



Chapter 1: Geologic History of the Midwestern US: The Big Picture

Geologic history is the key to this Guide and to understanding the story recorded in the rocks of the Midwest. By knowing more about the geologic history of our area, you can better understand the type of rocks that are in your own backyard and why they are there. We will look at the history of the Midwest as it unfolds: as a series of major events over the past one billion years that created and shaped the area. These events will act as the framework for the topics to follow and will shed light on why our region looks the way it does!

Geologic Time

How did geologists come up with the timeline for the history of the Earth? Over the course of many years and through the combined work of geologists around the world, the geologic time scale was developed (*Figure 1.1*). No rock record in any one place contains the complete sequence of rocks from Precambrian to present. Geology as a science grew as geologists studied individual sections of rock. Gradually, geologists discovered evolutionary successions of fossils that helped them determine the relative ages of groups of rocks. Rock units were then correlated with similarly aged rock units from around the world. The names you see for the different periods on the geologic time scale have diverse origins. Time periods were named after dominant rock types, geography, mountain ranges, and even ancient tribes like the Silures of England and Wales, from which the “Silurian period” was derived.

The **geologic time scale** is an important tool used to portray the history of the Earth—a standard timeline used to describe the age of rocks and **fossils**, and the events that formed them. It spans Earth’s entire history and is separated into four principle divisions.

Geologic Time

geologic time scale • a standard timeline used to describe the age of rocks and fossils, and the events that formed them.

fossil • preserved evidence of ancient life, including, for example, preserved skeletal or tissue material, molds or casts, and traces of behavior.

CHAPTER AUTHORS

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Geologic Time

About the Time Scale:

The time scale in The Teacher-Friendly Guides™ follows that of the International Commission on Stratigraphy (ICS). The Tertiary period, though it was officially phased out in 2008 by the ICS, remains on the scale in the Guides, since “Tertiary” is present extensively in past literature. In contrast, the Carboniferous and Pennsylvanian & Mississippian periods all enjoy official status, with the latter pair being more commonly used in the US.

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

lithosphere • the outermost layer of the Earth, comprising a rigid crust and upper mantle broken up into many plates.

asthenosphere • a thin semifluid layer of the Earth, below the outer rigid lithosphere, forming the upper part of the mantle.

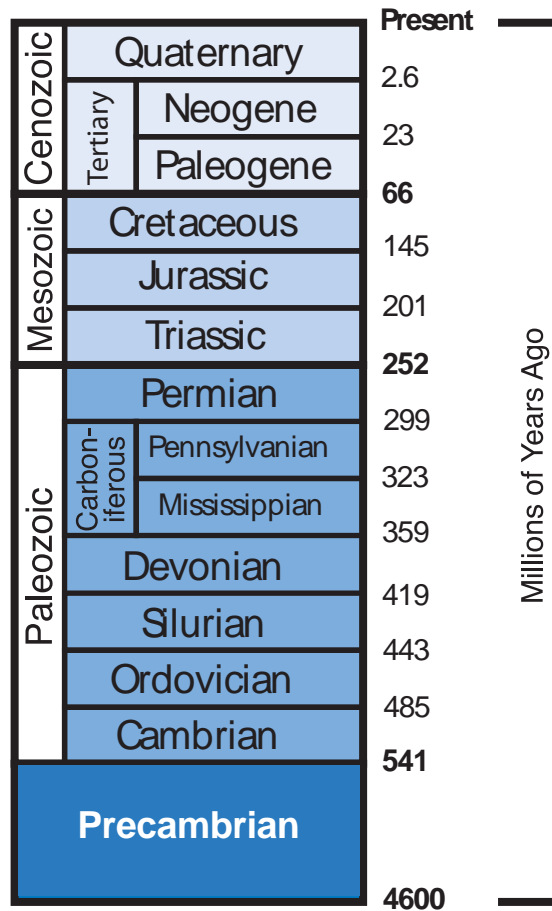


Figure 1.1: The Geologic Time Scale (spacing of units not to scale).

The first of these, the **Precambrian**, extends from about 4.6 billion years ago to 541 million years ago. Little is known about this time period since very few fossils or unaltered rocks have survived. What few clues exist indicate that life first appeared on the planet some 3.9 billion years ago in the form of single-celled organisms.

The second division, the **Paleozoic**, extends from 541 to 252 million years ago. Fossil evidence shows that during this time period, life evolved in the oceans and gradually colonized the land.

The third division, the **Mesozoic** (from 252 to 66 million years ago), is also called the “age of reptiles” since dinosaurs and other reptiles dominated both marine and terrestrial ecosystems. It is also

noteworthy that during this time the last of the Earth’s major supercontinents, **Pangaea**, formed and later broke up, producing the Earth’s current geography.

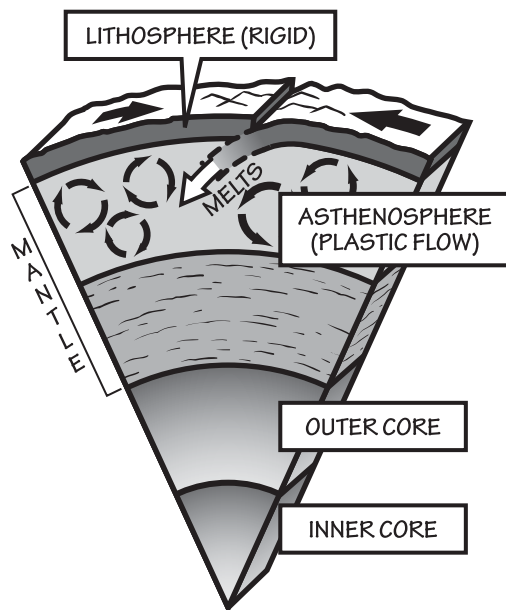
The last and current division, the **Cenozoic**, extends from the **extinction** of the dinosaurs, nearly 66 million years ago, to the present. With the demise of the dinosaurs, mammals became dominant and, subsequently, more diverse and highly developed. We humans don’t come into the picture until the last 2 million years. To get some perspective on this, if the entire geologic time scale were reduced to 24 hours, we wouldn’t come onto the stage until 2 seconds before midnight!

The Earth is dynamic, consisting of constantly moving **plates** that are made of rigid continental and oceanic **lithosphere** overlying a churning, plastically flowing **asthenosphere** (Figure 1.2). These plates are slowly pulling apart, colliding, or sliding past one another with great force, creating strings of **volcanic islands**, new ocean floor, **earthquakes**, and mountains. The continents are likewise continuously shifting position relative to each other. This not only shapes

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the land, but also affects the distribution of rocks and **minerals**, natural resources, **climate**, and life. Scientists can reconstruct what the ancient Earth might have looked like by studying rocks, fossils, and other geologic features.

Figure 1.2: The layers of the Earth include the rigid crust of the lithosphere, which is constantly moving over the plastically flowing asthenosphere.

Geologic Time

plates • large, rigid pieces of the Earth's crust and upper mantle, which move and interact with one another at their boundaries.

volcanic islands • a string of islands created when molten rock rises upwards through oceanic crust.

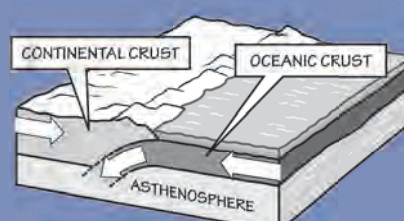
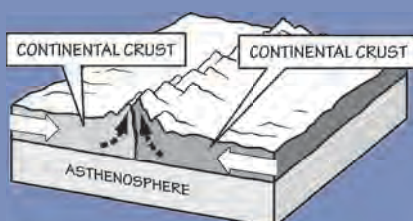
earthquake • a sudden release of energy in the Earth's crust that creates seismic waves.

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

climate • description of the average temperature, range of temperature, humidity, precipitation, and other atmospheric/hydrospheric conditions a region experiences over a period of many years.

Continental and Oceanic Crust

The lithosphere has two types of crust: continental and oceanic. Continental crust is less dense but significantly thicker than oceanic crust. The higher density of the oceanic crust means that when continental crust collides with oceanic crust, the more dense oceanic crust will be dragged (or subducted) under the buoyant continental crust. Although mountains are created at these oceanic/continental crust collisions due to the compression of the two plates, much taller ranges are produced by continental/continental collisions. When two buoyant continental crusts collide, there is nowhere for the crust to go but up! The modern Himalayas, at the collision site of the Asian and Indian plates, are a good example of very tall mountains formed by a collision between two continental crusts.



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Canadian Shield

terrane • a piece of crustal material that has broken off from its parent continent and become attached to another plate.

gneiss • a metamorphic rock that forms from granite or layered sedimentary rock, and is characterized by a striated appearance.

Archean • a geologic time period that extends from 4 billion to 2.5 billion years ago.

The Canadian Shield: Foundation of a Continent

The shape and position of North America has changed dramatically over the last few billion years, and geologic processes continue these changes today. The Earth is estimated to be approximately 4.6 billion years old. The oldest rocks known are located in northern Quebec and date to 4.3 billion years ago. Rocks dating to 4 billion years old are found on almost every continent. In North America they are found exposed at the surface in parts of Canada, composing the **Canadian Shield**, a stable core of the North American continental landmass.

The Canadian Shield is the original core, or **craton**, of the North American continent. It includes much of Greenland, more than half of Canada, and it extends into the Adirondack Mountains of New York and the Superior Upland region of the Midwest. It is an accumulation of smaller plates and **terrane**s that formed over a period of

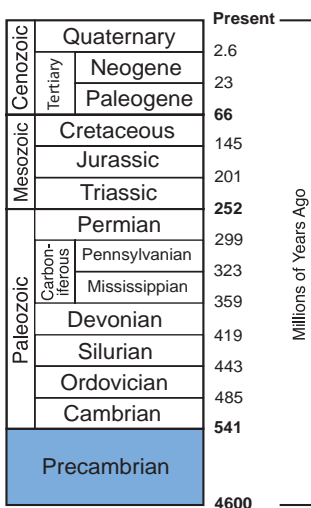
The oldest rocks found on Earth are 4.3-billion-year-old greenstone beds found along the eastern shore of Hudson Bay in northern Quebec. The oldest known materials are 4.4-billion-year-old zircons from Western Australia.

hundreds of millions of years, between 2.5 and 1.25 billion years ago. The shield was the first section of the North American continent to emerge above sea level, and it remains the largest exposure of Precambrian-aged rock in the world.

Seven distinct provinces compose the nucleus that is the Canadian Shield. The Superior Province is found in south central Canada, and it extends into northeastern Minnesota, northern Wisconsin, and the Upper Peninsula of Michigan. Metamorphic **gneisses** exposed within the Minnesota River Valley represent the oldest rocks found in the Midwest, dating back 3.5 billion years. The oldest rocks from Wisconsin are represented by 2.8-billion-year-old gneiss, while Precambrian outcrops in a small area of northwestern Iowa—the Sioux Quartzite in Gitche Manitou State Preserve—date to 1.7 billion years ago. No Precambrian rocks are exposed in Indiana, Illinois, or Ohio (*Figure 1.3*).

Mountain Building 1: The Proterozoic Record

Following the formation of the Superior Province around 2.7 billion years ago during the late **Archean**, the **Proterozoic** of the Midwest was characterized by the deposition and presence of **banded iron formations**. With the evolution of photosynthetic organisms (still single-celled at this time), their waste product, oxygen, was released into the oceans and ultimately the **atmosphere**. The



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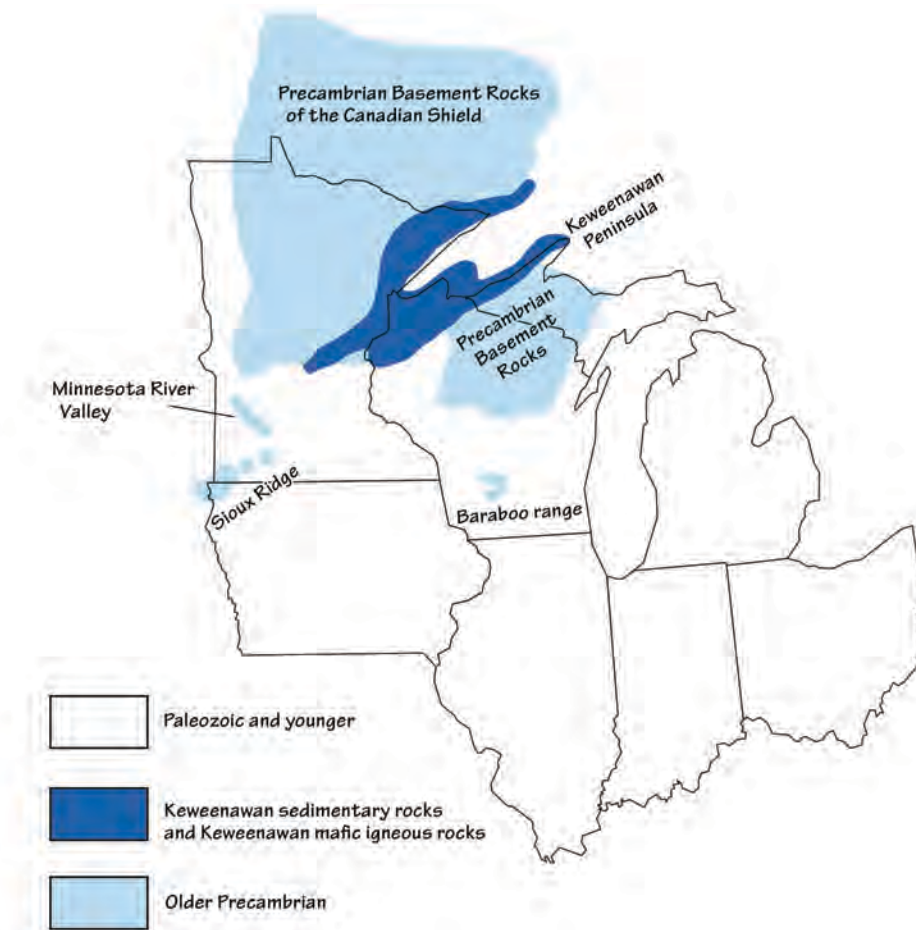


Figure 1.3: Precambrian outcrops within the Midwest.

basement rocks • the foundation that underlies the surface geology of an area, generally composed of igneous or metamorphic crystalline rock.

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

Proterozoic • a geologic time interval that extends from 2.5 billion to 541 million years ago.

atmosphere • a layer of gases surrounding a planet.

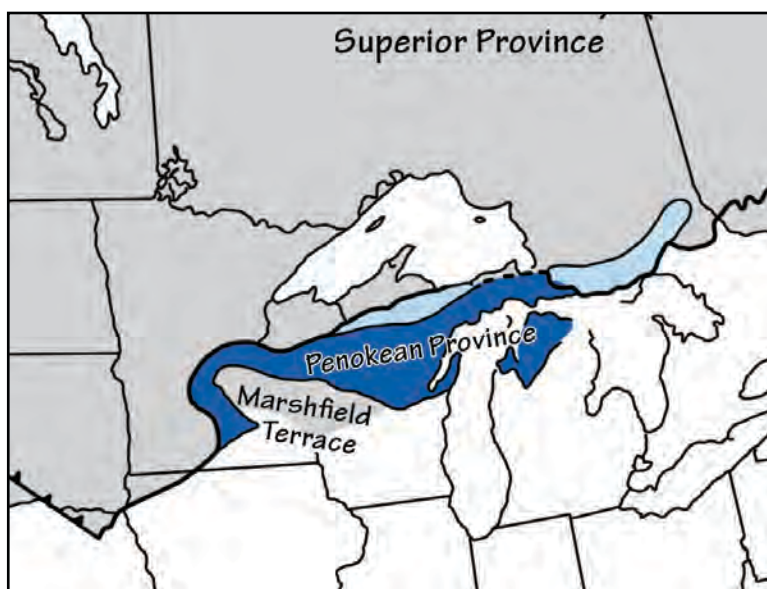


Figure 1.4: The accretion of the Pembine-Wausau island arc and the Marshfield terrane led to the Penokean Orogeny of the Proterozoic.

		Present	
Cenozoic	Quaternary	2.6	
	Tertiary	Neogene	23
		Paleogene	66
Mesozoic	Cretaceous	145	
	Jurassic	201	
	Triassic	252	
Paleozoic	Carboniferous	Permian	299
		Pennsylvanian	323
		Mississippian	359
	Devonian	419	
	Silurian	443	
	Ordovician	485	
Cambrian	541		
Precambrian		4600	

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orogeny • a mountain-building event generally caused by colliding plates and compression of the edge of the continents.

metamorphism • when pre-existing sedimentary, igneous, and metamorphic rocks are exposed to high enough temperature and/or pressure that minerals within the rock recrystallize and realign.

rift • a break or crack in the crust that can be caused by tensional stress as a landmass breaks apart into separate plates.

volcanism • the eruption of molten rock onto the surface of the crust.

oxygen reacted and combined with dissolved iron particles to produce bands of iron oxides such as **hematite** and **magnetite**.

Between 1.8 and 1.9 billion years ago, an **orogenic** event produced the Penokean Mountains, which extended from Minnesota into northern Wisconsin and Michigan. The Penokean Orogeny occurred as the Pembine-Wausau island arc and Marshfield terrane collided from the south, increasing the size of the Superior landmass (*Figure 1.4*). Erosion of the Penokean Mountains led to deposits of **sandstone** along the margin of a shallow sea. Around 1.7 billion years ago, after millions of years of heat and pressure, this sandstone produced the **metamorphic** Sioux Quartzite of Minnesota and Iowa. The Baraboo Quartzite of the Devil's Lake area in central Wisconsin also dates to this time.

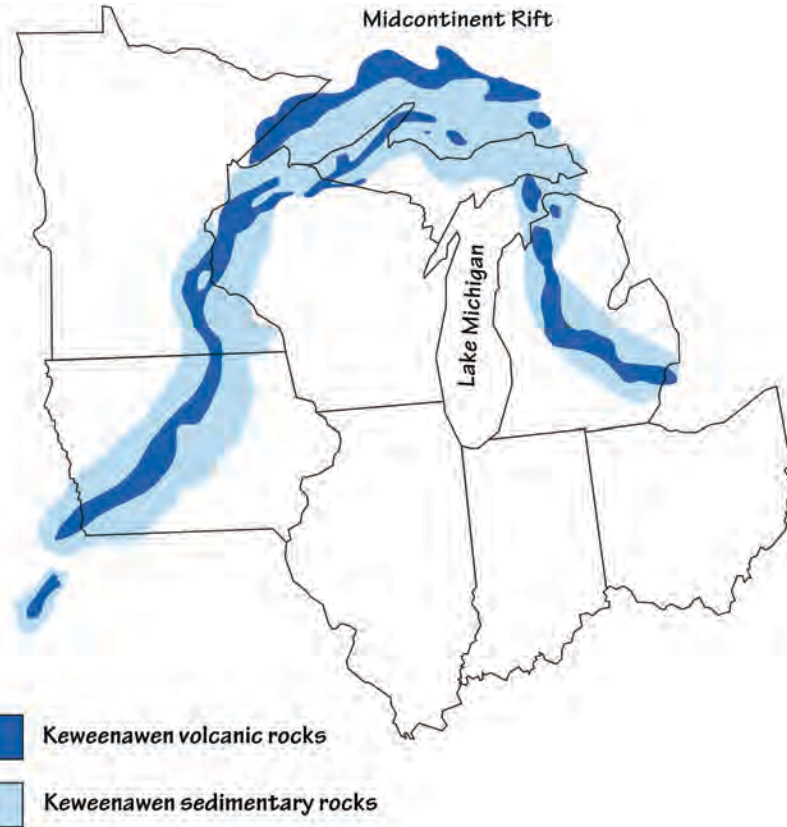


Figure 1.5: Active for 20 million years, a great rift valley extended through the Midwest from today's Lake Superior to Kansas.

Around 1.1 billion years ago, a **rift** valley called the Midcontinental Rift—extending from the eastern edge of modern-day Lake Superior to Kansas—began to split North America apart (*Figure 1.5*). Intense **volcanism** occurred along the rift, producing **igneous** deposits with a thickness of some 7.6 kilometers (25,000 feet). The spreading occurred for 20 million years, after which the rift zone began to sink and was gradually filled with sediment.

		Present
Cenozoic	Tertiary	Quaternary
		Neogene
		Paleogene
Mesozoic		66
	Cretaceous	145
	Jurassic	201
	Triassic	252
Paleozoic		299
	Carboniferous	Permian
		Pennsylvanian
	Mississippian	359
	Devonian	419
	Silurian	443
	Ordovician	485
Cambrian	541	
	Precambrian	4600
		Millions of Years Ago

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Mountain Building 2: the Paleozoic

Overlying the older rock of the Canadian Shield, much of the remaining geologic history of the Midwest records the presence of shallow seas, the formation of the supercontinent Pangaea, and—most recently—the modern **ice age**.

Cambrian deposits are recorded in Wisconsin, Illinois, Minnesota, and Iowa. During this time, shallow seas covered much of the Midwest, with several **transgression** and **regression** episodes recorded as well. Nearly all of what would become North America was located just *south* of the equator at the dawn of the Cambrian, and it drifted within the tropics for most of its existence.

During the middle of the **Ordovician** period, about 470 million years ago, the **Iapetus Ocean** began to close as **Baltica** (proto-Europe) approached the North American plate from the southeast (Figure 1.6). The intense pressure of the colliding plates and islands smashing into the side of North America caused its edge to crumple, crushing and folding it into mountains. This mountain-building event is called the Taconic Orogeny, and the resulting Taconic Mountains stretched from Newfoundland to Georgia, sharing roughly the same location and orientation of the Appalachian Mountains today, but with towering peaks in eastern Canada and New England.

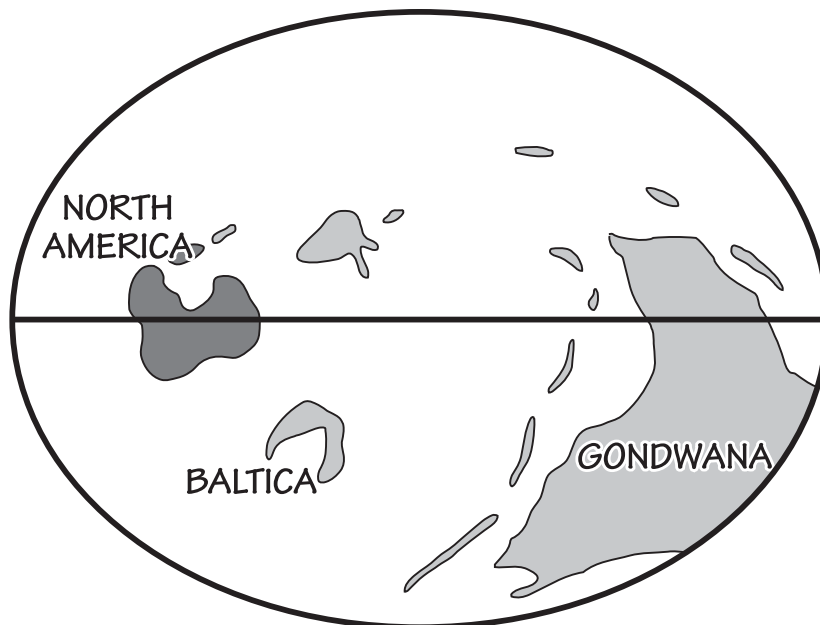


Figure 1.6: Ordovician: 458 million years ago. Shaded areas represent land that was above water.

This folding propagated far to the west, forming waves parallel to the Taconic Mountains themselves that ran roughly southwest to northeast. Nearest the mountains, the **crust** warped downwards from central New York to central North Carolina, creating the **Appalachian Basin**. From western Ohio to Alabama, it was warped up into the **Cincinnati Arch**, and, most distally, down again,

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igneous • derived from the cooling of magma underground or molten lava on the Earth's surface.

transgression • a relative rise in sea level in a particular area, through global sea level rise or subsidence of land.

regression • a drop in sea level.

Iapetus Ocean • the proto-Atlantic Ocean, located against the eastern coast of North America's ancestral landmass before Pangaea formed.

		Present	
Cenozoic	Quaternary	2.6	
	Tertiary	Neogene	23
		Paleogene	66
Mesozoic	Cretaceous	145	
	Jurassic	201	
	Triassic	252	
	Permian	299	
Paleozoic	Carboniferous	Pennsylvanian	323
		Mississippian	359
	Devonian	419	
	Silurian	443	
	Ordovician	485	
Cambrian	541		
Precambrian		4600	

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Michigan Basin • an inland basin centered on Michigan's Lower Peninsula, which formed when Baltica approached North America in the Ordovician.

Illinois Basin • an inland basin centered in the state of Illinois, which formed when Baltica approached North America in the Ordovician.

inland basin • a depression located inland from the mountains, and formed by the buckling (downwarping) of the Earth's crust.

creating the **Michigan** and **Illinois basins**. These formations are prominent features of Midwestern geology. The **inland basins** were flooded by the ocean for nearly all of their existence.

The mountain building ceased around the beginning of the **Silurian**, but the Taconic Mountains still played a major role in the formation of the Midwest. As sediment was eroded from the western side of the Taconic Mountains, deposits spread away, through the Northeast and Midwest, as far west as Wisconsin (Figure 1.7). Thousands of feet of this sediment built up on the floors of the seas that filled the Midwestern basins, and this sediment, along with the millions of generations of marine organisms that lived there, formed the Silurian and **Devonian** bedrock of much of the area.

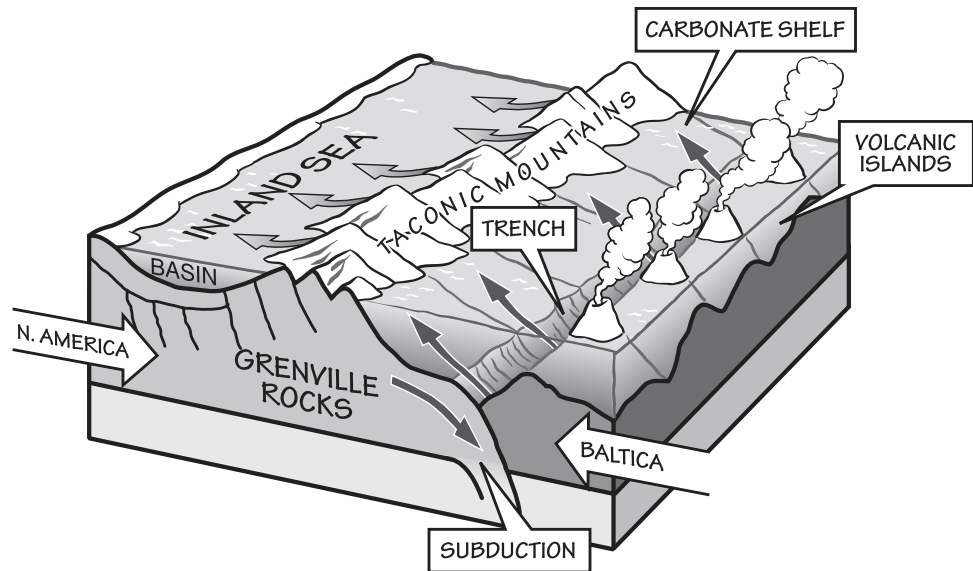


Figure 1.7: Volcanic islands formed where the plates were forced together as the Iapetus Ocean closed. The compression crumpled the crust, forming the Taconic Mountains and shallow inland seas.

		Present
Cenozoic	Quaternary	2.6
	Tertiary	
	Neogene	23
	Paleogene	66
Mesozoic	Cretaceous	145
	Jurassic	201
	Triassic	252
	Permian	299
Paleozoic	Carboniferous	
	Pennsylvanian	323
	Mississippian	359
	Devonian	419
	Silurian	443
	Ordovician	485
	Cambrian	541
	Precambrian	4600
		Millions of Years Ago

For millions of years during the Paleozoic, an inland extension of the Iapetus Ocean covered the eastern half of North America, filling the basins formed by the mountain-building events. The inland ocean was separated from the main Iapetus Ocean by the Taconic and Acadian Mountains.

Sea level rose and fell in this inland sea during the Paleozoic, in part because the convergence of the plates carrying North America and Baltica continued to buckle the inland basin, deepening the ocean. Sediment eroded from the mountains, however, was also filling the inland ocean.

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For about 60 million years, the eastern margin of North America was relatively quiet. The **subduction** of the oceanic Iapetus plate caused volcanic eruptions that occasionally spread ash over the Midwest, but for the most part, the Taconics were slowly eroding. Finally, Baltica collided with North America near the end of the Devonian period, around 380 million years ago, and mountain-building began again, creating the Acadian Mountains. The Acadian Mountains effectively replaced the Taconics, creating a massive range that was similar in location and extent (Figure 1.8). Just as in the Taconic mountain-building period, **compression** from the Acadian continental collision warped the crust downward, reinforcing the inland seas. Sediments eroding from the mountains formed the Catskill Delta, creating a new wedge of sediments stretching into a shallow inland sea; the Devonian and **Mississippian** rocks of Ohio are evidence of this event.

At the time of the Acadian mountain building and subsequent erosion during the Devonian, the Midwest was located at the Equator and experienced a tropical climate (Figure 1.9). Baltica and North America were united as one larger landmass. Africa, South America, India, Australia, Antarctica, and Florida formed a second continent—**Gondwana**—in the southern hemisphere.

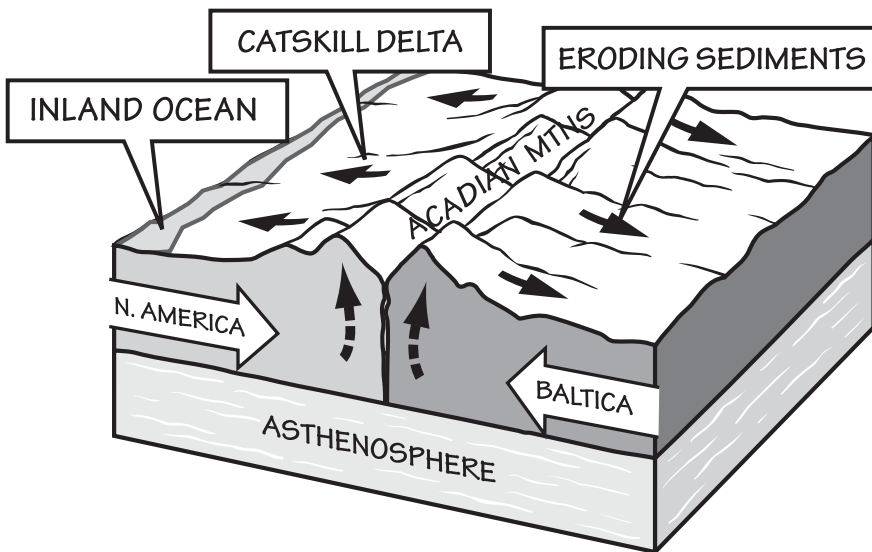


Figure 1.8: The collision of Baltica and North America, which led to the deposition of sediments in the shallow seas of the Midwest.

During the **Carboniferous**, the collision of North America with Gondwana (Figure 1.10) was the genesis of Pangaea. This event also resulted in the formation of both the Appalachian Mountains and, in the South Central region, the Interior Highlands. The interior seaways ultimately regressed from the Midwest.

In the Midwest, Mesozoic-aged rocks are preserved primarily in Minnesota, Iowa, and, to a lesser extent, in Illinois. For the remainder of the Midwest, the Mesozoic was a time of erosion and very little deposition. The rocks that do exist were deposited mainly during the **Cretaceous**. At that time,

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subduction • the process by which one plate moves under another, sinking into the mantle.

compression • forces acting on an object from all or most directions, resulting in compression (flattening or squeezing).

		Present	
Cenozoic	Tertiary	Quaternary	2.6
		Neogene	23
		Paleogene	66
Mesozoic		Cretaceous	145
		Jurassic	201
		Triassic	252
Paleozoic	Carboniferous	Permian	299
		Pennsylvanian	323
		Mississippian	359
		Devonian	419
		Silurian	443
		Ordovician	485
	Cambrian	541	
	Precambrian	4600	

Millions of Years Ago

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Phanerozoic • a generalized term used to describe the entirety of geological history after the Precambrian, from 541 million years ago to the present.

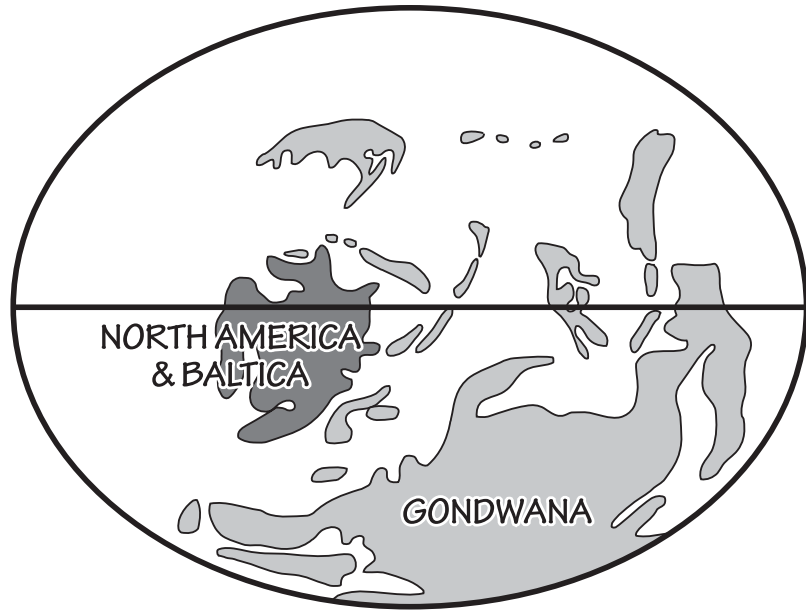


Figure 1.9: The Devonian period globe.

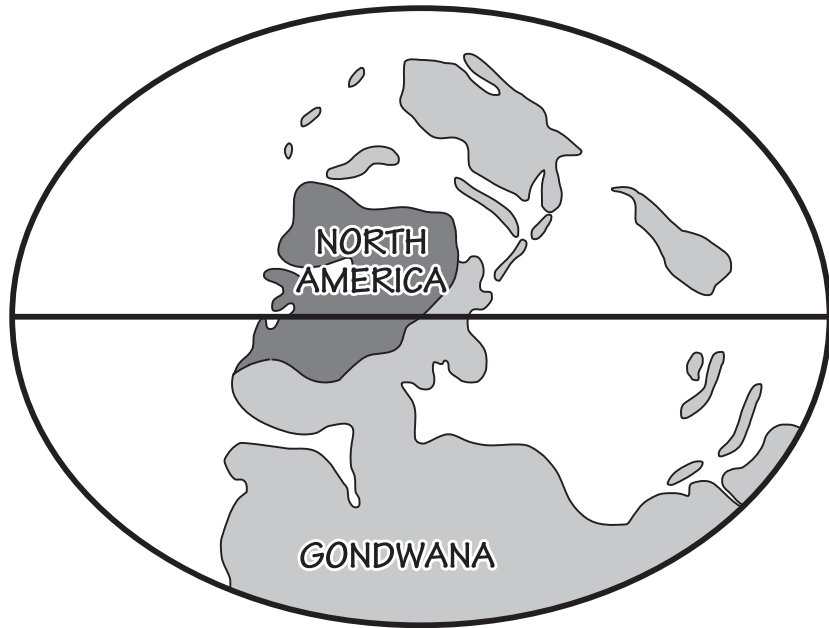


Figure 1.10: Late Carboniferous.

		Present	
Cenozoic	Tertiary	Quaternary	
		Neogene	
		Paleogene	
Mesozoic		66	
	Cretaceous	145	
	Jurassic	201	
Paleozoic	Carboniferous	Triassic	252
		Permian	299
		Pennsylvanian	323
	Mississippian	Devonian	359
		Silurian	419
		Ordovician	443
	Cambrian	485	
	Precambrian	541	
		4600	

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North America was roughly divided into thirds: a western portion, an eastern portion, and a vast seaway inundating the center. This seaway stretched from Utah to the western edge of the Midwest and connected the Gulf of Mexico to the Arctic Ocean (Figure 1.12). Deposits in western Minnesota and Iowa contain a variety of Cretaceous creatures that lived near the shores of the Western Interior Seaway. The early Cretaceous was the first time during the **Phanerozoic** that the Midwest was north of the tropics, approaching its current position.

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Evidence for Pangaea

How do we know that Pangaea (*Figure 1.11*) existed 250 million years ago? Fossil evidence and mountain belts provide some of the clues. For example, the Permian-age fossil plant *Glossopteris* had seeds too heavy to be blown across an ocean. Yet *Glossopteris* fossils are found in South America, Africa, Australia, India, and Antarctica! The mountain belts along the margins of North America, Africa, and Europe line up as well and have similar rock types, an indication that the continents at one time were joined as Pangaea. Despite the discovery of *Glossopteris* and other geologic evidence, the theory of continental drift was not accepted for decades, until the mechanisms of continental movement were discovered and reformulated under the modern theory of plate tectonics. The supercontinent Pangaea existed for approximately 100 million years, reaching its largest size during the Triassic period. During the Jurassic, the landmass began to fragment into the modern continents, slowly moving toward their present-day positions over the following 150 million years.

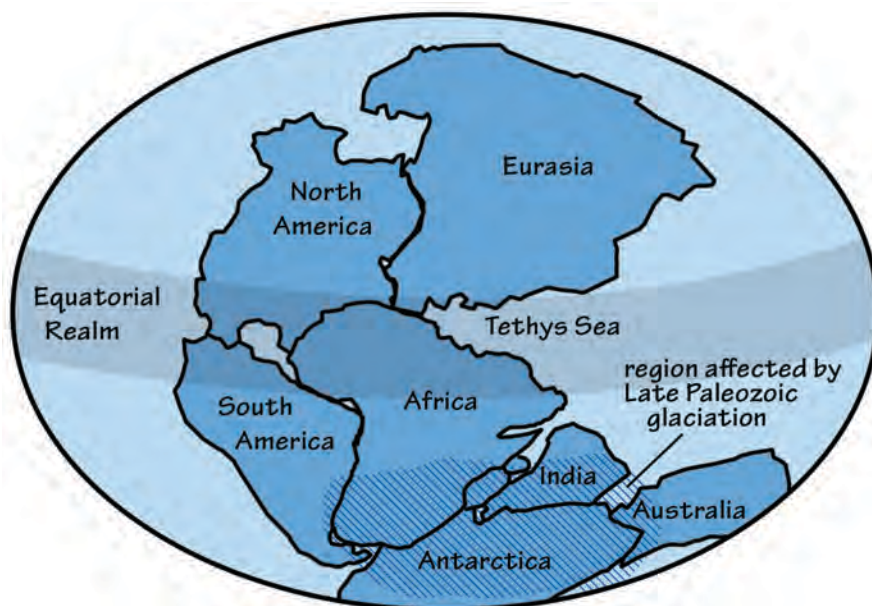


Figure 1.11: Pangaea during the late Paleozoic Era.

		Present	
Cenozoic	Quaternary	2.6	
	Tertiary	Neogene	23
		Paleogene	66
Mesozoic	Cretaceous	145	
	Jurassic	201	
	Triassic	252	
Paleozoic	Permian	299	
	Carboniferous	Pennsylvanian	323
		Mississippian	359
		Devonian	419
	Silurian	443	
	Ordovician	485	
	Cambrian	541	
Precambrian	4600		

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Ice Age

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

interglacial • a period of geologic time between two successive glacial stages.



Figure 1.12: Cretaceous continental seas over North America.

		Present	
Cenozoic	Tertiary	Quaternary	
		Neogene	
	Paleogene	66	
Mesozoic	Cretaceous	145	
	Jurassic	201	
	Triassic	252	
	Permian	299	
Paleozoic	Carboniferous	Pennsylvanian	323
		Mississippian	359
	Devonian	419	
	Silurian	443	
	Ordovician	485	
	Cambrian	541	
Precambrian	4600		
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The Ice Age: Mountains of Ice

At the start of the **Quaternary** period, about 2.5 million years ago, continental ice sheets began to form in northernmost Canada. Throughout this period, the northern half of North America has been periodically covered by continental **glaciers** (Figures 1.13, 1.14). The Quaternary period is divided into two epochs: the **Pleistocene** and **Holocene**. During the Pleistocene, the ice sheets advanced south and retreated north several dozen times. The Holocene Epoch is the most recent (and current) period of retreat, called an **interglacial** interval. The most recent glacial advance in North America reached its maximum extent 21,000–18,000 years ago, while the beginning of the Holocene is considered to be 11,700 years ago, or about 9,700 BCE.

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Ice Age



Figure 1.13: Continental glaciers originating in Canada spread across North America, including nearly all of the Midwest, during the Quaternary period.

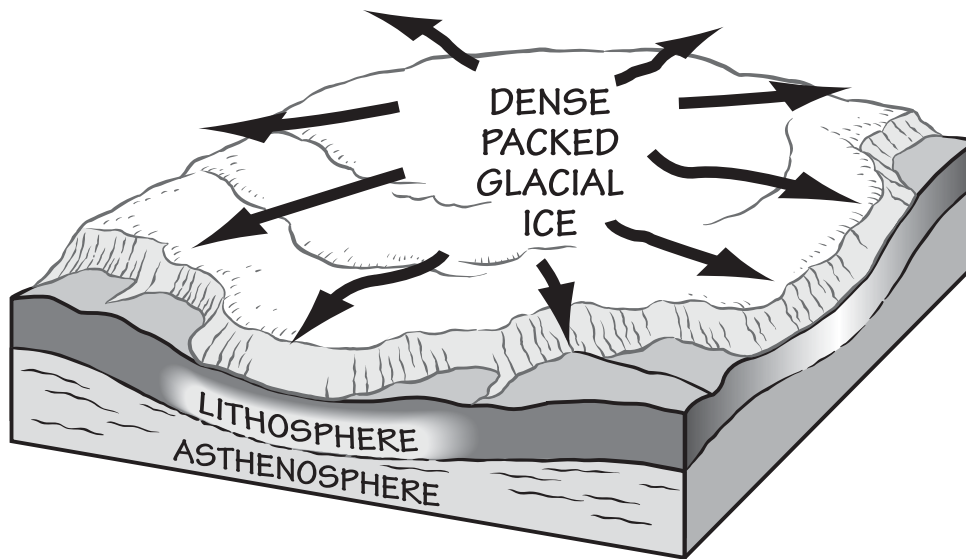


Figure 1.14: As dense glacial ice piles up, a glacier is formed. The ice begins to move under its own weight and pressure.

		Present	
Cenozoic	Quaternary	2.6	
	Tertiary	Neogene	23
		Paleogene	66
Mesozoic	Cretaceous	145	
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Precambrian		4600	

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Ice Age

esker • a sinuous, elongated ridge of sand and gravel.

drumlin • a teardrop-shaped hill of till that was trapped beneath a glacier and streamlined in the direction of the flow of the ice moving over it.

braided stream • a stream consisting of multiple, small, shallow channels that divide and recombine numerous times, forming a pattern resembling strands of braided hair.

kettle • a lake formed where a large, isolated block of ice became separated from the retreating ice sheet.

moraine • an accumulation of unconsolidated glacial debris (soil and rock) that can occur in currently glaciated and formerly glaciated regions, such as those areas acted upon by a past ice age.

The landscape of the Midwest has been heavily influenced and shaped by the advance and retreat of these glaciers, with the surface of every state shaped by the forces of the moving ice that scraped loose rock, gouged the bedrock beneath, and deposited sediment and water as the ice advanced and retreated (Figure 1.15).

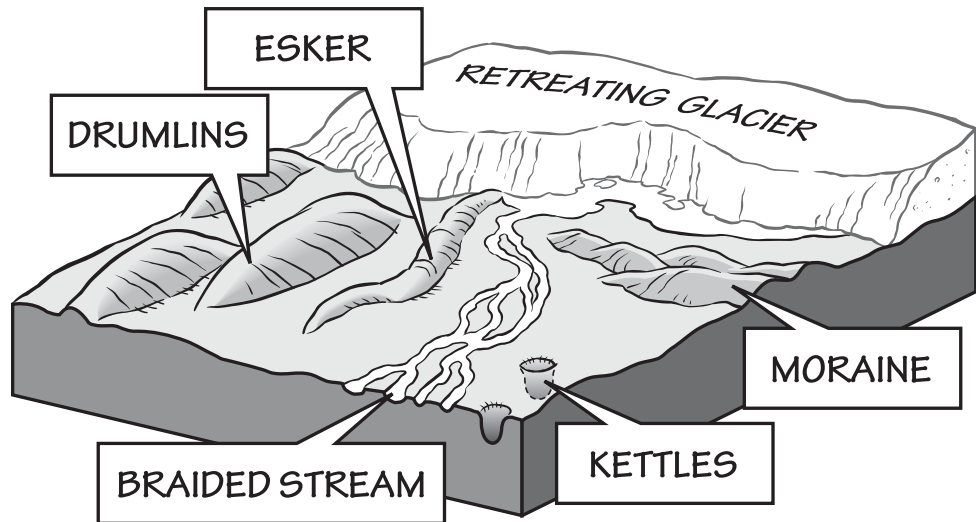


Figure 1.15: Glacial features.

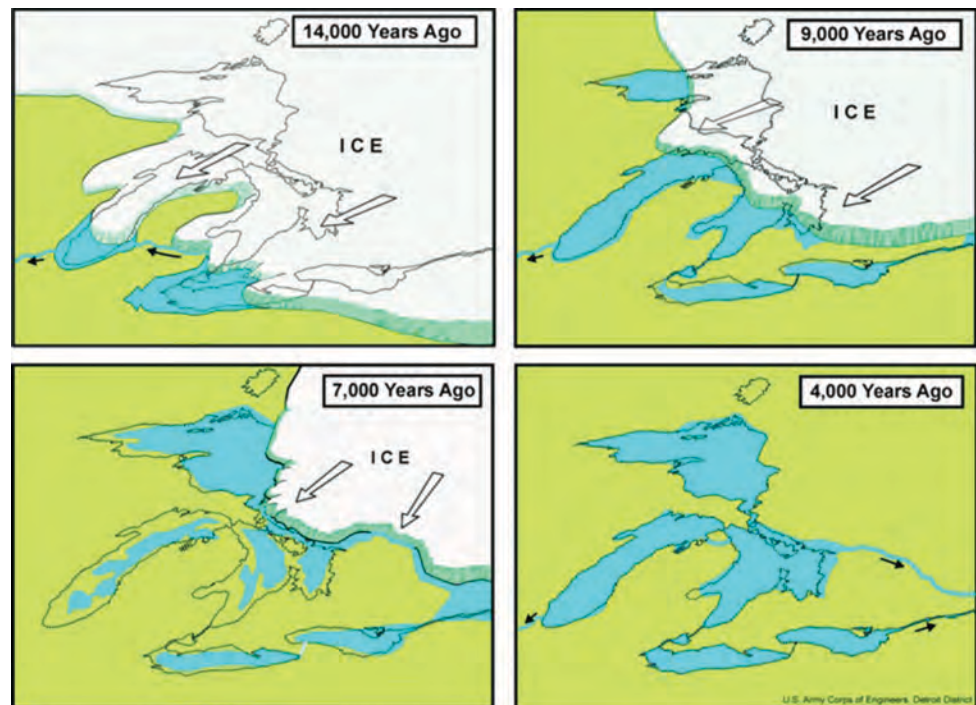


Figure 1.16: The formation of the Great Lakes.

Geologic History



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The **Great Lakes** of the Midwest and Northeast were formed during the last great glacial advance some 18,000 years ago. The broad, deep basins of the Great Lakes were flooded as the glaciers receded (*Figure 1.16*). Glacial meltwater poured into these basins, and the ice blocked the drainage that would eventually flow to the northeast via the St. Lawrence River. Once this path was available, the lakes gradually dropped to their current levels.

The ice age continues today, but the Earth is in an interglacial stage, since the ice sheets have retreated for now. The glacial-interglacial cycling of ice ages predicts that the world will return to a glacial stage in the future, but the impacts of human-induced climate change might radically shift the direction of these natural cycles.

With the onset of the Industrial Revolution, significant amounts of greenhouse gases have been released into the atmosphere that contribute to *global warming*.

See Chapter 9: Climate for more details.

Ice Age

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

global warming • the current increase in the average temperature worldwide, caused by the buildup of greenhouse gases in the atmosphere.



Resources

Resources

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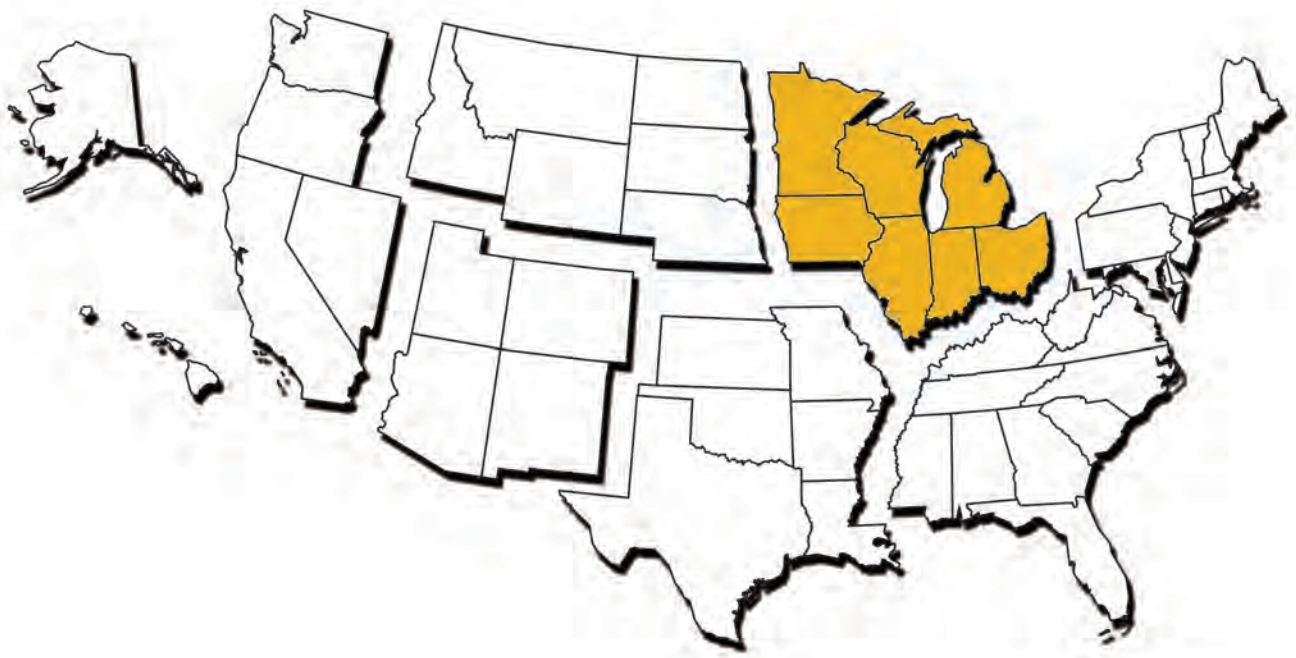
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The
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to the Earth Science of the
Midwestern US



Edited by Mark D. Lucas, Robert M. Ross, & Andrielle N. Swaby

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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>.