an area of the Exotic Terrane that experienced only weak metamorphism.

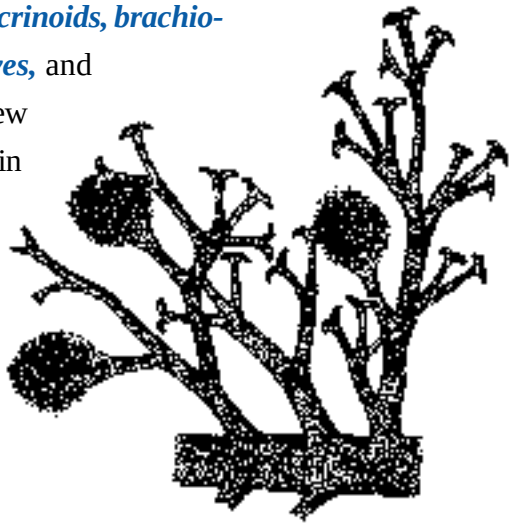


Figure 4.28: Maine state fossil: Pertica quadrifaria, *Devonian.*

Pennsylvanian basins found in

Rhode Island and Massachusetts contain a rich record of plant fossils, and rarer amphibian tracks, insects, and arachnids. These fossils are similar to those preserved in ***Pennsylvanian-age rocks*** in the Inland Basin, though in less extensive deposits.

see Fossils, p.92 for more on fossils found in **Pennsylvanian-age rocks.**

Triassic to Jurassic

The western Massachusetts Connecticut River Valley, part of a Triassic rift basin *(Figure 4.29)*, is the site of Pliny Moody's 1800 description of *three-toed* dinosaur footprints, which he thought were made by a raven from Noah's Ark *(Figure 4.30)*. This was also the area of Edward Hitchcock's early to mid-1800's interpretation of hundreds of dinosaur tracks as bird footprints. At one locality in ***Connecticut***, the footprints are so numerous that a museum has been built over them. In some localities there have also been discoveries of dinosaur bones, fish *(Figure 4.31)* , crocodiles, and other vertebrates. One well-known discovery by a teenage fossil collector was of an unusual gliding reptile. However, as in the Newark and Gettysburg rift basins in the Appalachian/Piedmont, vertebrate bone fossils are rare compared to the numerous footprints.

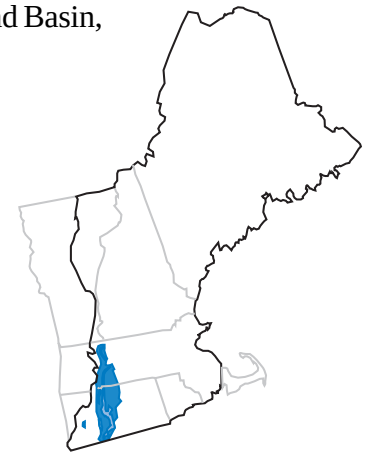


Figure 4.29: Triassic-Jurassic rift basin in the Exotic Terrane.

see Fossils, p.92, for more on **rift basin fossils.**

Many three-toed *footprints named* Grallator *are thought to have been made by the dinosaur* Coelophysis.

Dinosaur State Park in Rocky Hill, **Connecticut** *was established where the rift basin dinosaur trackways are particularly numerous.*

Where did the dinosaurs go?

Based on considerable geochemical and mineralogical evidence, many scientists have concluded that the Cretaceous-Tertiary boundary extinction was caused by a meteorite impact leading to the demise of the dinosaurs. In this scenario, a worldwide layer of dust was created by the impact, blocking out sunlight long enough to destroy the food chain and causing other ecological problems. The large reptiles disappeared, as well as significant numbers of ma-

Figure 4.30: Three-toed dinosaur track from Holyoke, Massachusetts (13 cm long).

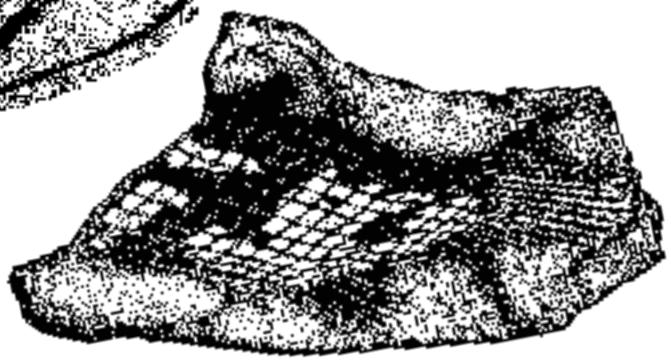
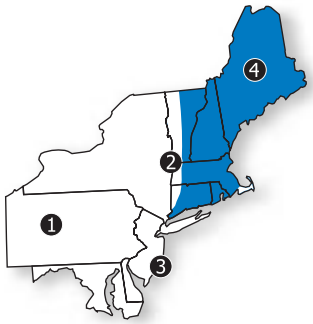


Figure 4.31: Fish, Semionotus, *Early Jurassic, Massachusetts (5.5 cm long).*



Ice Age Fossils
in Pleistocene deposits of the Northeast

Pleistocene deposits are like frosting over the rest of the geological layer cake. They follow mostly from Pleistocene climate and topography, so are in general less tightly controlled by bedrock than some other phenomena. Most terrestrial fossil remains are found either in ponds dating from the receding of previous glaciers or isolated teeth or bone fragments in glacial till. Some important faunas, however, are preserved in Pleistocene caves.

see Glaciers, p.57

One Maryland cave contained Pleistocene remains of vertebrates from a spectrum of climates:

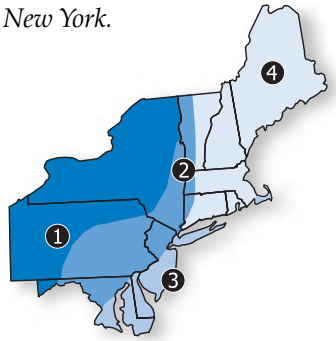
Pleistocene mammals representing **northern climates** *included wolverine, lemming, long-tailed shrew, mink, red sqirrel, muskrat, porcupine, jumping mouse, pika, hare, and elk.*

Pleistocene animals representing **southern climates** *included bats, peccaries, tapirs, crocodiles.*

Pleistocene animals representing an **intermediate climate** *included: horses, coyotes, badgers, several species of bears, otters, pumas, beavers, smaller rodents, mastodons, and deers.*

see Glaciers, p.61, for more on ice-margin deposits.

Over 100 mastodons have been recovered from Orange County, NY, which sits on the west side of the **Hudson** *in southeastern New York.*



Terrestrial and Lake Fossils

Caves are an example in which the underlying geology, generally limestone, influences the Pleistocene record. Cave faunas are not terribly common in the Northeast, but are very important in some other areas of the country where caves are numerous. Important examples in the Northeast include a cave in Montgomery County, southeast PA, which produced a large number of glacial age mammals, described by Edward Drinker Cope (more famous for his dinosaur descriptions), inluding a species saber tooth cat, a small species of black bear, and the sloth *Megalonyx*. Another Pleistocene cave formed from Devonian limestone in Allegheny County, Maryland, included a wide range of mammals representing both ***northern*** and ***southern climates***, as well as those of more ***intermediate climates***, suggesting a biogeographic transitional zone in which the climate had fluctuated.

Important and extensive freshwater and terrestrial remains occur in the innumerable pond sediments (not in the least lithified into rocks) left behind after retreat of the last glaciers. These ponds are well known from areas that were covered with ice and glacial sediment, especially kettles that formed along moraines and other ***ice-margin deposits.*** The ponds with large vertebrate remains are not randomly distributed, but can be clustered around well-known drainage systems, such as along the ***Hudson*** River Valley. Since such pond sediments are not surface outcrops, and since there is no foolproof technology for searching for bones under the sediment, most skeletons turn up during construction or pond alteration rather than through systematic searches for remains. Large vertebrate remains include mastodons, mammoths, giant beavers, peccaries, tapirs, foxes, bears, seals, deer, caribou, bison, and horses.

Nearly all glacial-age ponds contain a rich fossil record beyond vertebrates. In a typical pond, the first sediment to fill up the pond is fine-grained clays, followed later by organic-rich clays due to sedimentation of plant fragments as plant communities started to colonize the area after the glaciers had retreated. These clays often have plentiful late Pleistocene small freshwater mollusks, small pieces of fossil wood, and pollen, increasing as the plant community increased. The topmost sediment is often very late Pleistocene or Holocene peat, essentially pure plant matter made of innumerable tiny sticks and larger branches, leaves, cones, and other plant material. Since pollen shapes are indicative of the kinds of plants they come from, the pollen record can give a rather detailed account of how vegetation moved into the area as climate changed.

MASTODONS & MAMMOTHS

Among the most common Pleistocene vertebrate fossils in the Northeast are those of mastodons and mammoths. People frequently confuse these two kinds of ancient elephants (or, more technically, proboscideans). Both were common in the Northeast in the Pleistocene, but they had different ecological preferences and are usually found separately; mastodons (Figure 4.32) are by far the more common of the two in most areas of the Northeast. Mammoths are from the same line of proboscideans that gave rise to African and Asian elephants; mastodons are from a separate line of proboscideans that branched off from the modern elephant line in the Miocene. In body proportions mastodons have a shorter, stockier build and longer body; mammoths are taller and thinner, with a rather high "domed" skull. In skeletal details, the quickest way to tell the difference is with the teeth: mastodons have teeth with conical ridges, a bit like the bottom of an egg carton; mammoths, in contrast, have teeth with numerous parallel rows of ridges. The teeth are indicative of the ecological differences: Mastodons preferred to bite off twigs of brush and trees, for example from spruce trees, while mammoths preferred tough siliceous grasses, thus mastodon teeth are more suitable for cutting, while mammoth teeth are more suitable for grinding (Figure 4.33).

Figure 4.33: A mastodon tooth, suited for cutting twigs of spruce trees.

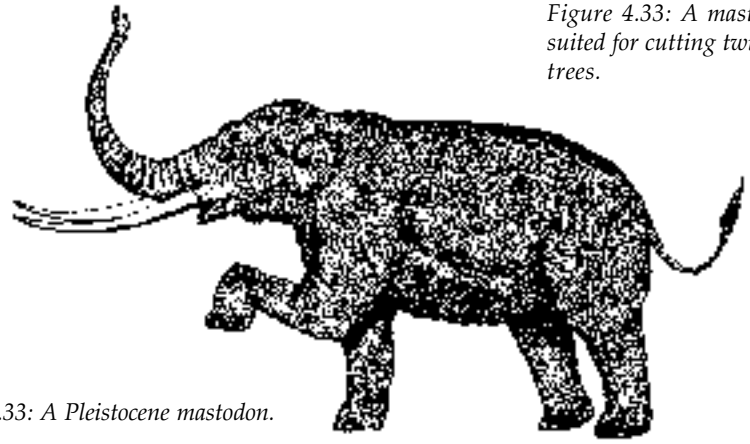
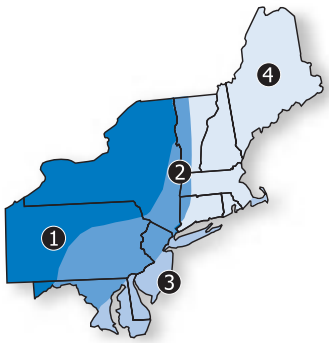


Figure 4.33: A Pleistocene mastodon.

One of the most complete and best preserved **mastodons** *recovered to date in the Northeast was excavated by the Paleontological Research Institution in late summer, 2000. It was found when a family in a suburban neighborhood, in Hyde Park near Poughkeepsie, NY, was deepening their backyard (glacial-age) pond. Other mastodons have been found near Rochester, Buffalo, and Albany, New York, and Amherst and Cambridge, Massachusetts (just to name a few.)*



Marine Fossils

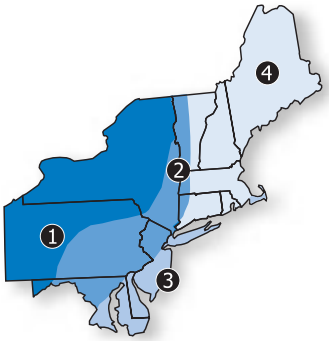
One can visit places in the Northeast where sea level rise outpaced the rebounding continental crust after meltback of the glaciers, flooding lowlands such as areas of Massachusetts and along the St. Lawrence Seaway. The Champlain Sea refers to an ocean bay that filled most of the Ottawa-St. Lawrence-Lake Champlain basin about 11,000 to 8,000 years ago. The fossils from these sediments are so recent that most or all are represented by living populations today, but mostly in more northerly, cooler locations. Lowland areas of the coastline in southern Maine are covered with glacial marine clay dating to about 11,000 years ago that also contain marine bivalves and other marine invertebrates.

see Glaciers, p.65, for more on rebounding crust.

The most celebrated fossil from the ***Champlain Sea*** deposits has been the '***Charlotte whale***,' a specimen of the modern beluga whale, found in Chittendon County, Vermont in 1849 by workers digging a railroad. Though initially shocked to find whale remains so far inland, it eventually became apparent that the whale had come down the St. Lawrence Seaway at a time that this area had been flooded with sea water. The Champlain Sea extended into New York, where a fossil beluga whale was also discovered in 1987. Other whale remains found have included the harbor porpoise, humpback whale, finback whale, and bowhead whale.

The Charlotte beluga whale can be seen in the University of Vermont's Perkins Museum of Geology. Today about 500 beluga whales live in the Gulf of the St. Lawrence.

Other common fossils in the **Champlain Sea** *include marine clams that today can be found living in cool Atlantic and Arctic Ocean waters. Other invertebrates include barnacles, gastropods, and sponges. A number of species of marine fish have been found as fossils, such as the Atlantic cod, which on the whole are most similar to fish in the southern coast of Labrador today. Several species of seals that breed on sea ice have been found, such as the harp seal, bearded seal, and ringed seal.*



How old does it have to be?

Fossils are any evidence of ancient life, whether shell, its imprint, or the trace made by a moving animal. Dictionary definitions often suggest that fossils are such remains greater than 10,000 years old. Popular conception holds that some process, such as permineralization (infilling of cavities and replacement by minerals), must occur for an object to be considered a fossil. The latter is not true — Pleistocene shells and bone materials are frequently nearly indistinguishable from modern material, except in some cases through color changes, such as by leaching of color or staining from tannins and iron in the sediment. The former (10,000 years) may be true by definition, but is only a practical guideline. Those studying successions of plant or animal remains since the last glaciation, from 20,000 years ago to the present, would not recognize any sudden change in the material at 10,000 years, and would typically refer to all material buried in sediments as fossil material. A compromise is to call younger material "subfossils," especially if they are in sediment that is still prone to movement by currents and burrowing organisms (as in surface sediment in shallow aquatic environments).

State Fossils
of the Northeast

The state fossils tell the geologic history of the Northeast in their own way *(Figure 4.34)*. New York and Pennsylvania are dominated by Paleozoic sedimentary rocks from the inland ocean and their state fossils, a eurypterid and trilobite, reflect this history. Because of its preservation in only the salty shallow sea deposits of the Silurian, the eurypterid in particular is testimony to the rise and fall of sea level in the inland ocean during this time. Northern Maine, which was only weakly metamorphosed during the mountain-building events of the Paleozoic, preserves the Devonian fossil plant, *Pertica quadrifaria*. This rare fossil was first discovered in Maine and reflects the vascularization and diversification of plants during this period in geologic history. New Jersey, Connecticut and Massachusetts all have dinosaur footprints as their state fossil. Not surprisingly, the rift basins of the Northeast that preserve Mesozoic sedimentary rock in which one might be able to find dinosaur fossils or traces, cut through each of these states. Cretaceous belemnites, the state fossil of Delaware, are preserved in abundance in Delaware Cretaceous sediments, indicative of the change in sea life since the Paleozoic. Gastropods from the Tertiary, found at the famous fossil-collecting location, Calvert Cliffs, Maryland, are the state fossil of Maryland. The beluga whale from late Pleistocene deposits of the Champlain seaway is the state fossil of Vermont. Buried in sediment when the ice sheet retreated and Lake Champlain was flooded by ocean water, the whale is a spectacular reminder of the relatively recent ice age history of the Northeast.

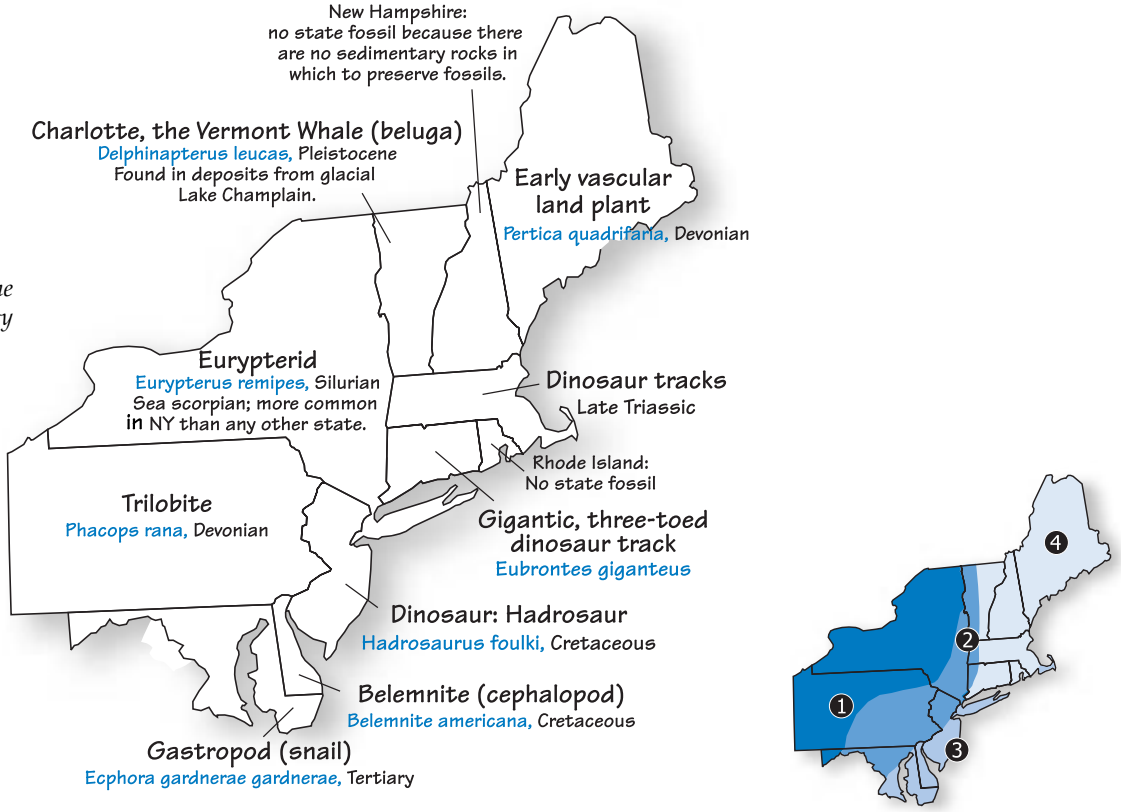


Figure 4.34: State fossils of the Northeast reflect the geology of the region.