



# Chapter 2: Rocks of the Midwestern US

There is an amazing diversity of rocks in the Midwest, but in many places they are hidden by a thick layer of **soil**. They record more than a three-billion-year history of failed **rifts**, **inland seas**, deposition, **erosion**, **uplift**, igneous **intrusions** and **extrusions**, and glacial activity. The different rock types of the Midwest influence its **topography** and tell us where to look for certain **fossils** and natural resources. Each type of rock forms in a particular environment under particular conditions (*Figure 2.1*).

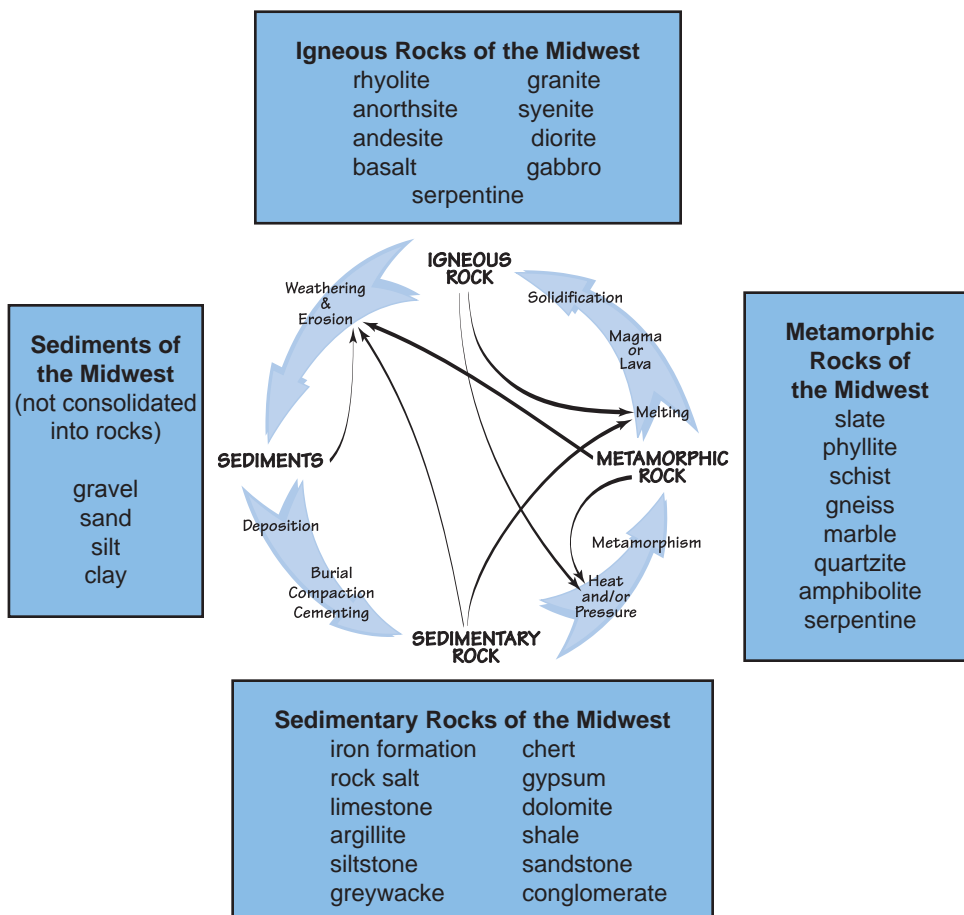


Figure 2.1: The rock cycle.

## Review

**soil** • the collection of natural materials that collect on Earth's surface, above the bedrock.

**uplift** • upward movement of the crust due to compression, subduction, or mountain building.

**intrusion** • a plutonic igneous rock formed when magma from within the Earth's crust escapes into spaces in the overlying strata.

**extrusion** • an igneous rock formed by the cooling of lava after magma escapes onto the surface of the Earth through volcanic craters and cracks in the Earth's crust.

**topography** • the landscape of an area, including the presence or absence of hills and the slopes between high and low areas.

## CHAPTER AUTHORS

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# 2



# Rocks

## Review

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

**plate tectonics** • the way by which the plates of the Earth's crust move and interact with one another at their boundaries.

**lithification** • the process of creating sedimentary rock through the compaction or cementation of soft sediment.

**weathering** • the breakdown of rocks by physical or chemical means.

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

**sandstone** • sedimentary rock formed by cementing together grains of sand.

**conglomerate** • a sedimentary rock composed of multiple large and rounded fragments that have been cemented together in a fine-grained matrix.

A rock is a naturally occurring solid substance composed of one or more **minerals**. Broadly speaking, there are three types of rock: sedimentary, igneous, and metamorphic. The rock cycle describes the many processes that produce rocks, while also illustrating the differences between rock types. One type of rock may be transformed into either of the other types, often with the help of other parts of the Earth **system**, including **plate tectonics**, the water cycle, and biological processes, to name a few.

**Sedimentary rock** is formed by the **lithification** of sediments (e.g., unconsolidated mineral and organic particles created through the **weathering** of other materials, like rock and organic matter). Typically, sediments are created in an environment where erosion is a dominant force, and they are transported by wind, water, or ice to a depositional environment. For example, a rushing river can wear away the rock it is flowing over, and it also has enough energy to transport the resulting sediment to a lake. The water slows down, losing energy, and deposits the sediment on the bottom of the lake.

### Sedimentary Rock Classification

Sedimentary rocks are classified by their sediment size or their mineral content, and each one reveals the story of the depositional environment where its sediments accumulated and were eventually lithified.

Sediment size (decreasing size)	Sedimentary rock	Environment of deposition
gravel	conglomerate	river beds, mountains
sand	sandstone	beaches, river sand bars, sand dunes
sand, silt, clay	graywacke	continental shelf
silt	siltstone	quiet water
clay	shale	very quiet water, lakes, swamps, shallow oceans

Lithification of sediments occurs in several ways. As sediments build up and lower layers are buried more deeply, they may become permeated by water. Minerals dissolved in the water are precipitated, filling the spaces between particles and cementing them together. This cementation helps to form many common sedimentary rocks, such as **shale**, **sandstone**, and most **conglomerates**. The evaporation of water may also form sedimentary rocks by leaving behind **evaporites** (previously-dissolved minerals) like **salt**. Deposits of calcium carbonate, usually created through the accumulation of calcium carbonate skeletal material (such as clams and corals), form the sedimentary rocks **limestone** and **dolostone**.



**Igneous rocks** form from the cooling of **magma** (molten rock underground) or **lava** (molten rock at the Earth's surface). When magma cools slowly underground, it has time to produce large crystals that are visible to the naked eye. Rocks that form in this manner, such as **granite**, are called **plutonic**. Molten rock that breaks through the **crust** to the surface (usually through a volcano) cools quickly as its heat escapes to the **atmosphere**. This produces **volcanic** or **glassy** rocks with very tiny crystals or no crystals at all.

## Igneous Rock Classification

Igneous rocks differ not only in their cooling rates and subsequent crystal sizes, but also in their chemical compositions. Rocks found in continental crust, such as granite, have high silica content and low iron and magnesium content. They are light in color and are called *felsic*. Rocks found in oceanic crust, like basalt, are low in silica and high in iron and magnesium. They are dark in color and are called *mafic*.

Crystal size	Felsic	Intermediate	Mafic	Ultramafic
large (plutonic)	granite	diorite	gabbro	peridotite
small (volcanic)	rhyolite	andesite	basalt	--
none (glassy)	obsidian, tuff, pumice	obsidian	obsidian	--

**Metamorphic rocks** form from pre-existing sedimentary, igneous, and metamorphic rocks that are exposed to increased temperature and pressure as a result of plate movements, very deep burial, or contact with molten rock or superheated water. The minerals within the rock recrystallize and realign, forming a much harder rock. This process destroys features in the rock that would have revealed its previous history, transforming it into an entirely new form.

See Chapter 1: Geologic History for a description of the mountain building episodes that created much of the metamorphic rock, and read about the rift valley that created many of the igneous rocks as a result of magma intrusions and volcanic events.

## Review

**salt** • a mineral composed primarily of sodium chloride (NaCl).

**limestone** • a sedimentary rock composed of calcium carbonate (CaCO<sub>3</sub>).

**dolostone** • a rock (also known as dolomitic limestone and once called magnesian limestone) primarily composed of dolomite, a carbonate mineral.

**plutonic rock** • a large body of intrusive igneous rock that formed under the Earth's surface through the slow crystallization of magma.

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

**atmosphere** • a layer of gases surrounding a planet.

**glassy rock** • a volcanic rock that cooled almost instantaneously, resulting in a rock with tiny crystals or no crystals at all.



## Review

**sand** • rock material in the form of loose, rounded, or angular grains, and formed as a result of the weathering and decomposition of rocks

**iron** • a metallic chemical element (Fe).

**ore** • a type of rock that contains minerals with valuable elements, including metals, that are economically viable to extract.

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

**gypsum** • a soft sulfate mineral that is widely mined for its use as fertilizer and as a constituent of plaster.

**aquifer** • a water-bearing formation of gravel, permeable rock, or sand that is capable of providing water, in usable quantities, to springs or wells.

### Metamorphic Rock Classification

Metamorphic rocks are classified differently depending on the protolith (parent rock) they are made from. The following chart shows common rocks and the metamorphic rocks that they can become.

Parent rock	Metamorphic rocks
shale	slate, phyllite, schist, gneiss (in order of increasing heat and pressure)
granite	gneiss
sandstone	quartzite
limestone	marble
peridotite	serpentinite

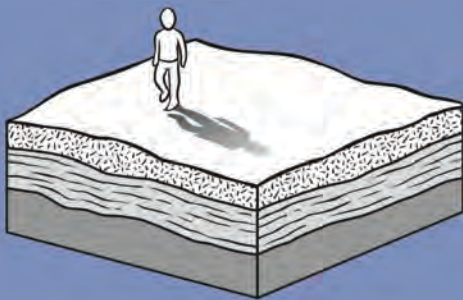
As you read through this chapter, keep in mind that once you understand the geologic events that have affected a given region, you should be able to predict the type of rocks found in that area. The Midwest has seen many dramatic changes, which are reflected in the diversity of the rocks found throughout the area. The oldest rocks of the Midwest formed more than three billion years ago from **sand** deposits, but being buried and “baked” for hundreds of millions of years metamorphosed them. Many of these rocks are largely composed of **iron**-rich minerals and are therefore, not surprisingly, mined for **ore**. Metamorphic rocks make up the majority of the bedrock of the Superior Upland. Sedimentary rocks, often fossiliferous, are found in every state. They represent the overwhelming majority of bedrock in the Midwest and include some important natural resources such as **coal**, salt, **gypsum**, and limestone, and some of their layers serve as **aquifers**. Igneous rocks, while not as abundant, are also widespread.



## Review

### Why do we see different kinds of rocks at the surface?

As you walk across the surface of the Earth, you will observe an amazing variety of rock types. If all rocks were flat-lying layers and there was no erosion, then we would only see one type of rock exposed on the surface. Often, however, rocks have been worn away (eroded), and the underlying layers are now exposed at the surface. Layers of rock may also be tilted, folded, or faulted to reveal the underlying rocks at the surface.



*When rocks are flat-lying layers and there is no erosion, folding, or faulting, the person walking across the surface sees only one rock type.*



*When rocks are worn away (often by streams), the person walking across the surface sees the underlying layers of rock exposed.*



*When rocks are folded or tilted, the person walking across the surface sees several layers of rock exposed.*



# 2



# Rocks

## Region 1

**Canadian Shield** • the stable core of the North American continental landmass, containing some of the oldest rocks on Earth.

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

**quartz** • the second most abundant mineral in the Earth's continental crust (after feldspar), made up of silicon and oxygen ( $\text{SiO}_2$ ).

**mantle** • the layer of the Earth between the crust and core.

**mica** • a large group of sheetlike silicate minerals.

## Rocks of the Superior Upland Region 1

The Superior Upland is the midwestern portion of the **Canadian Shield**, which extends from Minnesota to Nunavut and Greenland to New York. The shield as a whole represents the first portion of the North American continent to have emerged above sea level.

The Canadian Shield is the exposed portion of a larger **craton**. Its extremely old, hard rock was resistant to the weathering of repeated glacial advances, compared to the softer sedimentary strata to the south in the Central Lowland region, and this resulted in a higher, more rugged geographic upland.

The oldest rock in the region, and indeed the United States, is the **Morton Gneiss**. It was initially formed 3.6 billion years ago, during the **Archean** Eon. For hundreds of millions of years, magma welled up from the **mantle**, creating the foundation of granite below the surface, a rock composed mainly of **quartz**, **mica**, and **feldspar**. These minerals have densities that are lower than both those of oceanic crust and the average density of the mantle, allowing this lighter rock to essentially float on the upper portion of the **lithosphere**. The lithosphere, in turn, is pushed around on the **asthenosphere**, which effectively acts as a conveyor belt (*Figure 2.2*).

A *craton* can be thought of as the heart of a continent—it is typically the oldest, thickest, and most stable part of the bedrock. It is also usually far from the margins of tectonic plates, where new rock is formed and old destroyed. This very mature rock has usually been metamorphosed at some point during its history, making it very hard.

Over its exceedingly long history, this rock was metamorphosed, resulting in alternating bands that are distinctive of **gneiss**. Upwelling continued for hundreds of millions of years, injecting more and more magma into the region, which helped to metamorphose existing granite into gneiss. This magma would then cool to form yet more granite. This cycle continued until at least 2.7 billion years ago, though subsequent erosion could have erased rocks that are younger still. The result is a sequence of metamorphic and igneous rocks spanning nearly a billion years, remnants of which are found in northeastern Minnesota, northern Wisconsin, and parts of Michigan's Upper Peninsula.

One of the chief causes of the metamorphosis of the ancient granites of the Superior

Unless rock layers are overturned, older rocks are found at the bottom and younger rocks are found at the top of a sedimentary sequence. This is known as the *Law of Superposition*.



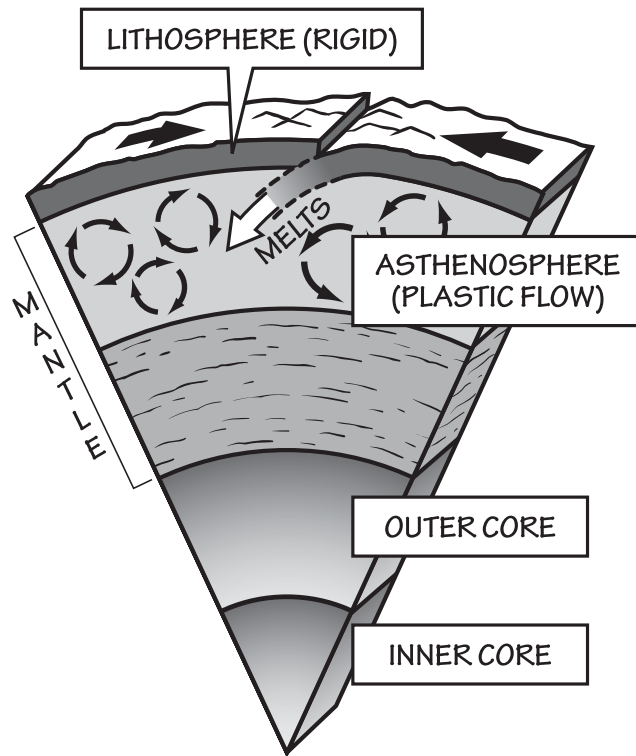


Figure 2.2: The layers of the Earth include the rigid crust of the lithosphere, which is constantly moving over the plastically flowing asthenosphere.

Upland was the collision of the Superior Province with the Minnesota River Valley **terrane** around 2.7 billion years ago. This triggered a period of intense mountain building, called an **orogeny**, as the two small continents pressed on each other, causing their rock to buckle, which forced some of the rock up as mountains and some down to be subjected to even greater pressure and heat (Figure 2.3).

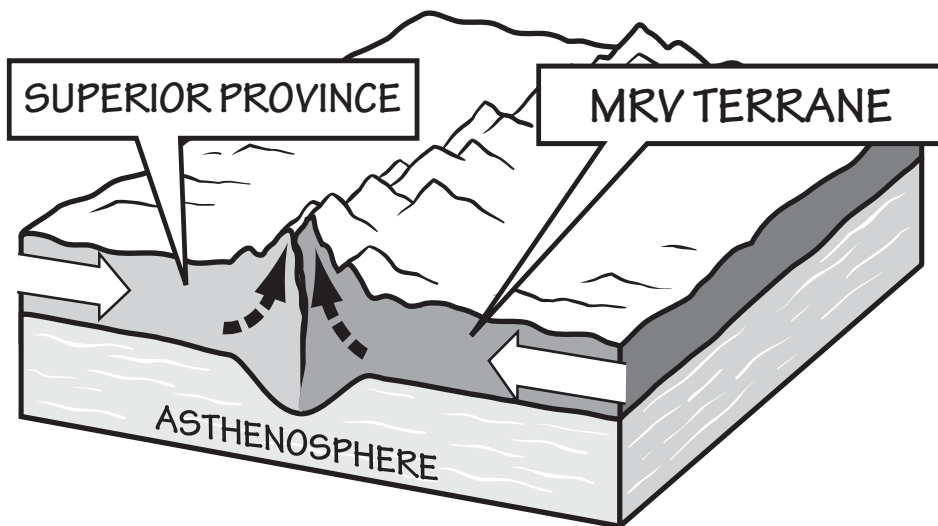


Figure 2.3: The Superior Province collides with the Minnesota River Valley (MRV) terrane, crumpling the margins of both continents.

## Region 1

**feldspar** • an extremely common, rock-forming mineral found in igneous, metamorphic and sedimentary rocks.

**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.

**gneiss** • a metamorphic rock that may form from granite or layered sedimentary rock such as sandstone or siltstone.

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



# 2



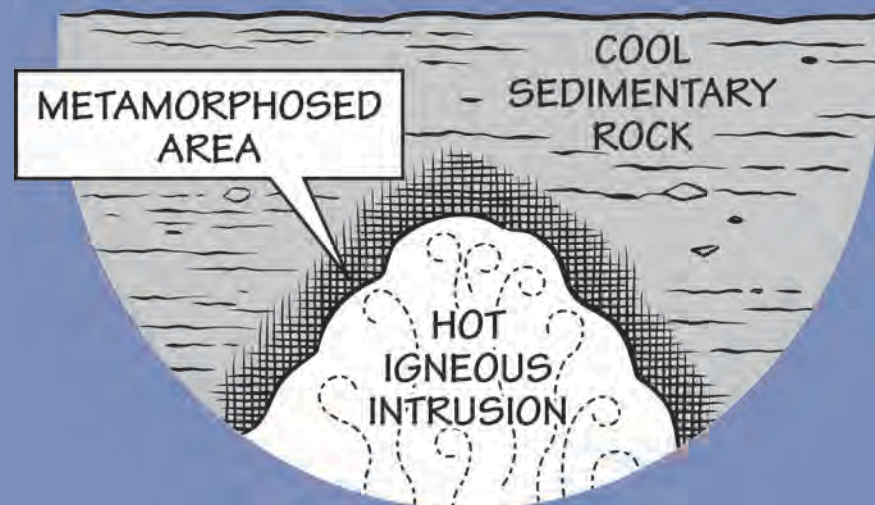
## Rocks

### Region 1

#### What happens to a rock when it is metamorphosed?

When rocks are subjected to high enough temperatures or pressures, their characteristics begin to change. The weight of overlying rock can cause minerals to realign perpendicularly to the direction of pressure, layering them in a pattern called foliation, as exemplified in gneiss and schist. Recrystallization, as seen in marble and quartzite, results as rock is heated to high temperatures, and individual grains reform as interlocking crystals, making the resulting metamorphic rock much harder than its parent rock.

*Contact metamorphism* describes a metamorphic rock that has been altered by direct contact with magma. Changes that occur due to contact metamorphism are greatest at the point of contact. The further away the rock is from the point of contact, the less pronounced the change.



*Regional or dynamic metamorphism* describes a metamorphic rock that has been altered due to deep burial and great pressure. This type of metamorphic rock tends to occur in long belts. Different types of metamorphic rock are created depending on the gradients of heat and pressure applied.







After a 200-million-year gap, the rock record picks up in the **Proterozoic** with 2.4-billion-year-old quartz sandstones and dolostones, which were deposited in a shallow marine environment. In some cases, these sedimentary rocks preserve **ripple marks** and **stromatolites**. Ancient glacial sediments are also found in the Superior Upland, evidence of the Huronian glaciation, which is thought to be the first-ever **ice age** on Earth. Following a gap of about 100 million years from 2.2 to 2.1 billion years ago, the sandstones reappeared and extended to 1.9 billion years ago.

## Stromatolites

Stromatolites are regularly banded accumulations of sediment created by the trapping and cementation of sediment grains in bacterial mats (especially photosynthetic cyanobacteria). 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. Over time, this cycle of growth combined with sediment capture creates a rounded structure filled with banded layers.

Stromatolites peaked in abundance around 1.25 billion years ago, and likely declined due to predation by grazing organisms. Today, stromatolites exist in only a few locations worldwide, such as Shark Bay, Australia. Modern

**s t r o m a t o l i t e s** form thick layers only in stressful environments, such as very salty water, that exclude animal grazers. Even though there are still modern stromatolites, the term is often used to refer specifically to fossils. For more information, see Chapter 3: Fossils.



## Region 1

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

**ripple marks** • surface features created when sediment deposits are agitated, typically by water currents or wind.

**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.



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# Rocks

## Region 1

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

**quartzite** • a hard metamorphic rock that was originally sandstone.

**dolomite** • a carbonate mineral, consisting of calcium magnesium carbonate ( $\text{CaMg}(\text{CO}_3)_2$ ).

**marble** • a metamorphic rock composed of recrystallized carbonate minerals, most commonly calcite or dolomite.

**hot spot** • a volcanic region thought to be fed by underlying mantle that is anomalously hot compared with the mantle elsewhere.



Beginning about 2 billion years ago, thick and increasingly widespread **banded iron formations** also appear in the Superior Upland. As with much of the Canadian Shield, most of this rock has been metamorphosed to some degree: sandstones have become **quartzite**, **dolomites** have become **marble**, and banded iron formations have been deformed and folded. The Penokean Orogeny, from 1.9 to 1.8 billion years ago, transformed the area into a primarily erosional environment, so few rocks are preserved from this time. The tectonic activity did, however, force some magma up near the surface where it cooled into the granite found in northeastern Wisconsin and the Upper Peninsula.

About 1.1 billion years ago, a major event in the history of the Superior Upland took place when the North American continent began to split apart along the Midcontinental Rift. It is thought that a **hot spot** in the mantle caused a great upwelling of magma, centered near where Lake Superior is today. Over the course of 20 million years, the pressure from below caused the crust to spread in all directions, eventually thinning the Canadian Shield considerably.

The rift eventually failed, but it left its mark on the region. Huge volumes of lava burst through to the surface, forming deposits of **basalt**. Magma of the same composition cooled underground to form gabbro. The tectonic activity also broke up many of these new rocks, producing large amounts of sediment that were preserved as sandstones and conglomerates. An age of 1.1 billion years is old even for a rock, yet this is currently the youngest exposed bedrock in the Superior Upland. On the southern and western shores of Lake Superior, one can see volcanic sequences, sandstones, and the Copper Harbor Conglomerate, evidence of the processes occurring during rifting (*Figure 2.4*). While the rocks produced by the Midcontinental Rift are only found at the surface around Lake Superior, now-buried legs of the failed rift extend north into Canada, southeast nearly to Lake Erie, and southwest all the way to Kansas (*Figure 2.5*).

See Chapter 1: Geologic History for more information on the Penokean Orogeny and Midcontinental Rift.

In some areas, water and carbon dioxide that had been trapped in the magma formed bubbles. After the lava cooled, these bubbles were slowly filled by mineral-rich water flowing through them, depositing layers of fine quartz crystals and enough iron to color the resulting rocks red. Lake Superior agate, the Minnesota state gemstone, was formed in this manner.



## Region 1

**basalt** • an extrusive igneous rock, and the most common rock type on the surface of the Earth.

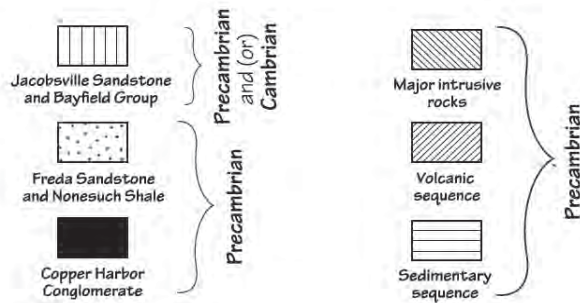
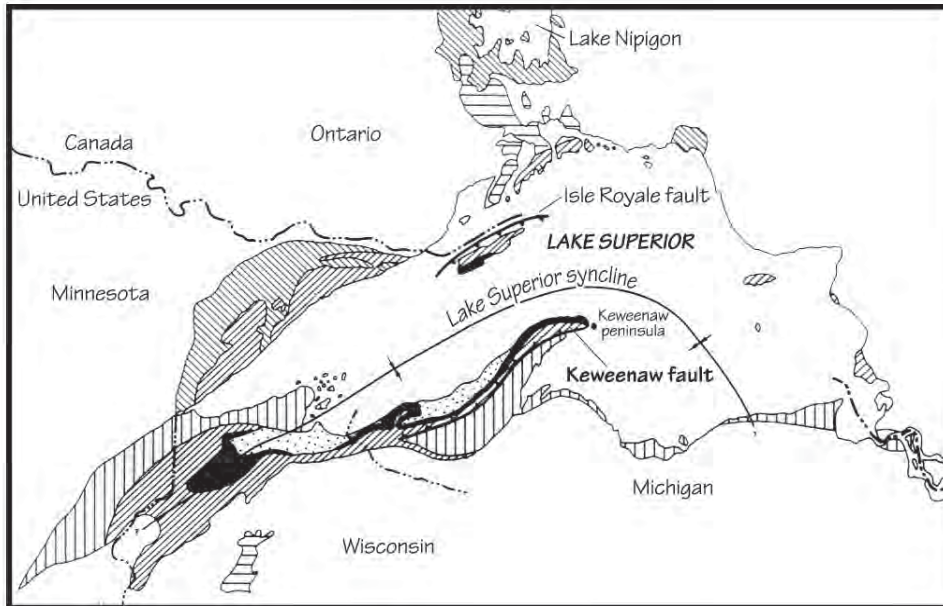


Figure 2.4: The geology around Lake Superior is perhaps the most complex in the Midwest. A variety of sedimentary, igneous, and metamorphic rocks representing more than a billion years of history are found within a few kilometers of each other.



# 2



# Rocks

## Regions 1–2

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

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

**rhyolite** • a felsic volcanic rock high in abundance of quartz and feldspar.

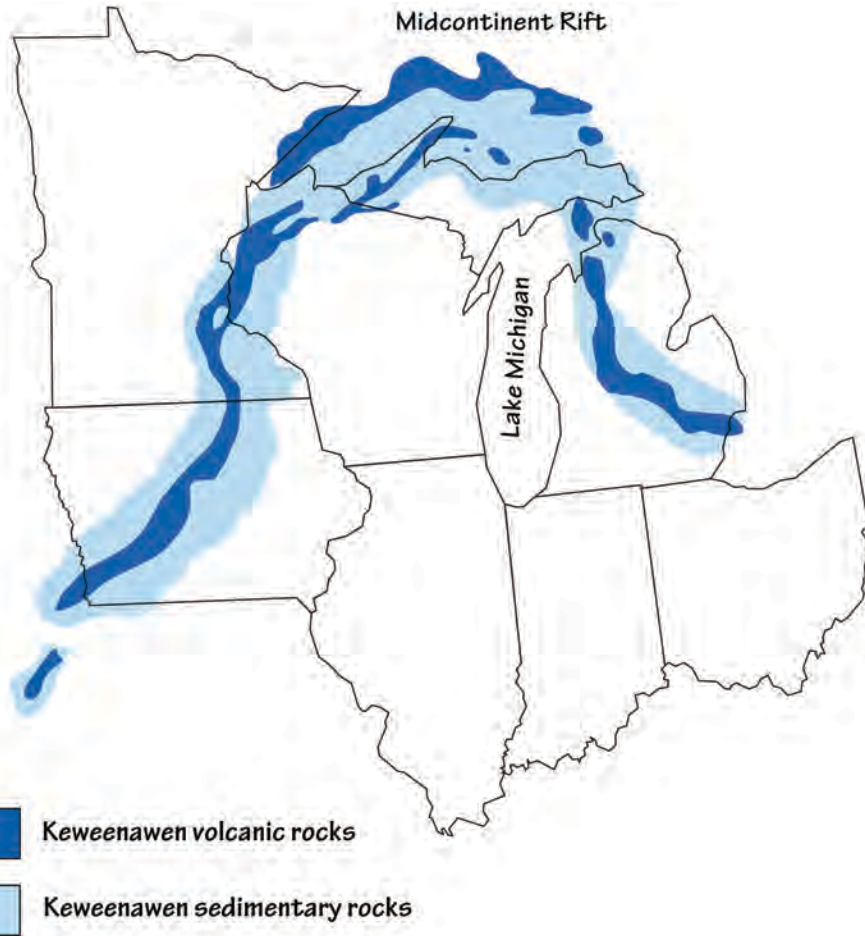


Figure 2.5: The scars of the Midcontinental Rift span nearly the entire Midwest, but are buried deep below the surface in most of the region. The inset box represents the outcrops of Midcontinental Rift rocks found at the surface.

## Rocks of the Central Lowland Region 2

While most of the Central Lowland's bedrock is **Paleozoic** in age, and some is **Mesozoic**, there is a single exposure that is as much as 1.6 billion years old. Both **rhyolite** and the pink to purple quartzite (an extremely hard metamorphic rock) (Figure 2.6) found at Baraboo, Wisconsin stand out above the flatter and much younger landscape around it. At just 40 kilometers (25 miles) long and 16 kilometers (10 miles) wide, it is not an extensive range, yet, as it is more than a billion years older than any other rock in the region, it is extremely significant. Based on the ripple marks that persist in many of the quartzite layers, it has been determined that this rock was deposited during the Proterozoic eons on the shores of an ancient sea.







Figure 2.6: The Baraboo Quartzite is the remains of a 1.6-billion-year-old shoreline that, in its incredibly long history, has been tilted nearly vertical.

The vast majority of bedrock in the Central Lowland is sedimentary and was formed during the Paleozoic. These rocks were primarily formed in shallow seas that covered great portions of North America at different times during its history.

**Cambrian** age sandstones and shales are exposed around the Mississippi River Valley through the **Driftless Area**, or Paleozoic Plateau, near where

See Chapter 6: Glaciers for more on the Driftless Area.

the borders of Iowa, Illinois, Minnesota, and Wisconsin converge, and they extend in a band northeast across central Wisconsin to Michigan's Upper Peninsula. These rocks are often fossiliferous, but they are covered by glacial material in many areas. Since the sea level was quite high at this time, and most of the Midwest was underwater, much of the rock formed is fine-grained.

By the **Ordovician**, reef ecosystems had become more extensive, forming expanses of limestone, dolostone, and limey (i.e., calcium carbonate-rich) shales. Occasional **bentonite** deposits may be found in Minnesota and Iowa, the result of volcanic ash blown from other parts of the continent. In the western part of the region, the Ordovician deposits overlie, and may be found generally southward of, the Cambrian deposits mentioned above. Ordovician rocks are also found around the southern part of Indiana and Ohio's shared border. While the rocks here are similar in composition, the sediment came primarily from the Taconic Mountains to the northeast.

## Region 2

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

**Driftless Area** • a region that did not experience glaciation, located in parts of southwestern Wisconsin, eastern Minnesota, and northeastern Illinois and Iowa.

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

**bentonite** • a clay, formed from decomposed volcanic ash, with a high content of the mineral montmorillonite.







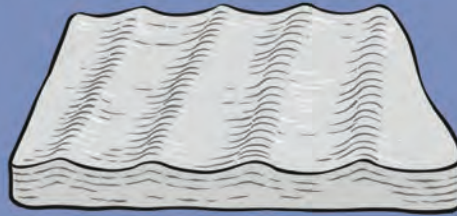

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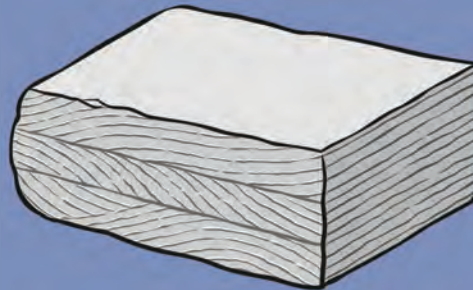
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**Sedimentary Structures**

Sedimentary rocks often reveal the type of environment in which they formed by the presence of structures within the rock. Sedimentary structures include ripple marks, cross-beds, mud cracks, and even raindrop impressions. Consider the type of environments in which you see these sedimentary structures today in the world around you.



*Ripple marks suggest the presence of moving water (though wind can also create ripples and even dunes). Mud cracks indicate that the sediment was wet but exposed to the air so that it dried and cracked.*



*Cross-beds form as flowing water or wind pushes sediment downcurrent, creating thin beds that slope gently in the direction of the flow as migrating ripples. The downstream slope of the ripple may be preserved as a thin layer dipping in the direction of the current, across the natural flat-lying repose of the beds. Another migrating ripple will form an additional layer on top of the previous one.*





## Region 2

### Why are there different sedimentary rocks in different environments?

Most sedimentary rock deposited in underwater settings originated from material eroded on land and washed down streams or rivers before settling to the bottom of a body of water. Intuitively, the faster the water is moving, the larger the sediments it may carry. As the water slows down, the size of sediments it can carry decreases. Furthermore, the farther the grains of sediment are carried, the more rounded they become as they are tumbled against each other. In this way, rivers emptying into a sea are effectively able to sort sediment. Near the mouth of the river, the water is still relatively high-energy, dropping only the largest pieces; farther from the shore, the dropped particles get smaller. Therefore, conglomerates and sandstones are interpreted to have been deposited on or near the shore, siltstone farther from the shore, and shale in deep water quite far from shore where currents are slow enough that even very tiny particles may settle.



Increased distance from shore and water depth can also reduce the presence of oxygen in the water, causing organic material to decompose less completely. This causes more carbon-rich, darker rocks, including some that contain exploitable fossil fuels, to form in these areas. Limestone is made primarily of calcium carbonate, the components of which are dissolved in the water. Living creatures, like coral and foraminifera, take those components out of the water to make calcium carbonate shells, which, after the creatures die, accumulate to become limestone. This process happens over much of the seafloor, yet if more than 50% of the sediment being deposited is from another source, the rock that forms is, by definition, not limestone. Furthermore, these shelled creatures tend to fare better in clear water, so limestone tends to form far from other sources of sediment.



# 2



# Rocks

## Region 2

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

**capstone** • a harder, more resistant rock type that overlies a softer, less resistant rock.

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

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

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

Similar processes continued through the **Silurian** and helped form many of the dominant ridges around the northwest of Lake Michigan, an arc through Lake Huron, and, most famously, the foundation of Niagara Falls in the east. The top of the escarpment is a hard dolostone, which protects the softer shales beneath it from erosion. This resistant **capstone** helps define the shapes of the basins of the **Great Lakes**, but these rock formations are also found beneath the surface in parts of Illinois, Michigan, and Ohio (*Figure 2.7*).



*Figure 2.7: The Niagara Escarpment, shown in blue, creates such a distinct topographic and geologic boundary that the Great Lakes Michigan, Huron, and Ontario owe large portions of their shorelines to its influence.*

In the east, Ohio and Indiana were sediment-starved as tens of millions of years of weathering made the Taconic Mountains low and mature, allowing reefs to cover the area and produce thick beds of limestone. West of Indiana, limestones were also deposited extensively, and often subsequently converted to dolostone. Relatively deep basins in the Upper Peninsula were surrounded by reefs that reduced circulation. This resulted in increased salinity in the basin, leading to the deposition of salt and gypsum on the basin floor. Evaporation in shallow basins in Michigan and northern Ohio caused a similar process to occur, evidenced by the salt and gypsum deposits also present there.

The **Devonian** saw the formation of the Acadian Mountains in the east, which provided a new source of sediment to Ohio, Indiana, and Michigan. Because of this, rocks found in these states that date from this time are mostly shales and mudstones. Limestone and dolostone dominate the swath of Devonian rock in eastern Iowa, spilling over into Minnesota, Illinois, and Wisconsin.

Changes in sea level during the **Mississippian** and **Pennsylvanian** periods turned much of the Midwest into dry land at various times. Sequences of





familiar marine rocks began to give way to sediments deposited near shore, in extensive deltas, and in freshwater settings. Sandstones and mudstones dominate the bedrock from these periods, as well as coal formed from vast volumes of vegetation from the swampy forests covering the region.

For most of the Central Lowland, the rock record stops here—if much rock formed afterward, it was subsequently eroded away. In western Minnesota and Iowa, following a 240-million-year gap, rocks of the **Cretaceous** period are found. The oldest of these are sandstones deposited by rivers running towards the Western Interior Seaway. As time went on, the shores of the seaway moved eastward, laying down muddier sediment and finally limey shales, which sometimes contain marine fossils. Two isolated outcrops in Illinois contain sandstone and mudstone deposited by rivers flowing into an arm of the ancient Gulf of Mexico, called the Mississippi Embayment. One of these outcrops is in the Central Lowland, near Quincy, Illinois, while the other is at the southern tip of the state and is part of the **Inland Basin**.

## Regions 2–3

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

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

## Rocks of the Inland Basin Region 3

### Mississippian Rocks

The Inland Basin is a large geophysical province, and only a small portion of it exists in the Midwest in eastern Ohio, southern Indiana, and Illinois. Here, only a relatively narrow slice of time is represented in the rocks. During the Mississippian and Pennsylvanian periods, the limestones, sandstones, and shales of this region formed. Except for a small band of Cretaceous sedimentary rock in extreme southern Illinois, rock from no other period is found here.

During the Mississippian and Pennsylvanian periods, the Inland Basin region was an inland sea environment, with sediment being shed into the basin from the Acadian highlands to the east (*Figure 2.8*). Gradually, the amount of sediment settling into the basin declined, as the mountains were weathered down. The shoreline of the inland sea moved back and forth across the basin as the sea level rose and fell during this period. The

*Inland sea* may sound like a contradiction in terms, but there is a very simple, yet important, distinction that differentiates it from other seas: an inland sea is located on continental crust, while other seas are located on an oceanic crust. An inland sea may or may not be connected to the ocean. For example, Hudson Bay is on the North American plate and connects to the Atlantic and Arctic Oceans, while the Caspian Sea is on the European plate but does not drain into any ocean at all.





# 2



# Rocks

## Region 3

**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).

**peat** • an accumulation of partially decayed plant matter.

fluctuating water levels created alternating sequences of marine and non-marine sedimentary rocks, known as **cyclothems**, that are characterized by their light and dark colors (*Figure 2.9*). Limestones were also forming in the inland sea in areas receiving very little sediment. The Midwest was still located near the equator at this time, and the warm **climate** created lush vegetation. Large swamp forests covered the shorelines, and plant remains accumulated as thick piles of **peat**. Buried by sediment and more vegetation, the peat was compressed. Over time and through continued burial, the peat was transformed into layers of coal. The Pennsylvanian and Mississippian rocks of the Inland Basin region are the result of shorelines advancing and retreating, creating alternating bands of marine sandstone or mudstone and terrestrial coal deposits, respectively.

See Chapter 1: Geologic History for more information on the position of the Midwest during the Paleozoic.



Figure 2.8: Much of the Midwest region was covered by an inland sea during the Mississippian and Pennsylvanian periods, with sediment being brought in from the erosion of the Acadian highlands to the east.







## Region 3

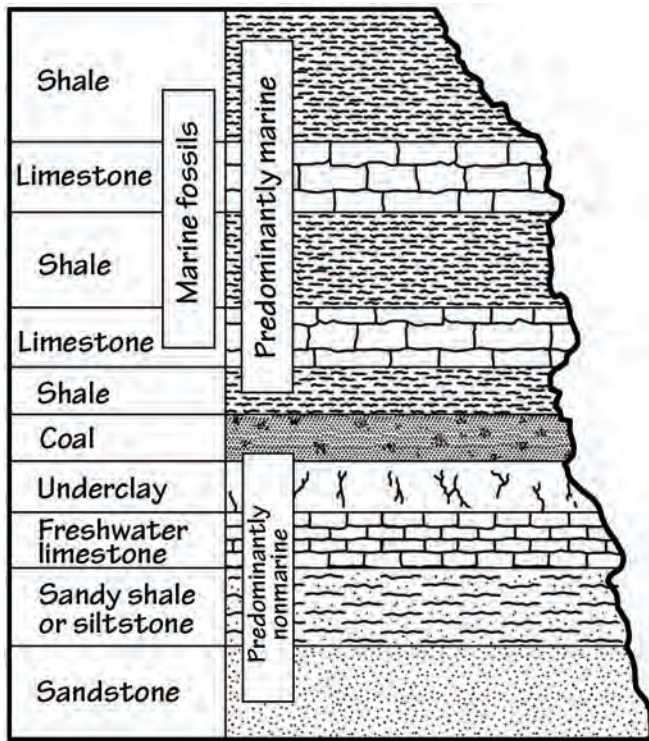


Figure 2.9: An example of a cyclothem.

As mentioned above, a portion of the Inland Basin in the southern tip of Illinois is made up of the second isolated outcrop of sandstone and mudstone from the Mississippi Embayment.





## State Rocks

**fluorite** • the mineral form of calcium fluoride ( $\text{CaF}_2$ ).

**geode** • a hollow, roughly spherical node of crystal that forms when minerals precipitate within hardened vesicles (gas bubbles) in volcanic rocks, or within dissolved nodules that leave openings within sedimentary rock.

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

**pumpellyite** • a group of metamorphic silicate minerals that produce translucent green crystals with a fibrous texture.

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

## State Rocks, Minerals, and Gems

### Illinois

State mineral: **fluorite**

Southeastern Illinois once produced the majority of fluorite in the US, and it is the site of the most recently active fluorite mine in the country.

### Indiana

State rock: Salem limestone

Salem limestone is a high-quality building material that may be seen in the facades of buildings from the Empire State Building to the Pentagon to Yankee Stadium. It has also been used in the construction of scores of university and government buildings throughout the country.

### Iowa

State rock: **geode**

The town of Keokuk in southeastern Iowa is one of the most productive sites of geodes in the world. The formation of these geodes is not completely understood, but it is thought that when the bedrock initially formed, spherical **concretions** of calcium carbonate were accumulated among the layers of mudstone. Subsequently, water richer in silicon dissolved these concretions, leaving an open space in the rock where silicon, as quartz, could precipitate. In this way, the quartz crystals grew slowly from the outside inward, frequently leaving a hollow space in the center. Because quartz geodes are much harder than mudstone, the hollow orbs may often be found loose on the ground after the bedrock has been eroded away.

### Michigan

State rock: Petoskey stone

Petoskey stone is fossilized *Hexagonaria* coral from the Devonian period.

State gem: **chlorastrolite**

Also called Michigan Greenstone, chlorastrolite is a variety of **pumpellyite** with a distinctive “turtleback” pattern created by its interlocking green crystals. It formed in void spaces in basalt during the Midcontinental Rift event, and, because it is substantially harder than the surrounding igneous rock, it is often found as loose, bean-sized pebbles. It is especially abundant on Michigan’s Isle Royale.



## State Rocks

### Minnesota

State gem: Lake Superior agate

Characteristically red, Lake Superior agate originates near its namesake lake, but **glaciers** have redistributed enough of the stone that it may be found throughout much of the state.

### Ohio

State gem: Ohio **flint**

Ohio flint is a high-quality **chert** found throughout eastern and central portions of the state. Native Americans used Ohio flint to make tools as early as 12,000 years ago. It is a variety of microcrystalline quartz and a favorite of lapidarists.

### Wisconsin

State mineral: **galena**

Galena played an important role in the founding of the state of Wisconsin because early settlers mined it as a **lead** ore.

State rock: red granite

Red granite is mined extensively in Wisconsin and, depending on its quality, is used to make products from countertops to gravel. It was formed around 1.85 billion years ago when an island arc crashed into the Superior Upland.

*flint • a hard, high-quality form of chert that occurs mainly as nodules and masses in sedimentary rock.*

*chert • a common sedimentary rock composed of microcrystalline quartz.*

*galena • an abundant sulfide mineral with cubic crystals.*

*lead • a metallic chemical element (Pb).*



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## Resources

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### Resources

#### Rock and Mineral Field Guides

- Dixon, Dougal, 1992, *The Practical Geologist: The Introductory Guide to the Basics of Geology and to Collecting and Identifying Rocks*. Simon and Schuster: New York.
- Johnsen, O., 2002, *Minerals of the world*. Princeton University Press: Princeton, NJ.
- National Audubon Society, 1979, *Field Guide to North American Rocks and Minerals*. National Audubon Society Field Guides: New York.
- Mitchell, J., 2008, *The rockhound's handbook*. Gem Guides Book Co.: Baldwin Park, CA.
- Pellant, C., 2002, *Smithsonian Handbooks: Rocks & Minerals* (Smithsonian Handbooks). DK Publishing, Inc.: New York.
- Prinz, M., Harlow, G., and Peters, J. (eds.), 1978, *Simon & Schuster's Guide to Rocks & Minerals*. Simon and Schuster: New York.

#### Books

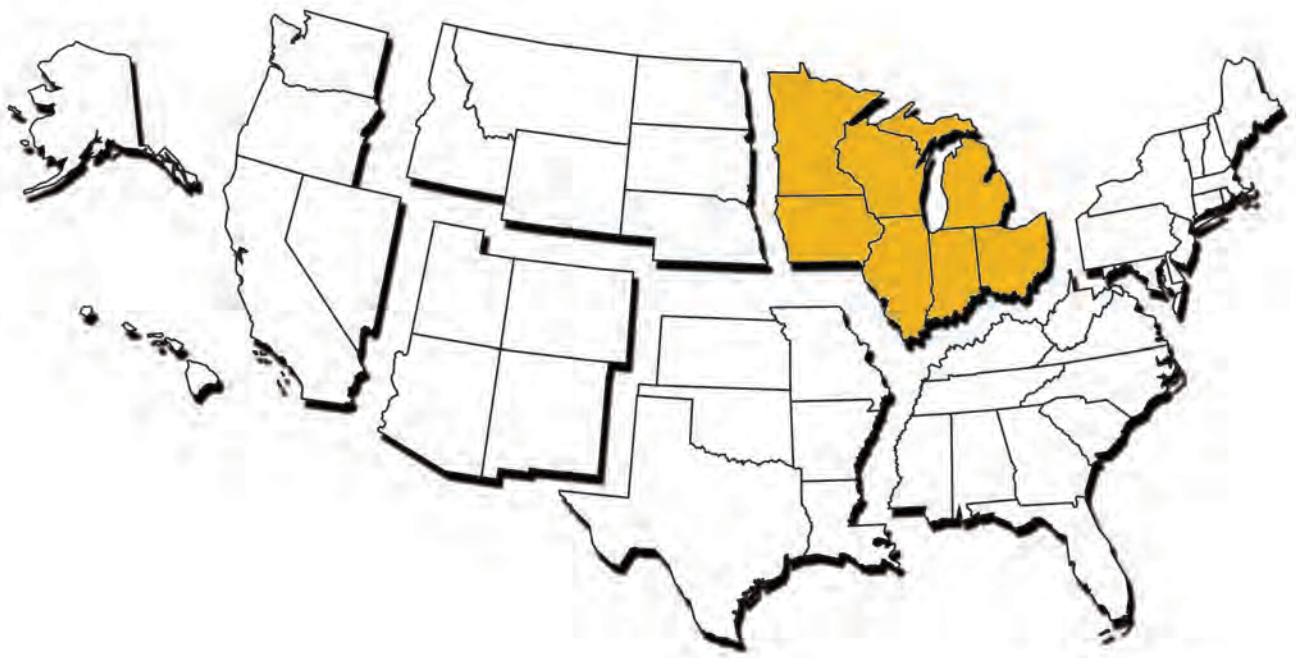
- Vernon, R. H., 2000, *Beneath our feet: The rocks of planet Earth*. Cambridge University Press: Cambridge, UK.

#### Websites

- Atlas of Igneous and Metamorphic Rocks, Minerals and Textures*, Univ. North Carolina Geology Department (Older but still useful resource.)  
<http://leggeo.unc.edu/Petunia/IgMetAtlas/mainmenu.html>.

The  
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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>.