Chapter 3: Fossils of the Midwestern US

Fossils (from the Latin word *fossilis*, meaning "dug up") are the remains or traces of organisms that lived in the geologic past (older than the last 10,000 years), now preserved in the Earth's **crust**. Most organisms never become fossils, but instead decompose after death, and any hard parts are broken into tiny fragments. In order to become fossilized, an organism must be buried quickly before it is destroyed by **erosion** or eaten by other organisms. This is why fossils are found almost exclusively in sediment and **sedimentary rocks**. **Igneous rocks**, which form from cooling **magma** or **lava**, and **metamorphic rocks**, which have been altered by **heat** and pressure, are unlikely to contain fossils.

The "soft" tissues of an organism, such as skin, muscles, and internal organs are typically not preserved as fossils. Exceptions to this rule occur when conditions favor rapid burial and mineralization or very slow decay. The absence of oxygen and limited disruption of the sediment by burrowing are both important for limiting decay in those deposits where soft tissues are preserved. Examples of such exceptional preservation include fossils in concretions, such as those in the Mazon Creek deposit in Illinois.

Since rapid burial in sediment is important for the formation of fossils, most fossils form in marine environments, where sediments are more likely to accumulate. Fossils come in many types. Those that consist of an actual part of an organism, such as a bone, shell, or leaf, are known as **body fossils**; those that record the actions of organisms, such as footprints and burrows, are called **trace fossils**. Body fossils may be preserved in a number of ways. These include preservation of the original **mineral** skeleton of an organism, mineral **replacement** (chemical replacement of the material making up a shell by a more stable mineral), **recrystallization** (replacement by a different **crystal form** of the same chemical compound), **permineralization** (filling of empty spaces in a bone or shell by minerals), and molds and casts (see *Figure 3.10A*), which show impressions of the exterior or interior of a shell. **Chemical fossils** are chemicals produced by an organism that leave behind an identifiable record in the geologic record. Chemical fossils provide some of the oldest evidence for life on Earth.

Review

crust • *the uppermost, rigid outer layer of the Earth, composed of tectonic plates.*

erosion • *the transport of weathered materials.*

sedimentary rock • *formed through the accumulation and consolidation of grains of broken rock, crystals, skeletal fragments, and organic matter.*

magma • *molten rock located below the surface of the Earth.*

lava • *molten rock located on the Earth's surface.*

mineral • *a naturally occurring solid with a specific chemical composition and crystalline structure.*

crystal form • *a physical property of minerals, describing the shape of the mineral's crystal structure.*

CHAPTER AUTHORS

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3 Fossils

Review

extinction • *the end of species or other taxonomic groups, marked by death of the last living individual.*

stratigraphy • *the branch of geology specifically concerned with the arrangement and age of rock units.*

Cambrian • *a geologic time period lasting from 541 to 485 million years ago.*

biodiversity • *the number of kinds of organisms at any given time and place.*

Paleontologists use fossils as a record of the history of life. Fossils are also extremely useful for understanding the ancient environment that existed in an area when they were alive. The study of the relationships of fossil organisms to one another and their environment is called **paleoecology**.

Fossils are also the most important tool for dating the rocks in which they are preserved. Because species only exist for a certain amount of time before going **extinct**, their fossils only occur in rocks of a certain age. The relative age of such fossils is determined by their order in the stacks of layered rocks that make up the **stratigraphic** record (older rocks are on the bottom and younger rocks on the top—a principle called the **Law of Superposition**). Such fossils are known as **index fossils.** The most useful index fossils are abundant, widely distributed, easy to recognize, and occur only during a narrow time span.

Index fossils are used to determine the age of many deposits that cannot be dated radiometrically. An ideal index fossil lived during a short period of time, was geographically and environmentally widespread, and is easy to identify. Some of the most useful index fossils are hard-shelled organisms that were once part of the marine plankton.

Ancient Biodiversity

Since life began on Earth more than 3.7 billion years ago, it has continuously become more abundant and more complex. It wasn't until the beginning of the **Cambrian** period, around 543 million years ago, that *complex life*—living things with cells that are differentiated for different tasks—became predominant. The diversity of life has, in general, increased explosively through time since then. Measurements of the number of different kinds of organisms—for example, estimating the number of species alive at a given time—attempt to describe Earth's **biodiversity**. With a few significant exceptions, the rate at which new species evolve is significantly greater than the rate of extinction.

Most species have a lifespan of several million years; rarely do species exist longer than 10 million years. The extinction of a species is a normal event in the history of life. There are, however, intervals of time during which extinction rates are unusually high, in some cases at a rate of 10 or 100 times the normal rate. These intervals are known as **mass extinctions** (*Figure 3.1*). There were five particularly devastating mass extinctions in geologic history, and these specific mass extinction events have helped to shape life through time. Unfortunately, this is not just a phenomenon of the past—it is estimated that the extinction rate on Earth right now may be as much as 1000 times higher than normal, and that we are currently experiencing a mass extinction event.

Review

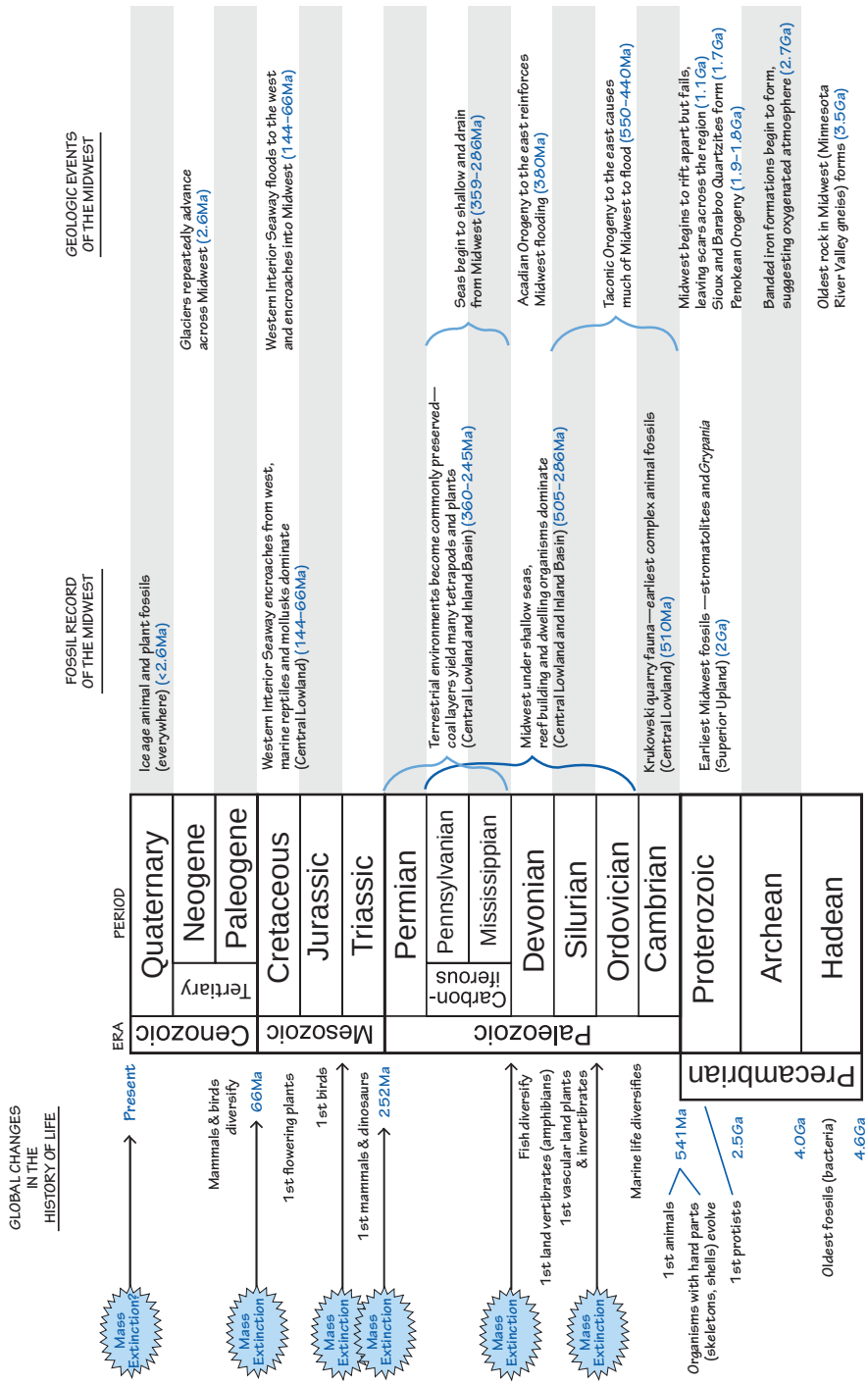


Figure 3.1. The history of life in relation to global and regional geological events and the fossil record of the Midwest (time scale is not to scale).

3 Fossils

Review

silt • *fine granular sediment most commonly composed of quartz and feldspar crystals.*

clay • *the common name for a number of very fine-grained, earthy materials that become plastic (flow or change shape) when wet.*

cross-bedding • *layering within a bed in a series of rock strata that does not run parallel to the plane of stratification.*

Paleozoic • *a geologic time period that extends from 541 to 252 million years ago.*

reef • *a feature lying beneath the surface of the water, which is a buildup of sediment or other material built by organisms, and which has positive relief from the sea floor.*

Pennsylvanian • *a subperiod of the Carboniferous, spanning from 323 to 299 million years ago.*

inland sea • *a shallow sea covering the central area of a continent during periods of high sea level.*

Different fossils are found in different regions because of the presence of rocks deposited at different times and in a variety of environments. The availability of fossils from a given time period depends both on the deposition of sedimentary rocks and the preservation of these rocks through time.

Discovering Ancient Environments

The kinds of animals and plants living in a particular place depend on the local environment. The fossil record preserves not only fossil organisms, but also evidence of what the environment in which these organisms lived was like. By studying the geological and biological information recorded in a rock that contains a fossil, scientists can determine some aspects of its environment.

Grain size and composition of the rock **can tell us what type of sediment surface the animal lived on, what the water flow was like, or whether it was transported in a current. Grain size also tells us about the clarity of the water. Fine-grained rocks such as shales are made of tiny particles of *silt* or *clay* that easily remain suspended in water. Thus a fossil found in shale might have lived in muddy or very quiet water. Filter-feeding organisms, such as clams or corals, are not usually found in muddy water because the suspended sediment can clog their filters!**

Sedimentary structures**, such as asymmetrical ripples and *cross-beds*, can indicate that the organism lived in moving water. Mud cracks or symmetrical ripples are characteristic of shoreline or intertidal environments.**

Broken shells or concentrated layers of shells **may indicate transportation and accumulation by waves or currents.**

Color of the rock **may indicate the amount of oxygen in the water. If there is not enough oxygen in the water, organic material (carbon) in sediments will not decompose, and the rock formed will be dark gray or black in color.**

Fossils 3

The rocks of the Midwest preserve an excellent fossil record of the history of life, especially from the **Paleozoic** Era. Most periods of the Paleozoic are very well represented in the Midwest, with fossils of increasingly diverse **reef** communities found in parts of every state. When the sea level dropped after the **Pennsylvanian** period, the **inland sea** drained from the region. Since the region was exposed to the air during most of the **Mesozoic**, far less of this era's fossil record was preserved. **Cenozoic** fossils in the region include abundant **Pleistocene** land mammals.

Fossils of the Superior Upland
Region 1

The Superior Upland region of the Midwest contains the largest surface exposure of North America's ancient core, the **Canadian Shield**. The shield is composed almost entirely of metamorphic rock that is 1.6 to 2.6 billion years old. Its composition would normally preclude it from containing fossils, as the heat and pressure associated with metamorphism would typically destroy any original fossil remains, but this region contains significant evidence of ancient life! The Earth's first photosynthesizers have been implicated in aiding the creation of the **banded iron formations** throughout the region. **Stromatolites** provide some of the earliest direct fossil evidence for life on Earth, and they can be found in northern Minnesota and Michigan's Upper Peninsula (*Figure 3.2*).

Stromatolites are formed by mats of single-celled **cyanobacteria**—as the bacteria reproduce, new generations form new layers on top of the older mats, also trapping sediment. After many generations, the layers form a dome above the surface of the seafloor. The sediment stuck in these structures makes them fairly robust and easily preserved, some of them surviving despite the fact that even the *youngest* rocks in this region are 1.6 billion years old.

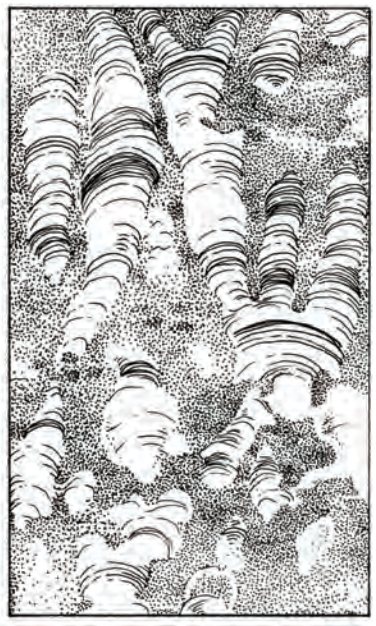


Figure 3.2. Precambrian stromatolites, about 1–2 billion years old, from northern Minnesota. About 4.5 cm (1.75 inches) wide.

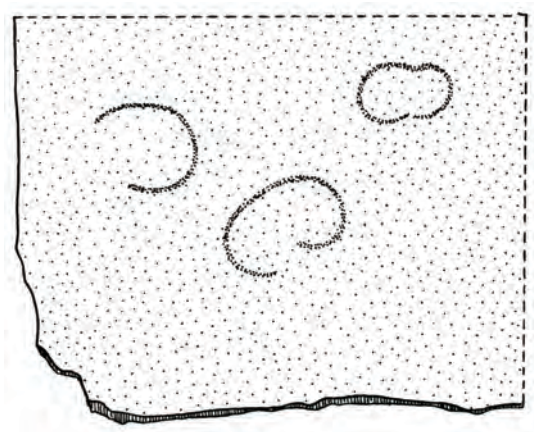


Figure 3.3. Grypania. *Possibly one of the oldest known multicellular fossils. About 2.1 billion years old from Marquette County, Michigan. Each fossil is about 1.5 cm (0.6 inches) across.*

Region 1

Mesozoic • *a geologic time period that spans from 252 to 66 million years ago.*

Cenozoic • *the geologic time period spanning from 66 million years ago to the present.*

Pleistocene • *a subset of the Quaternary, lasting from 2.5 million to about 11,700 years ago.*

banded iron formation • *rocks with regular, alternating thin layers of iron oxides and either shale or silicate minerals.*

cyanobacteria • *a group of bacteria, also called "blue-green algae," that obtain their energy through photosynthesis.*

3 Fossils

Regions 1–2

protists • *a diverse group of single-celled eukaryotes.*

shale • *a dark, fine-grained, laminated sedimentary rock formed by the compression of successive layers of silt- and clay-rich sediment.*

chert • *a sedimentary rock composed of microcrystaline quartz.*

Precambrian • *a geologic time period that spans from the formation of Earth (4.6 billion years ago) to the beginning of the Cambrian (541 million years ago).*

ice age • *a period of global cooling of the Earth's surface and atmosphere, resulting in the presence or expansion of ice sheets and glaciers.*

The Upper Peninsula of Michigan is home to fossils of *Grypania spiralis* (*Figure 3.3*), which many experts think may be filaments of algae appearing as spirals on rock that is about 2.1 billion years old. These fossils are very important because if they are the oldest examples of multicellular organisms, then they are also the first **eukaryotes**. Before eukaryotes, all life consisted of single-celled, **prokaryotic** organisms, which were similar to bacteria in that their cells were small and had no organelles. This means that if *Grypania* is indeed the first eukaryote, it is a very early relative of all plants, fungi, animals, and **protists**.

Banded iron formations consist of repeated, thin layers (a few millimeters to a few centimeters in thickness) of silver to black **iron** oxides, either **magnetite** (Fe_3O_4) or **hematite** (Fe_2O_3), alternating with bands of iron-poor **shales** and **cherts**, often red in color, of similar thickness, and containing thin layers of iron oxides. They are not fossils in the strictest sense, yet they are important evidence for the **Precambrian** life of the region located around the northern edge of Lake Superior.

See Chapter 1: Geologic History for more about banded iron formations.

Although the details of their formation are still not completely understood, it is thought that banded iron formations formed when the oceans on the early Earth were anoxic and contained significant quantities of dissolved iron. With the evolution of photosynthesis, increasing amounts of oxygen were released as waste products. This oxygen combined with dissolved iron to form insoluble iron oxides, which precipitated out of solution to form layers. Eventually, all the readily available iron was used up, and oxygen levels became too high for the cyanobacteria to survive, so their population plummeted. In their absence, iron was allowed to build up in the water again, creating a band of iron-poor rock to be deposited. With a renewed buffer against oxygen, the photosynthesizers could rebound, and the cycle repeated itself, creating the regular bands that give the rock its name. Today, banded iron formations are a crucial source of iron ore.

No younger rock is preserved in the Superior Upland portion of the Canadian Shield, but **ice age** fossils found in this region are discussed near the end of this chapter.

Fossils of the Central Lowland
Region 2

The Paleozoic is well represented in the Central Lowland region of the Midwest, from the Cambrian through the Pennsylvanian periods. Together, fossils from across the region record some of the most important chapters in life's story. The Central Lowland's fossils take us on a journey from when complex organisms first became abundant, through the development of reefs and other recognizable components of marine ecosystems, to the invasion of land. To the west, a few **Cretaceous** fossils of giant marine reptiles and **sharks** may be found. Terrestrial

fossils from the most recent ice age, beginning just two million years ago, have also been discovered in every state in the Midwest, preserved in sediment left by the **glaciers**.

Cambrian

The Cambrian period is represented in the Central Lowland by an irregular strip that cuts east and west through Wisconsin, crossing into neighboring parts of Minnesota and Michigan. The beginning of this period is marked by the relatively sudden appearance of an unprecedented diversity of creatures. Within a span of roughly 30 million years, all of the major animal groups that we know today, such as mollusks, **arthropods**, **echinoderms**, and vertebrates, appeared within the Earth's oceans. This time of rapid diversification and evolution is known as the "Cambrian Explosion." These new kinds of animals interacted with each other and their environments radically in new ways. It was during this time that animals quickly evolved a suite of innovations, including mobility, vision, and hard mineralized parts.

While the Cambrian period was the beginning of complex life, its cast of characters is very unlike the animals of today. Cambrian-aged rocks in Wisconsin and Minnesota preserve the hard parts of **trilobites** (*Figure 3.4*), **brachiopods**, trace fossils of worms, algae, and jellyfish, and the mysterious **hyoliths** (*Figure 3.5*). Hyoliths are animals with cone-shaped shells that existed throughout the Paleozoic Era. Their affinities to other animals are uncertain, with some scientists classifying them as mollusks and others placing them in their own phylum. The Krukowski Quarry in central Wisconsin reveals an extraordinary fossil assemblage of Cambrian marine invertebrate trackways and jellyfish in cream-colored **sandstone** that looks like it formed on a beach.

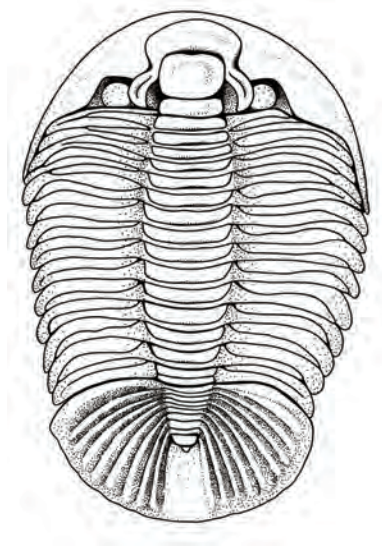


Figure 3.4. Trilobite. Dikelocephalus. *Length about 2 cm (1 inch).*

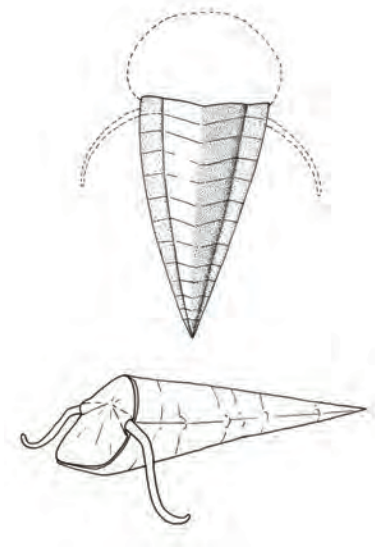


Figure 3.5. Hyolithid. About 1–2 cm (less than an inch) long.

Region 2

Cretaceous • *a geologic time period spanning from 144 to 66 million years ago.*

glacier • *a body of dense ice on land that does not melt away annually and has sufficient mass to move under its own weight.*

echinoderm • *members of the Phylum Echinodermata, which includes starfish, sea urchins, and crinoids.*

trilobite • *an extinct marine invertebrate animal characterized by a three-part body and a chitinous exoskeleton divided longitudinally into three lobes.*

brachiopod • *a marine invertebrate animal characterized by upper and lower calcareous shell valves joined by a hinge, and a crown of tentacles (lophophore) used for feeding and respiration.*

3 Fossils

Region 2

Ordovician • *a geologic time period spanning from 485 to 443 million years ago.*

Devonian • *a geologic time period spanning from 419 to 359 million years ago.*

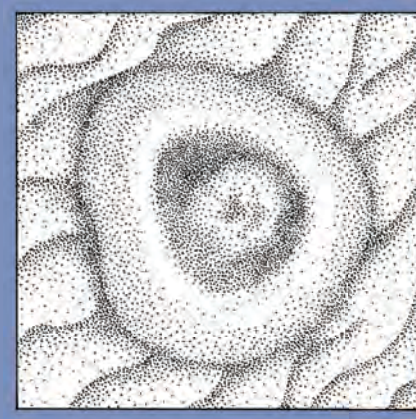
ice sheet • *a mass of glacial ice that covers part of a continent and has an area greater than 50,000 square kilometers (19,000 square miles).*

bryozoan • *a marine or freshwater colonial invertebrate animal characterized by an encrusting or branching calcareous skeleton from which multiple individuals (zooids) extend from small pores to filter-feed using crowns of tentacles (lophophores).*

The Krukowski Quarry

The Krukowski Quarry, near Mosinee, Wisconsin, is a locality famous for its unique preservation of trace fossils from a 510-million-year-old beach. Fossilized trackways found there give paleontologists clues about the organisms and the way they moved around under the shallow water. Amazingly, the quarry also contains fossilized traces of scyphozoan jellyfish. Preservation of such soft creatures is rare enough, but these are both the oldest and, at a diameter of up to 50 centimeters, several times larger than any other fossil jellyfish! At a time when few animals had hard parts, these jellyfish were likely top predators. Their extraordinary preservation seems to indicate that these unfortunate individuals had become stranded on the beach, long before any life (except perhaps bacteria) had colonized land.

Climactichnites. ***The maker of this trackway is unknown, but may have been a mollusk. Each trackway is about 10 cm (4 inches) wide. The trackways can extend for many meters.***



Jellyfish impression from the Cambrian of Wisconsin. Impression is about 30 cm (1 foot) in diameter.

Ordovician to Pennsylvanian

Trilobites and brachiopods, which had dominated the Cambrian period, expanded somewhat in diversity and abundance in the post-Cambrian. As the Paleozoic Era progressed, they were joined by many other new or expanding groups of animals. Many of these were **filter feeders**. Trilobites (which probably fed on seafloor mud) developed defenses against threats from new kinds of predators and competitors: spines, acute vision, and the ability to swim or burrow.

Filter feeding **describes a method of consumption characterized by passing water through a filtering structure that traps food. The water may then be expelled and the food digested. This strategy is employed by a wide range of animals today, from clams and krill to flamingos and whales.**

Ice ages occurred at the ends of both the **Ordovician** and **Devonian** periods, dramatically affecting life in the then-tropical Central Lowland by sequestering water in polar **ice sheets**. This caused dramatic changes in sea level, which resulted in devastating mass extinctions, allowing new successions of organisms to come to the fore.

Ordovician fossils are found in all seven Midwestern states. Life in the tropical sea that covered much of the central United States at the time experienced a burst of diversity, which increased fourfold compared with that of the Cambrian. Beginning in the Ordovician and expanding through the rest of the Paleozoic, great reefs were formed by organisms like **bryozoans**, corals, algae, and sponges, which are found in rocks in the Central Lowland region. These reefs played a major role in forming the ecosystems that were also home to straight-shelled **cephalopods** (*Figure 3.6*), trilobites (*Figure 3.7*), **bivalves, gastropods, crinoids**, **graptolites** (*Figure 3.8*), brachiopods (*Figures 3.9–3.11*), and fish (*Figure 3.12*). By the Devonian, fish had become increasingly prominent and diverse. Meanwhile, plants and arthropods had begun to populate the hitherto barren land.

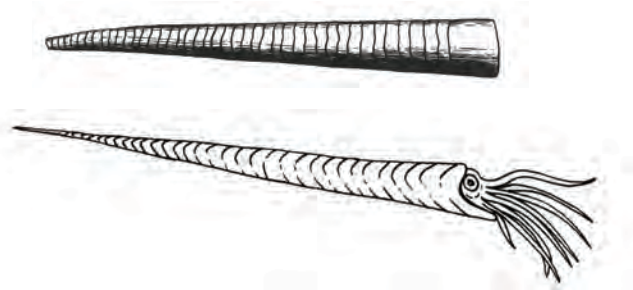


Figure 3.6: Straight (orthocone) nautiloid, shell and animal reconstruction. These animals reached lengths of more than 4 meters (12 feet), making them among the largest invertebrate animals that ever lived. Specimens 30–90 cm (1–3 feet) long are frequently found.

Region 2

cephalopod • *a marine invertebrate animal characterized by a prominent head, arms and tentacles with suckers, and jet propulsion.*

bivalve • *a marine or freshwater invertebrate animal characterized by right and left calcareous shells (valves) joined by a hinge.*

gastropod • *a marine, freshwater, or terrestrial invertebrate animal characterized by a single, coiled, calcareous shell, a muscular foot for gliding, and internal asymmetry caused by torsion.*

crinoid • *a marine invertebrate animal characterized by a head (calyx) with a mouth surrounded by feeding arms.*

graptolite • *an extinct colonial invertebrate animal characterized by individuals housed within a tubular or cup-like structure.*

3 Fossils

Region 2

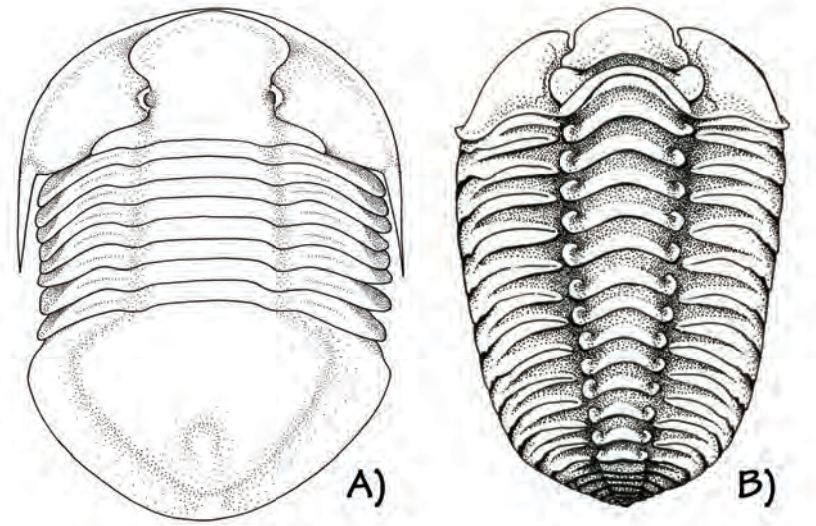


Figure 3.7: Ordovician trilobites. A) Isotelus maximus*, state fossil of Ohio. This species reached more than 30 cm (1 foot) long. B)* Calymene celebra*, state fossil of Wisconsin. About 2 cm (1 inch) long.*

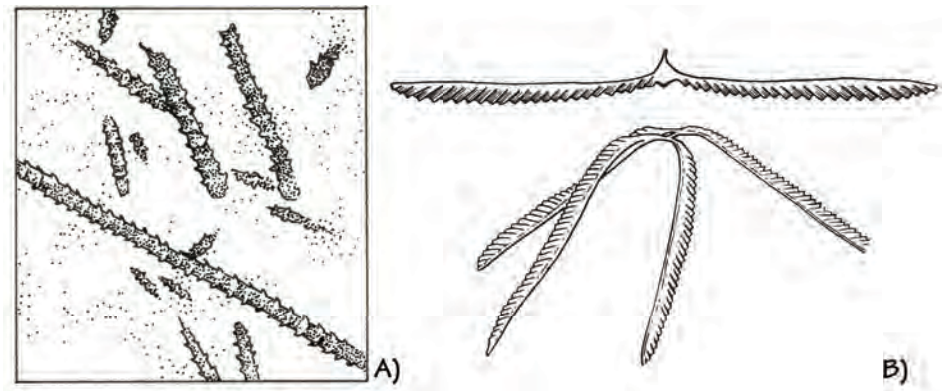


Figure 3.8: Graptolites. A) Specimen with many fragments of colonies of Climacograptus*. B) Restorations of what graptolite colonies may have looked like when they were alive, floating in the water. Graptolite specimens are 2–5 cm (1–2 inches) long*

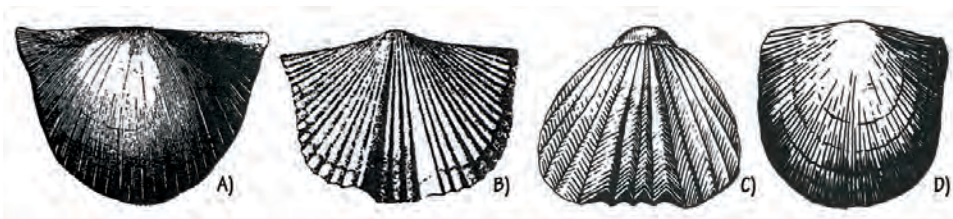


Figure 3.9: Ordovician brachiopods from Ohio and Minnesota. A) Strophomena incurvata*. B)* Platystrophia biforata*. C)* Rhynchotrema capax*. D)* Rafinesquina alternata*. Each about 4 cm (1.5 inches) wide.*

Region 2

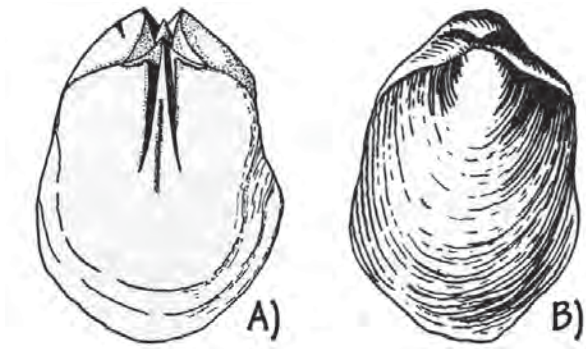


Figure 3.10: The Silurian brachiopod Pentamerus *is often preserved as an internal mold. A) The "slots" show the location of supports for internal organs that extended into the interior of the shell. These strange-looking fossils are sometimes called "pig's feet." B) The exterior of the shell. Specimens are about 2 cm (1 inch) long.*

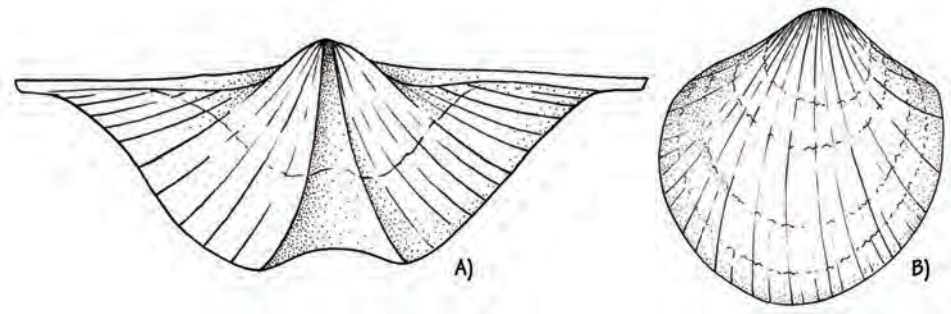


Figure 3.11. Devonian brachiopods from Iowa. A) Platyrachella *sp. [about 8 cm (3 inches) wide]. B)* Atrypa devoniana *[about 3.5 cm (1.5 inches) wide].*

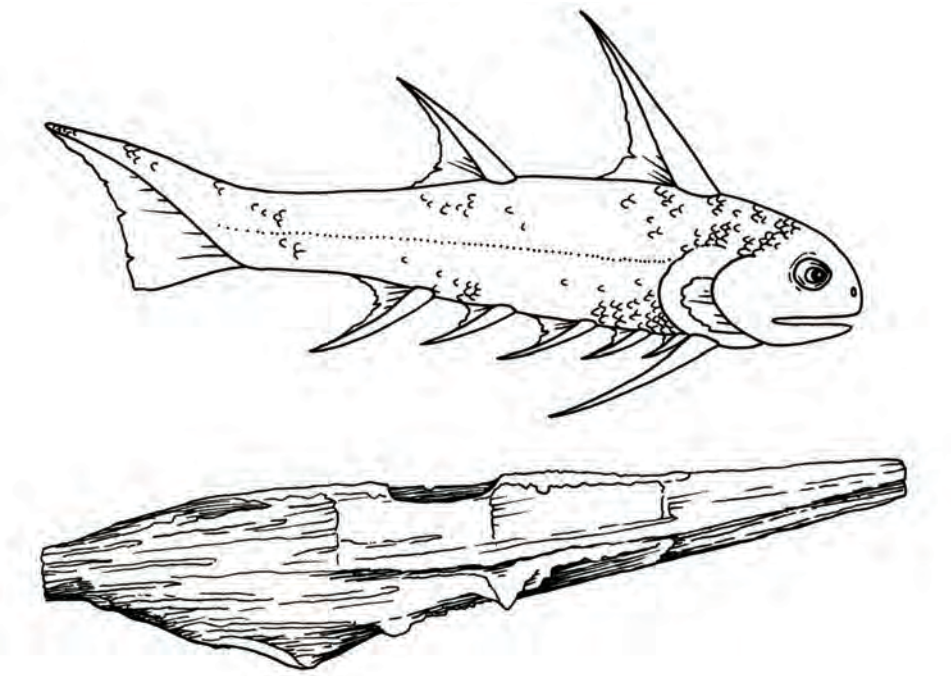


Figure 3.12: Silurian acanthodian fish reconstruction and spine. These fish reached lengths of up to 30 cm (1 foot). Spines are 5–10 cm (2–4 inches).

3 Fossils

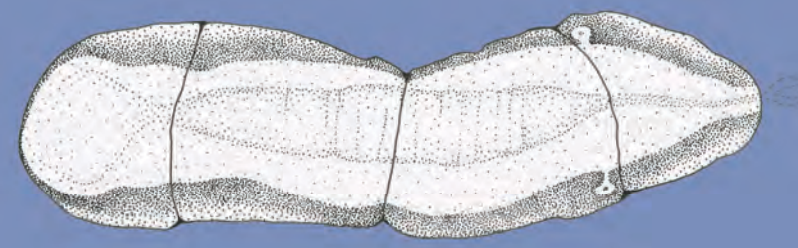
Region 2

lagerstätte • *fossil deposit containing animals or plants that are preserved unusually well, sometimes even including the soft organic tissues.*

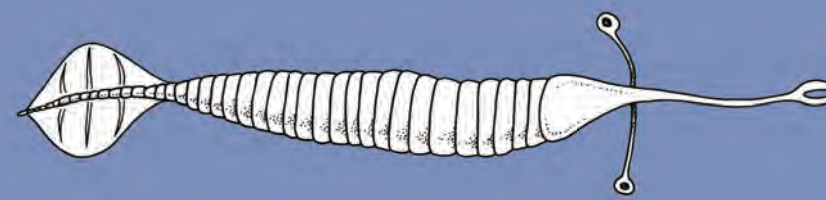
concretion • *a hard, compact mass, usually of spherical or oval shape, found in sedimentary rock or soil.*

Mazon Creek

The Mazon Creek *lagerstätte* is a fossil deposit of Pennsylvanian age exposed in coal mines in northeastern Illinois. It's hematite concretions (or nodules) preserve hundreds of fossil plant and animal species in beautiful detail,(both terrestrial and marine), with many found nowhere else in the world. Among the amazing fossils of Mazon Creek is Illinois' state fossil, the Tully Monster or *Tullimonstrum*, an unusual invertebrate that is thought to have swum using its three-finned tail and hunted using its eight-toothed proboscis to bring prey to the mouth. Its place on the tree of life is uncertain, though some scientists suspect it is a mollusk. Without the exceptionally preserved specimens at Mazon Creek, this soft-bodied predator would be unknown to science. Tully Monsters reached lengths of up to 30 cm (1 foot), but most specimens are less than half that length.



A fossil specimen of Tullimonstrum gregarium***, the state fossil of Illinois.***



A reconstruction of the Tully Monster in life.

During the **Mississippian** and Pennsylvanian, the expansion and contraction of glaciers far to the south caused sea levels to fluctuate. In the Central Lowland, these periods produced **cyclothems**, which are cycles of alternating marine and terrestrial rocks, often including **coal**. By that time, the first vertebrates had crawled onto the land, joining numerous arthropods that already lived in expansive, swampy forests. In the ocean, brachiopods, trilobites, and reef-builders were decimated by the mass extinction at the end of the Devonian.

Reef Builders

Through the **Silurian** and Devonian periods, reefs expanded across the shallow sea that covered the Midwest. While these reefs performed ecological functions similar to those of modern coral reefs, many of the animals that constructed them were very different. Now-extinct tabulate corals, like *Halysites* (*Figure 3.13*) found in Ohio, formed elaborate honeycomb-like colonies. Bryozoans (*Figure 3.14*) are an entire phylum of colonial marine animals, and during the Paleozoic, their erect, branching skeletons formed vast thickets that are fossilized in the Ordovician rock around Cincinnati. Michigan's state rock, the Petoskey Stone, is actually a colonial rugose coral of the genus *Hexagonaria (Figure 3.15*), a reef-builder that is also the namesake of Coralville, Iowa. Other rugose corals were solitary—composed of only one coral polyp (*Figure 3.16*). All tabulate corals were colonial.

***Colonial* corals live in colonies of hundreds or even thousands of individuals that are attached to one another.**

***Solitary* corals live independently, as single isolated polyps.**

The Cedar Valley Group in Iowa yields abundant remains of Devonian reefs composed of layered sponges called **stromatoporoids** (*Figure 3.17*). The mass extinction event at the end of the Devonian left bryozoans as the major reef-building group until the Mesozoic.

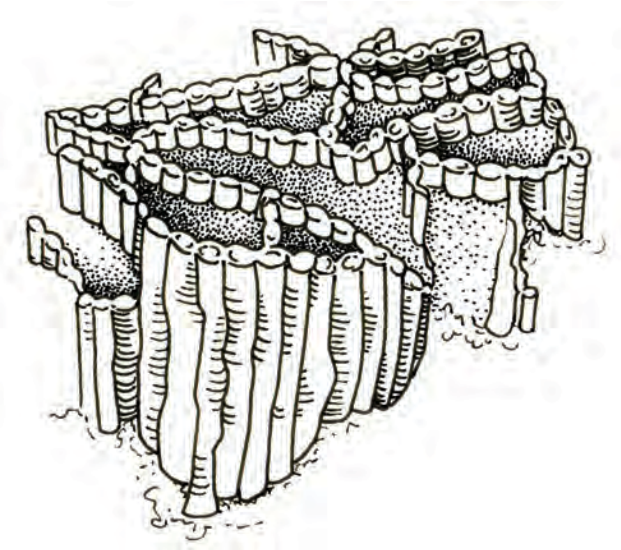


Figure 3.13: Tabulate coral, Halysites *sp. About 10 cm (4 inches) across.*

Region 2

Mississippian • *a subperiod of the Carboniferous, spanning from 359 to 323 million years ago.*

cyclothem • *alternating sequences of marine and non-marine sedimentary rocks, usually including coal, characterized by their light and dark colors.*

coal • *a combustible, compact black or dark-brown carbonaceous rock formed by the compaction of layers of partially decomposed vegetation.*

Silurian • *a geologic time period spanning from 443 to 419 million years ago.*

stromatoporoid • *a type of calcareous sponge that acted as an important reef-builder throughout the Paleozoic and the late Mesozoic.*

3 Fossils

Region 2

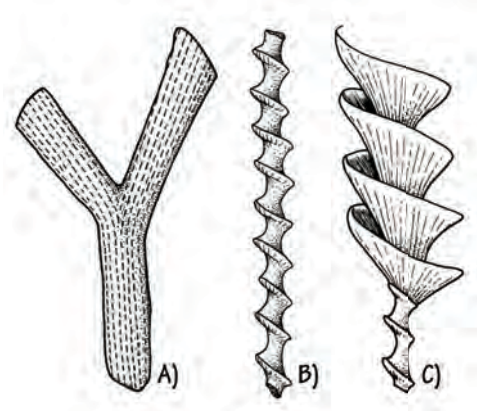


Figure 3.14: Bryozoans. A) Rhombopora *sp., Ordovician. About 5–10 cm (2–4 inches) long. B)* Archimedes *sp., Carboniferous.* Archimedes *colonies consisted of a screw-shaped axis, with a spiral fan connected to the "threads" of the screw. The tiny bryozoan animals lived in chambers on the fan. In some localities, thousands of these "fossil screws" cover the ground. They are usually less than an inch long. C)* Archimedes *life reconstruction.*

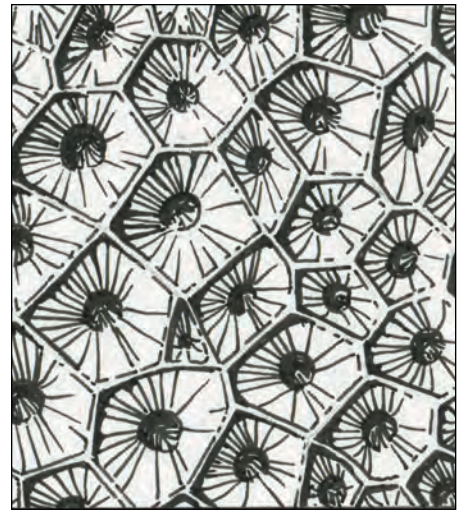


Figure 3.15: Surface of the colonial rugose coral Hexagonaria*, Devonian. When polished, this fossil is called the Petoskey Stone, the state rock of Michigan.* Hexagonaria *colonies were sometimes bowling ball-sized; most Petoskey stones are the size of ping pong balls. Individual corallites are about 12 mm (0.4 inches) in diameter.*

Figure 3.16: A solitary rugose, or "horn" coral. Some horn corals reached lengths of 20 cm (8 inches), but most were less than 2 cm (about 1 inch) long.

Figure 3.17: Stromatoporoid sponge. About 30 cm (1 foot) across.

Region 2

Fishes and Filter-Feeders

Sharks trace their lineage to the Ordovician, more than 420 million years ago, and they became increasingly diverse throughout the remainder of the Paleozoic Era. Ohio's Cleveland Shale preserves specimens of the well-studied primitive shark *Cladoselache* (*Figure 3.18*). This shark was relatively common during the late Devonian and possessed an interesting blend of primitive and derived characteristics. Superficially, its body looked like that of a modern shark—but the 1.2-meter-long (4-foot-long) *Cladoselache* had a terminal mouth (rather than a mouth somewhat under the "nose" as in modern sharks), almost no scales**,** and no **claspers**—leaving scientists to wonder how they reproduced.

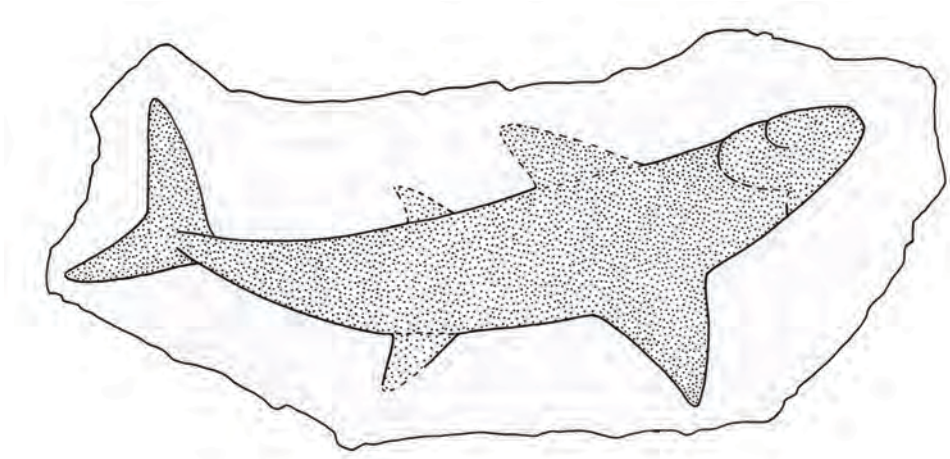


Figure 3.18: Cladoselache*, a shark about 1.2-meter-long (4-foot-long).*

The Devonian saw fishes explode in diversity, from tiny scavengers to huge hunters. The 9-meter-long (30-foot-long) *Dunkleosteus* (*Figure 3.19*) did not have a bony internal skeleton, but its head was covered in bony armor. While remains of its soft parts, including its unarmored rear two-thirds, have yet to be discovered, the plates of numerous specimens have been found in the Cleveland Shale of Ohio, and the Cleveland Museum of Natural History houses the largest known specimens. The plates that formed the jaw functioned as huge blades, rubbing against each other to stay sharp as the fish chomped its prey: sharks, other fish, and large invertebrates. Along with *T. rex*, it is estimated to have had one of the most powerful bites in the history of life, and it was the apex predator of the late Devonian seas. Despite its apparent advantages, it and all of its its **placoderm** kin became extinct at the end of the Devonian.

The Mississippian is sometimes known as the "Age of Crinoids" because of the increase in the abundance and diversity of crinoids (*Figure 3.20*), as well as starfish, **edrioasteroids** (*Figure 3.21*), urchins, and other echinoderms (*Figure 3.22*) during this time. Sites near Crawfordsville, Indiana are world-famous for containing abundant specimens of more than 60 well-preserved crinoid species. While it is common to find stem pieces of crinoids throughout the Midwest, discoveries of the head, or **calyx**, are much rarer. Crawfordsville provides a wealth of unbroken lengths of stem and calyxes from these filter-feeding animals.

clasper • *an anatomical structure used by sharks for mating.*

placoderms • *an extinct class of heavily armored fishes.*

edrioasteroids • *an extinct class of echinoderms that had a simple, cushion-shaped body and five arms.*

calyx • *the head of a crinoid.*

3 Fossils

Region 2

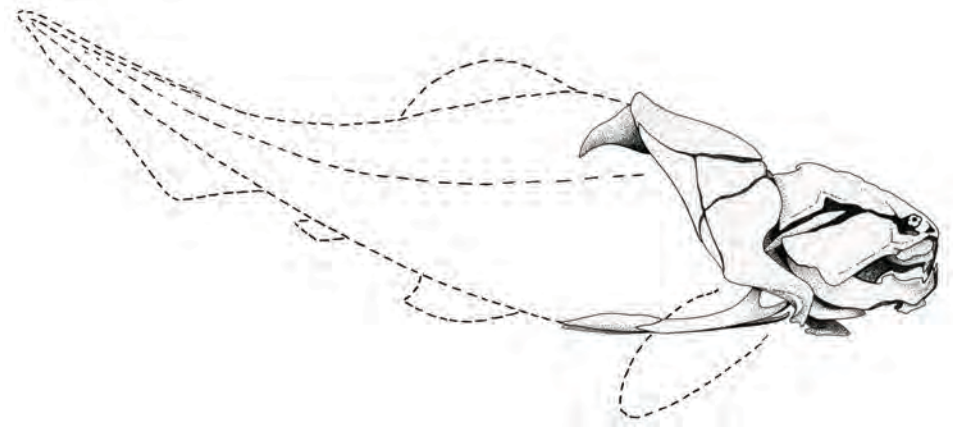


Figure 3.19: Dunkleosteus. The dotted lines show inferred shape of the unpreserved part of the body. Total length was probably about 9 meters (30 feet).

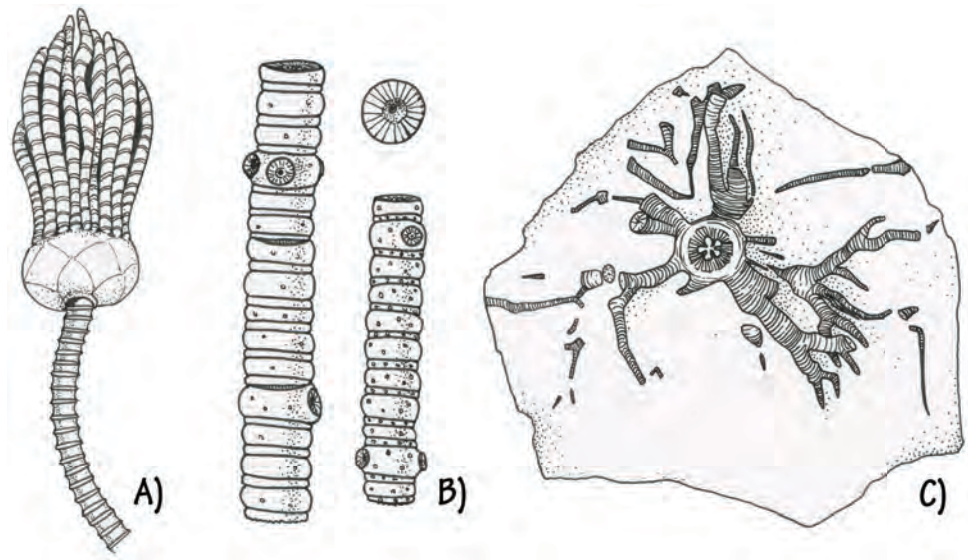


Figure 3.20: Crinoids from the Mississippian of Indiana. A) Crown and stem; about 15 cm (6 inches) long. B) Stem fragments. C) Holdfast; about 8 cm (3 inches) across.

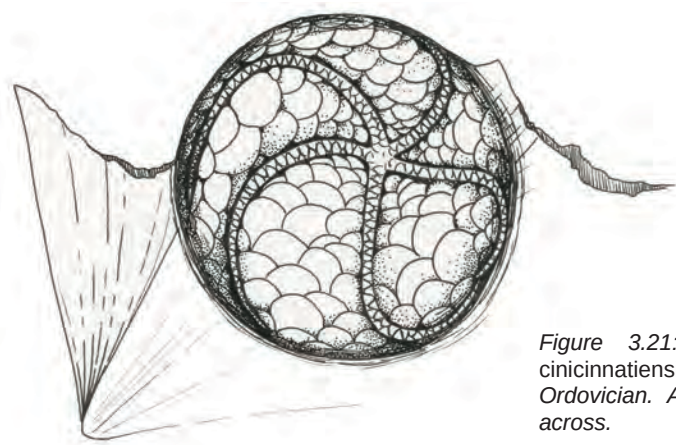


Figure 3.21: Edrioasteroid, Isorophus cinicinnatiensis, *attached to a bivalve shell. Ordovician. About 2 cm (about 1 inch) across.*

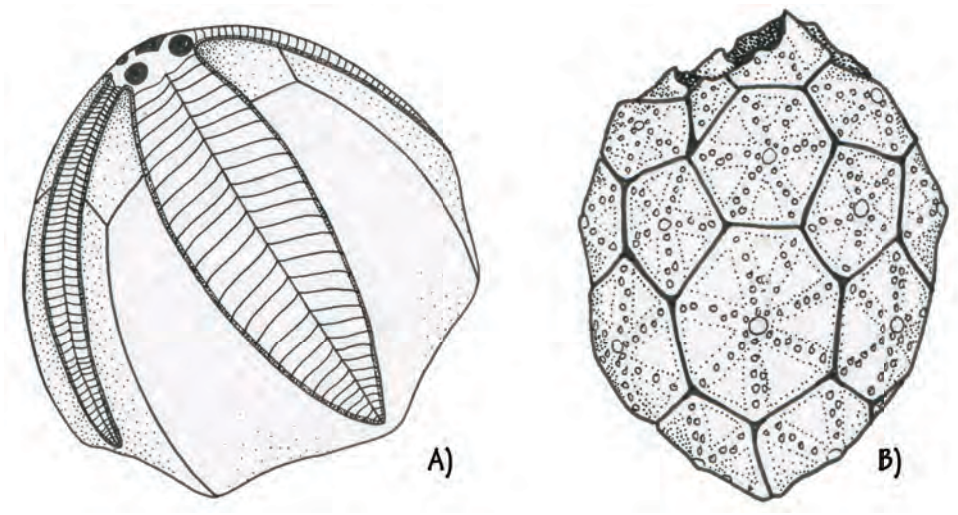


Figure 3.22: A) Blastoid. Pentremites *sp. 1–2 cm (about .75 inches) long. B) Cystoid.* Caryocrinites *sp. 1–2 cm (about .75 inches) long.*

Land Ho!

After the appearance of land plants in the Ordovician and the presence of established forests by the beginning of the Mississippian, much of the Midwest's land through the remainder of the Paleozoic consisted of swampy deltas. Wetland forests were home to a tangle of **lycopod** and **sphenopsid trees**, early **conifers**, the now-extinct **seed ferns** (*Figure 3.23*), and other plants. By the Pennsylvanian, huge lycopods like *Lepidodendron* (*Figure 3.24*) and other plants grew thickly on the Midwestern landscape. (Lycopods survive today but only as very small plants on the forest floor, sometimes called "ground pines.") These ancient ecosystems are sometimes called "coal swamps" because the stagnant, wet environments in which they thrived protected huge volumes of vegetation from decomposing. As the decaying plant matter accumulated for tens of millions of years, it formed thick, extensive deposits of coal underlying much of the Central Lowland as well as the parts of the Inland Basin.

Cretaceous

While an expansive record of Paleozoic life is present in the Midwest, the Mesozoic Era is relatively poorly represented. Still, Cretaceous-aged rocks in Minnesota, Iowa, and southern Illinois provide some glimpses into life during this time period.

A *tree* is any woody perennial plant with a central trunk. Not all trees are closely related; different kinds of plants have evolved the tree form through geological time. The trees of the Paleozoic were more closely related to club mosses or ferns than they were to today's trees.

To learn more about how the Midwest's coal is exploited for fuel today, see Chapter 7: Energy.

Region 2

lycopod • *an extinct, terrestrial tree characterized by a tall, thick trunk covered with a pattern of diamond-shaped leaf scars, and a crown of branches with simple leaves.*

sphenopsid • *a terrestrial plant characterized by hollow, jointed stems with reduced, unbranched leaves at the nodes.*

conifer • *a woody plant bearing cones that contain its seeds.*

seed fern • *an extinct terrestrial plant characterized by a fern-like appearance, but bearing seeds instead of spores.*

3 Fossils

Region 2

dinosaurs • *a group of terrestrial reptiles with a common ancestor and thus certain anatomical similarities, including long ankle bones and erect limbs.*

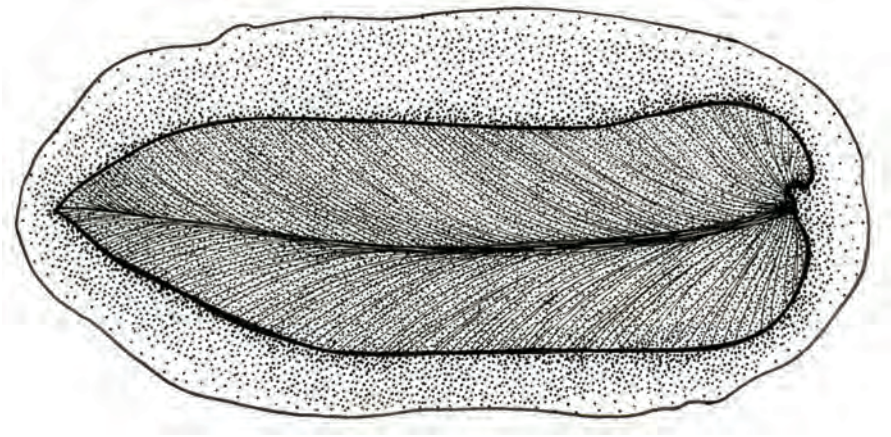


Figure 3.23: Neuropteris*, a seed fern in a Mazon Creek nodule. Length about 9 cm (4 inches).*

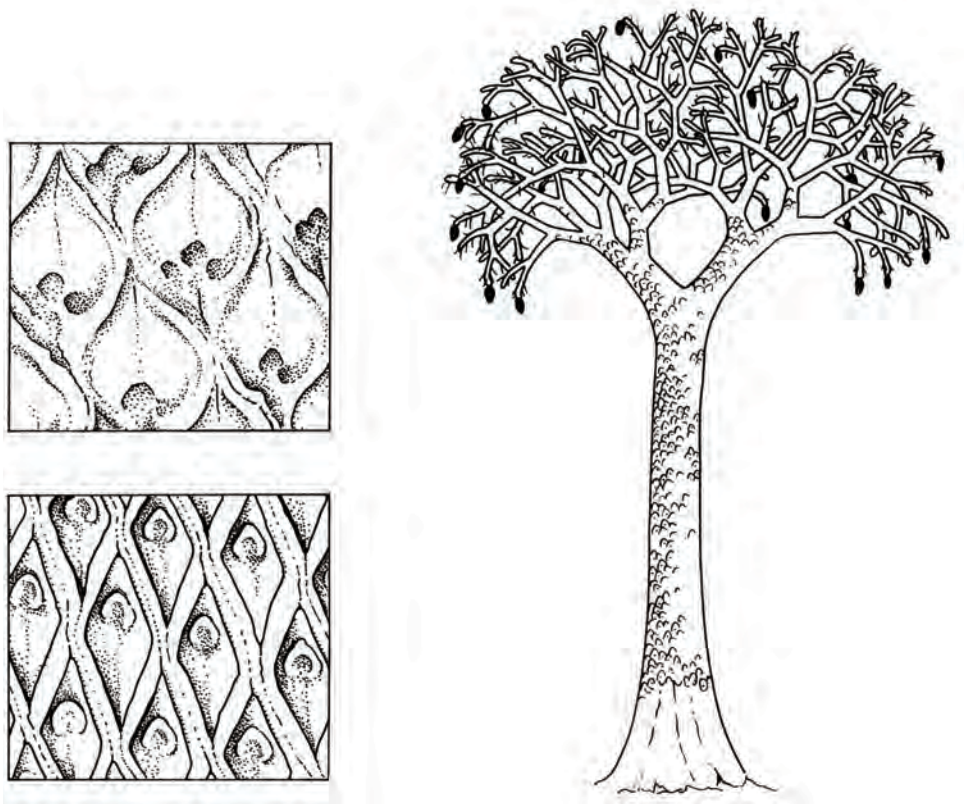


Figure 3.24: Lepidodendron*. Left: close-ups of leaf scars on the trunk. Right: reconstruction of the entire tree, which reached 30 meters (100 feet) in height.*

A few **dinosaur** fossils have been found in riverine deposits in the lower parts of the Dakota Formation of Minnesota and Iowa (and also in nearby Kansas and Nebraska). Later layers were deposited under marine conditions, as the huge Western Interior Seaway invaded farther into the upper Midwest. In Iowa, these marine strata (including the Graneros, Greenhorn, Carlile, and Niobrara formations) have yielded a few bones of large sea reptiles called **plesiosaurs**

Region 2

Early Vertebrates

A Mississippian-aged site near Delta, Iowa has yielded some of the best-preserved examples of early land-dwelling vertebrates. For example, *Whatcheeria deltae*, described in 1985, is considered a "reptile-like amphibian," having some anatomical features more like those of amphibians and some more like those of *amniotes*. This animal measured about 1 meter (3 feet) long, and dates to around 340 million years ago.

(*Figure 3.25*). In southern and western Minnesota, similar layers have produced shark teeth (*Figure 3.26*), sea turtles, and scattered marine invertebrates, including ammonites (*Figure 3.27*), bivalves, and microfossils (**foraminifera**). Abundant fossil leaves of flowering broadleaf plants have been found in south-central Minnesota (*Figure 3.28*).

These Midwestern fossils provide a snapshot of the dramatic changes in marine fauna once the Paleozoic ended. The once-dominant trilobites were now extinct, brachiopods and bryozoans had become very scarce, and tabulate and rugose corals, once abundant, were gone. Reefs remained a crucial ecosystem for marine life, but they were now formed almost exclusively by **scleractinian corals** and bizarre rudist clams. Other mollusks like ammonoid cephalopods, snails, and clams were also much more diverse and abundant than they had

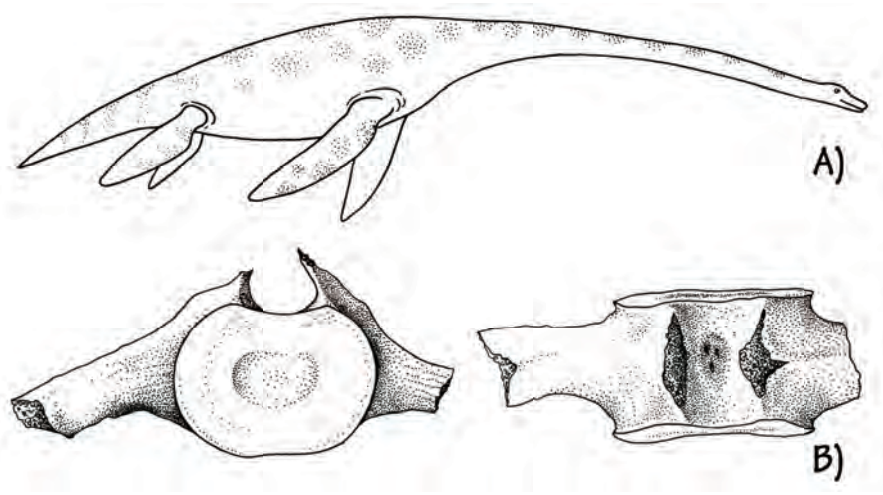


Figure 3.25: A) Reconstruction of a plesiosaur in life. Some plesiosaurs reached 15 meters (50 feet) long. B) Plesiosaur vertebrae. About 20 cm (8 inches) across.

amniotes • *the group of tetrapods distinguished from amphibians by the development of an egg capable of maturing entirely out of water.*

plesiosaur • *a group of extinct long-necked Mesozoic marine reptiles.*

foraminifera • *a class of aquatic protists that possess a calcareous or siliceous exoskeleton.*

scleractinian coral • *a colonial or solitary marine invertebrate animal characterized by an encrusting calcareous skeleton enclosing polyps that capture prey with small tentacles equipped with stinging cells (nematocysts).*

3 Fossils

Region 2

mosasaurs • *extinct, carnivorous, marine vertebrate reptiles characterized by a streamlined body for swimming, a powerful fluked tail, and reduced, paddle-like limbs.*

ichthyosaurs • *extinct Mesozoic marine reptiles that were probably similar in size and habitat to the toothed whales, dolphins, and large sharks of today.*

pterosaurs • *extinct flying reptiles with wingspans of 30 cm to 15 meters.*

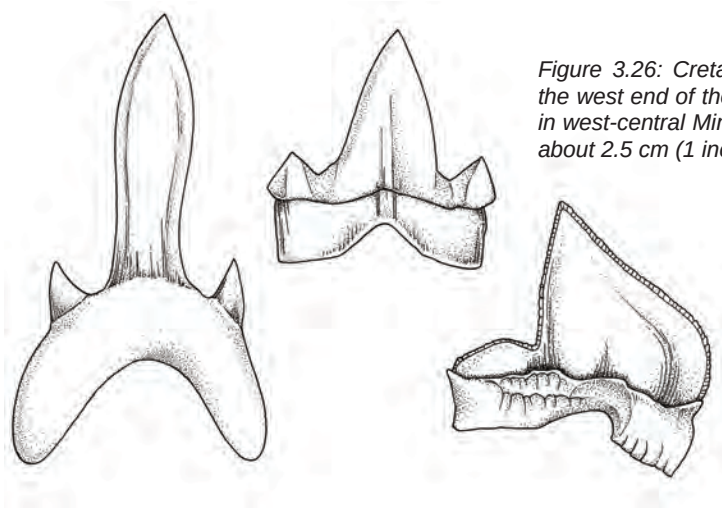


Figure 3.26: Cretaceous shark teeth from the west end of the Minnesota River valley in west-central Minnesota. Tooth on far left about 2.5 cm (1 inch) long.

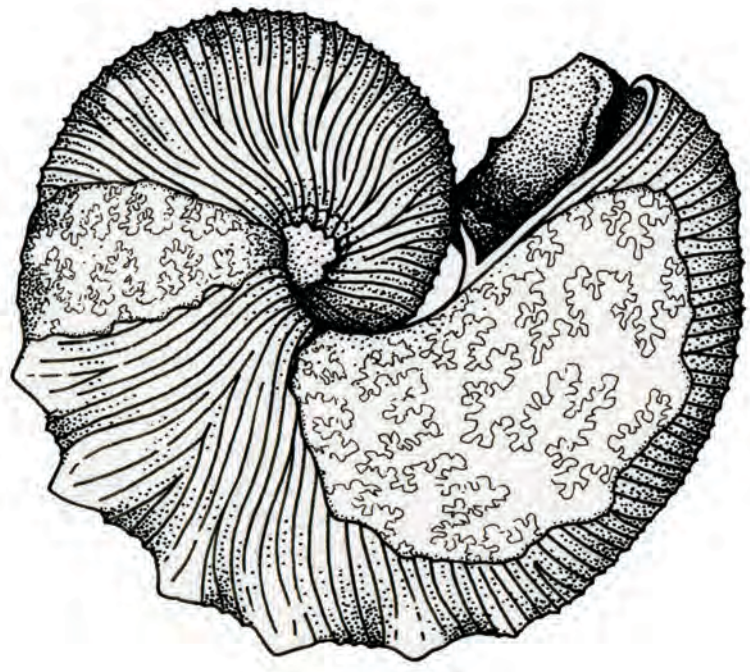


Figure 3.27: Jeletzkytes*, a scaphitid ammonite cephalopod. Fossils of these animals have been found in Cretaceous rocks in southern Minnesota. Specimen is about 10 cm (4 inches) across.*

been during the Paleozoic. Life on land also changed dramatically: by the mid-Cretaceous, flowering plants and insects had suddenly become ubiquitous. In addition to dinosaurs, which dominated the land, various other kinds of reptiles, including **mosasaurs, ichthyosaurs,** and plesiosaurs, dominated the sea, and **pterosaurs** as well as the first birds filled the air. The oceans teemed with newly abundant and diverse bony fish, sharks, and rays.

Figure 3.28: Cretaceous fossil leaves from Minnesota. A) Metasequoia *sp. Leaves about 0.25 cm (0.1 inch) long. B)* Magnolia *sp. Leaf about 12 cm (5 inches) long.*

Ice Age Fossils in Pleistocene Deposits

About 2.6 million years ago, permanent ice sheets formed in the Northern hemisphere, marking the beginning of the **Quaternary** period (which extends to the present). During this time, glaciers repeatedly scraped their way southward across the Midwest and melted back northward. Some gaps in the fossil record are due to glaciers eroding bedrock away. Fossils from the Quaternary are found either in pond and stream sediment dating from the receding of glaciers, or they exist as isolated tooth or bone fragments found in glacial **till**. Some important animal fossils are preserved in Pleistocene caves. The glaciers began to retreat from the Midwest about 15,000 years ago, leaving behind the landscape we see today as well as the sediment in which we find fossils and sometimes human artifacts.

As the glaciers melted away from the Midwest, some of the geographic features they created filled with water and formed many of the lakes and ponds present in those states today. Even the **Great Lakes** were formed by ice sheets, though their geologic underpinnings go back much farther. Many smaller bodies of water left by the glaciers have since been filled with sediment and are virtually invisible at the surface. When flooding or construction exposes these pond sediments, the organisms preserved in them are suddenly revealed. Nearly all glacial-age ponds contain a rich fossil record of small freshwater mollusks, pieces of wood, pollen, and seeds, many of which increased over time as plant communities recolonized land freed from the ice. Since the shape of pollen indicates the kind of plant it came from, the pollen record can give a detailed account of how vegetation moved into an area as the **climate** changed. As plants returned, so did large animals: large vertebrate remains include those of **mammoths** (*Figure 3.29*), **mastodons** (*Figure 3.30*), giant beavers, peccaries, tapirs, foxes, bears, seals, deer, caribou, bison, and horses. Numerous mastodon skeletons have been found throughout the Midwest, especially in Michigan, Illinois, Ohio, and Indiana.

Region 2

Quaternary • *a geologic time period that extends from 2.6 million years ago to the present.*

till • *unconsolidated sediment that is eroded from the bedrock, then carried and eventually depositied by glaciers as they recede.*

Great Lakes • *the largest group of freshwater lakes on Earth (by total surface area and volume), located on the US-Canadian border.*

climate • *a description of the average temperature, range of temperature, humidity, precipitation, and other atmospheric/hydrospheric conditions a region experiences over a period of many years (usually more than 30).*

3 Fossils

Region 2

The remains of a mastodon that is two-thirds complete was discovered near Boaz, Wisconsin. The bones were found with a stone spearhead, suggesting the huge animals were hunted by humans. The point and reconstructed skeleton are housed at the University of Wisconsin in Madison.

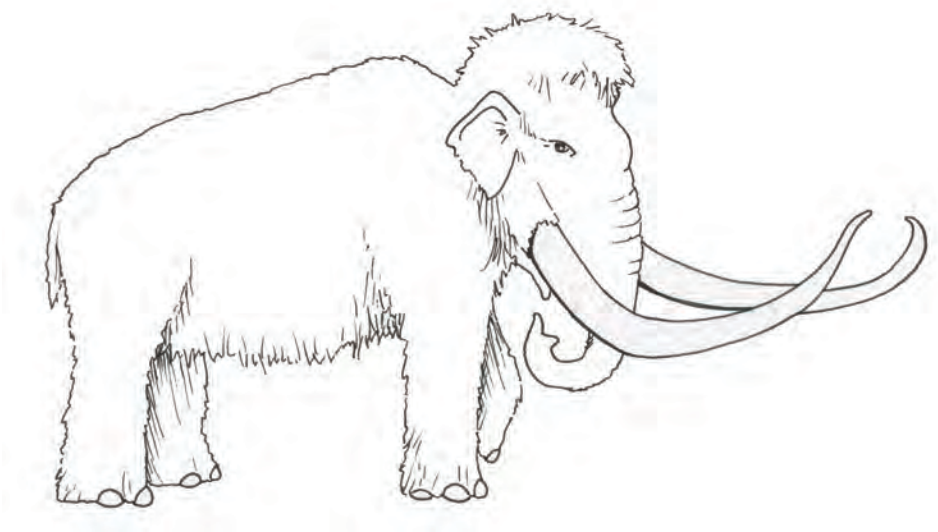


Figure 3.29: A Pleistocene woolly mammoth, Mammuthus primigenius.

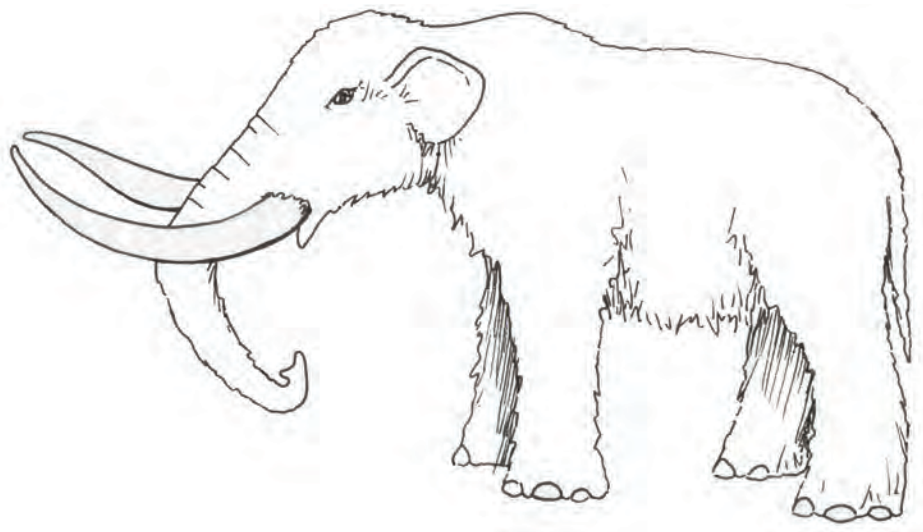


Figure 3.30: A Pleistocene mastodon, Mammut americanum.

Region 2

Mastodons & Mammoths

Among the most common Pleistocene vertebrate fossils in the Midwest are those of mastodons and mammoths. People frequently confuse these two kinds of ancient elephants (or, more technically, proboscideans). Both were common during the Pleistocene, but they had different ecological preferences and are usually found separately. 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. 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 two species' ecological differences. Mastodons preferred to bite off twigs of brush and trees, while mammoths preferred tough siliceous grasses. Thus, mastodon teeth are more suitable for cutting, while mammoth teeth are more suitable for grinding.

A mammoth tooth, suitable for grinding grass and softer vegetation. About 25 cm (almost a foot) long.

A mastodon tooth, suitable for chewing twigs and tree leaves. About 20 cm (8–9 inches) long.

Region 3

Permian • *the geologic time period lasting from 299 to 252 million years ago.*

Carboniferous • *a geologic time period that extends from 359 to 299 million years ago.*

Fossils of the Inland Basin
Region 3

Much of the Inland Basin is located in the Northeastern United States, but the parts extending into the Midwest span nearly 100 million years of the Paleozoic Era. A band of rocks running from extreme northeastern to central southern Ohio are from the Devonian period, while most of the Inland Basin, including eastern Ohio, and the southern portions of Indiana and Illinois, is composed of younger Mississippian and Pennsylvanian rocks. The youngest bedrock of the region, from the **Permian** period, is located in the southeasternmost part of Ohio.

When the rocks of this region were formed, much of central North America was covered by a relatively shallow, tropical, inland sea. The late Devonian- and early **Carboniferous**-aged rocks of the Inland Basin contain the fossils of a diverse marine ecosystem. Younger Carboniferous rocks show the environment transitioning from the shallow sea to an environment of extensive deltas and swamps. These rocks contain the fossils of organisms from freshwater and forest ecosystems.

Marine Environments in the Devonian

During the Devonian period, communities of corals, crinoids, bryozoans, brachiopods, and mollusks thrived in the warm sea that covered most of the Inland Basin. Fish and sharks were also common, but their fossils are much rarer. At the time, what is now the Midwest was just south of the equator. Sediment was washed from the rising Acadian mountain range far to the east, carried down rivers, and deposited into the sea where it settled to the bottom and occasionally buried the organisms living there. Driftwood from the world's first terrestrial forests, made up mostly of lycopod trees, sometimes found its way to the seafloor to be preserved alongside the shells of the animals living there.

The Carboniferous and a Transition to Terrestrial Environments

At the end of the Devonian, fluctuations in sea level caused the water to retreat from portions of the Inland Basin. By the beginning of the Carboniferous, the landscape was dominated by deltas and swampy forests, similar to what occurred in the Central Lowland region at this time. In addition to plants, the fossils of freshwater fish, sharks, early amphibians, and arthropods can be found in coal beds from the late Carboniferous. At the beginning of the Permian, Ohio was a terrestrial environment where lake and river deposits preserved horsetail and fern fossils. These are the youngest fossils found in the Inland Basin's bedrock.

State Fossils

Illinois
Tullimonstrum gregarium (Pennsylvanian “Tully Monster”) (page 68)

Indiana
Indiana has no state fossil.

Iowa
Iowa has no state fossil.

Michigan
Mammut americanum (American Mastodon) (*Figure 3.30*)

Minnesota
Minnesota has no state fossil.

Ohio
Isotelus maximus (Ordovician trilobite) (*Figure 3.7A*)

Wisconsin
Calymene celebra (Ordovician trilobite) (*Figure 3.7B*)

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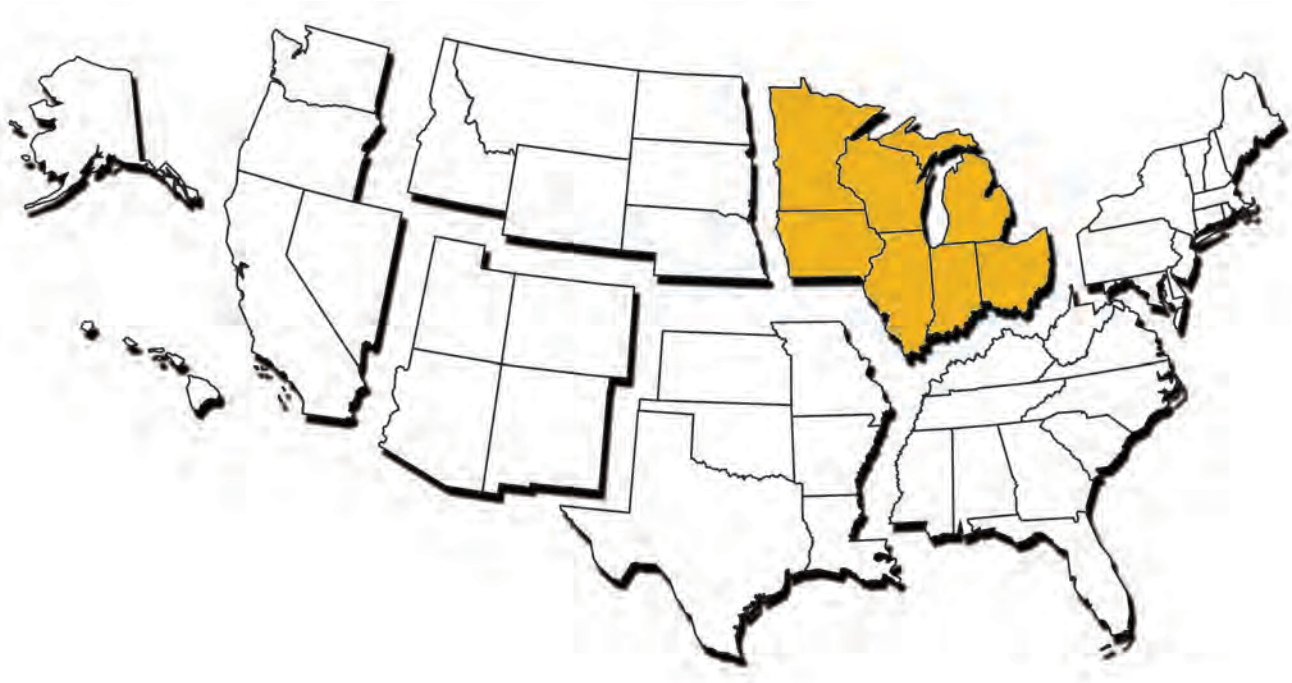
The **Teacher-Friendly** Guide™

to the Earth Science of the Midwestern US



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On the back cover: Blended geologic and digital elevation map of the Midwest. Each color represents the age of the bedrock at the surface. Adapted from Barton, K.E., Howell, D.G., Vigil, J.F., *The North America Tapestry of Time and Terrain*, US Geological Survey Geologic Investigations Series I-2781, http://pubs.usgs.gov/imap/i2781.