Chapter 6:
Glaciers of the Midwestern US

The ancient geologic history of the Midwest is often disguised by its more recent geologic history, one that was dominated by **glaciers**. During the **Quaternary** period, which began just 2.6 million years ago and extends to the present, ice at times extended southward from the Hudson Bay area and began to encroach on the northern United States. At different points during the Quaternary period, ice has covered all of the Midwest except for the extreme southern parts of Illinois, Indiana, Ohio, and a unique region called the **Driftless Area** (*Figure 6.1*). These **ice sheets** scraped away and ground up whatever rock was at the surface. When the ice finally retreated, it dropped its load of rock and dirt, forming much of the landscape we see today and obscuring the bedrock below in many feet of sediment. More than any other force, the glaciers are responsible for the landscape of the Midwest: they smoothed peaks, filled valleys, pocked the area with ponds, and carved the **Great Lakes**. Because the ice sheets affected the Superior Upland, Central Lowland, and Inland Basin similarly, this chapter discusses the Midwest as a whole.

Fig 6.1: Extent of glaciation over North America at the Last Glacial Maximum.

Review

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

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

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

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).*

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

CHAPTER AUTHOR

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6 Glaciers

Review

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).*

firn • *compacted glacial ice, formed by the weight of snow on top.*

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

Glaciers will only form under certain conditions and in specific environments. A cold **climate** and sufficient moisture in the air for the precipitation of snow are both necessary factors that permit at least some snow to last year-round. This allows for the build-up and compaction of snow that will eventually become glacial ice. Sufficiently cold climate conditions exist at high altitudes and high latitudes.

Glacial ice is formed as snow is buried; the weight of more snow above causes lower layers to compact. Individual flakes break down by melting, refreezing, and bonding to the snow around them, eventually forming grains called **firn**. This process can be facilitated with water filling the space between flakes, but the pressure alone will cause the flakes to melt and refreeze. Air is forced up and out, or into bubbles, increasing the density of the ice. As more snow falls at the surface, adding more weight, the firn becomes denser and denser until the ice crystals interlock, effectively leaving no space between them—this is known as glacial ice. At a depth greater than about 50 meters (165 feet), the pressure is high enough for plastic flow to occur. Ice flow is driven by gravity, and it causes movement downhill and out from the center.

Most broadly, there are two types of glaciers: smaller alpine glaciers and larger continental glaciers. Found in mountainous regions, alpine glaciers have a shape and motion that is largely controlled by **topography**, and they naturally flow from higher to lower altitudes. Continental glaciers are much larger, and they are less controlled by the landscape, tending to flow outward from their center of accumulation.

It is not surprising that today's continental glaciers, also called ice sheets, are located in the high latitude polar regions of Greenland and Antarctica, where temperatures are low most of the year. There must be landmasses at high latitudes for continental glaciers to occur, as they cannot form over open water. While persistent sea ice can and does form, because it floats, it does not flow as a glacier does. The glaciers that stretched over North America 20,000 years ago were primarily continental ice sheets.

Alpine glaciers are found at high altitudes, and they sometimes occur relatively close to the equator. They accumulate snow at their tops and flow downhill. Alpine glaciers may fill part of a single valley, or they may cap an entire mountain range.

While only the two broadest categories of glaciers are discussed here, glaciers exist in a diversity of forms. Even this broadest of distinctions is not completely clean-cut (e.g., continental glaciers often have tongues that feed into valleys, which may become alpine glaciers).

In general, glaciers grow when it is cool enough for the ice sheet to accumulate snow more quickly than it melts. As they grow, ice sheets become so massive that they flow outwards, covering an increasing area until melting at the margins catches up to the pace of accumulation. Glaciers in the Midwest flowed from centers of accumulation to the north (now Canada), and glacial growth southward through the Midwest was more a result of this lateral flow than of direct precipitation from falling snow.

Glaciers 6

Landscapes

Glacial Landscapes

The interaction of the glaciers with the landscape is a complex process. **Scouring** abrades bedrock and removes sediment, while melting causes the ice to deposit sediment. Glacial features like **moraines**, **drumlins**, and **kettles** occasionally break the pattern of gently rolling hills found in most of the Midwest. Even in southernmost Illinois, Indiana, Ohio, and the Driftless Area where the glaciers did not reach, glacial runoff changed the landscape: meltwater loaded with abrasive sediment carved the landscape, making it more rugged.

Erosion

Thousands of years of scraping by ice can have dramatic, and sometimes dramatically varied, effects on a landscape. An important factor determining the effect is the kind of rock being **eroded**. Harder bedrock will be scratched and polished by sediment stuck in the ice, while **frost wedging**, when water freezes and expands in cracks, can eventually break chunks of rock away. Softer bedrock is much more easily carved and crushed.

The flowing ice cracks and breaks rock as it passes over, pieces of which become incorporated in the sheet or bulldozed forward, in front of the glacier's margin. The process of glaciers picking up sediment in this way is called **plucking**. The less resistant rock over which glaciers move is often eroded and ground-up into very fine **sand** and **clay** (called **rock flour**). More resistant **igneous** and **metamorphic rock** is often polished and scratched by the grinding action of the sediments in the glacial ice. Streams of meltwater from the glacier, frequently gushing and full of sediment, cause significant amounts of scour as well. The abrasive sediments in the flowing water create **potholes** in the bedrock and

How do we know the mark of glaciers?

How do we know that striations, polish, scoured basins, U-shaped valleys, and the variety of deposits attributed to glaciers are in fact a result of glacial action? Before the modern understanding of the ice ages, many believed that the features now attributed to glaciers were the result of a great flood similar to the one found in the Biblical story of Noah and the Ark. By studying modern glaciers, however, geologists have come to understand the resulting features of glacial scour and deposition that are readily identified in much of the Midwest. Modern glaciers include the large-scale ice sheets in Greenland and Antarctica as well as the small-scale valley glaciers found in mountain ranges in places such as Alaska, Canada, and the Alps.

scouring • *erosion resulting from glacial abrasion on the landscape.*

moraine • *an accumulation of unconsolidated glacial debris (soil and rock) that can occur in currently glaciated and formerly glaciated regions.*

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.*

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

frost wedging • *weathering that occurs when water freezes and expands in cracks.*

plucking • *process in which a glacier "plucks" sediments and larger chunks of rock from the bedrock.*

pothole • *a shallow, rounded depression eroded in bedrock by a glacier.*

Landscapes

plunge pool • *a stream pool, lake, or pond that is small in diameter, but deep.*

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

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

plunge pools at the base of waterfalls. At the edge of the sheet, where the ice at last succumbs to melting, the rock is finally deposited. Piles of this rock form many of the distinctive landforms found in the Midwest today.

The nature of the glacier causing the erosion is also crucial. Because continental glaciers spread from a central accumulation zone, they can't go around peaks in their path, so they instead slowly crush and scrape them away. For the most part, this results in flatter landscapes. Conversely, alpine glaciers tend to follow the existing topography, flowing downhill. This frequently causes them to scour existing low places, making them lower still. While this gouging increases the overall relief of an area, anything directly in the path of the ice is flattened. For example, a glacier might deepen a valley while surrounding peaks remain high, yet the valley itself, initially cut by a narrow stream into a sharp V-shape, is smoothed into a distinctive U-shape by the wider glacier.

Deposition

As glaciers scrape over the earth, sediment is incorporated into or shoved ahead of the advancing ice (*Figure 6.2*). The unsorted mixture of boulders, gravel, sand, **silt**, and clay that is picked up and later deposited by glaciers is called **till**. It is important to note that whether a glacier is advancing, in equilibrium, or retreating, its ice is still flowing forward, like a conveyor belt that is constantly depositing till at its margin. Where a glacier stopped its advance and then melted back, a ridge of till that had been pushed in front of it is left behind,

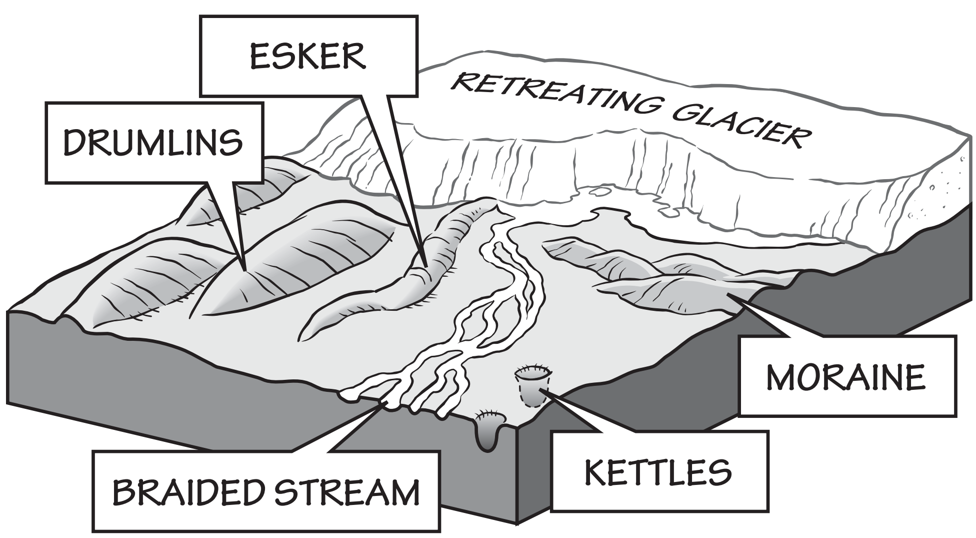

Figure 6.2: Glacial features.

marking the farthest extent of its margin, or terminus. A ridge of till formed this way is called a moraine, and it may range in length from hundreds to thousands of meters. A drumlin is 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. The elongation of a drumlin is an excellent clue to the direction of flow during an ice sheet's most recent advance.

Meltwater flowing off a glacier also leaves behind deposits. Unlike till deposits, meltwater deposits are well-sorted: large rocks can only be moved by high-energy water, while finer sand and mud are washed downstream until enough energy is lost that even they are dropped. In other words, the faster the water is moving, the coarser the sediment deposited (*Figure 6.3*). As a glacier melts, streams of sediment-laden meltwater often create networks of **braided streams** in front of the glacier. Streams of meltwater flowing under a glacier can deposit sand and gravel. When an ice sheet retreats, these snaking ridges of stream deposits, known as **eskers**, are left standing.

Other glacial features include kettles, **kames**, and **erratics**. Kettles are depressions left behind by the melting glacier. Blocks of ice may be broken off from the glacier and buried or surrounded by meltwater sediments (*Figure 6.4*). When the ice eventually melts, the overlying sediments have no support, so they frequently collapse and form a depression that often fills with water to become a lake. Many kettle lakes and ponds are found throughout the Midwest, particularly the 10,000 lakes area of Minnesota, and most of the inland lakes of Wisconsin and Michigan formed in this way as well. Kames are formed in nearly the opposite way; layers of sediment fill in depressions in the ice, leaving mound-like deposits of sorted sediment after the glacier retreats (*Figure 6.5*). Often the kettles and kames occur near one another. Erratics are rocks that the ice sheet picked up and transported further south, sometimes hundreds of miles from their origin.

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

kame • *an irregularly shaped mound made up of sediment that accumulated in a depression on a retreating glacier.*

erratic • *a piece of rock that differs from the type of rock native to the area in which it rests, carried there by glaciers often over long distances.*

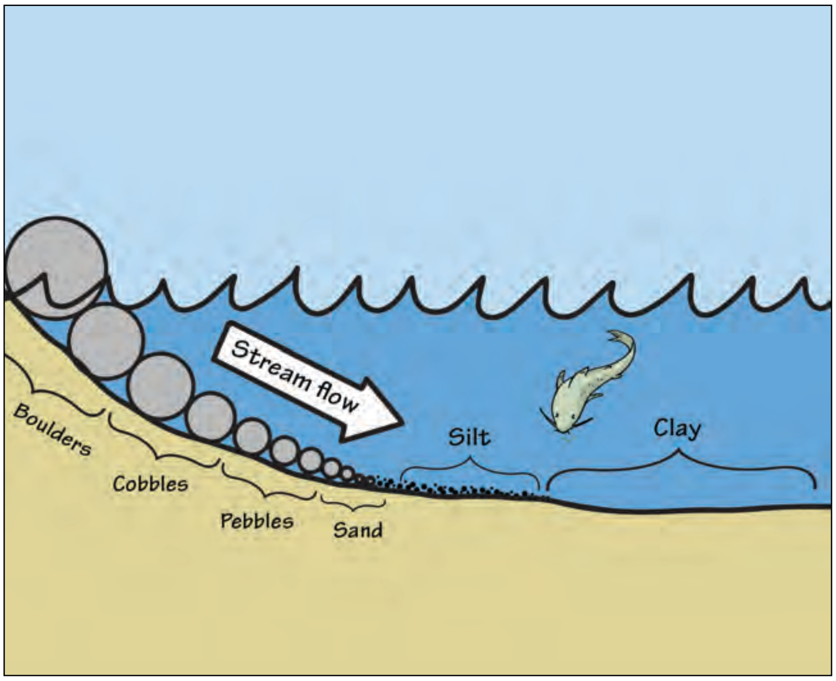

Figure 6.3: Moving water deposits sediments in what is known as a horizontally sorted pattern. As the water slows down (i.e., loses energy), it deposits the larger particles first.

A well-sorted deposit has a relatively uniform grain size.

Glaciers

Landscapes

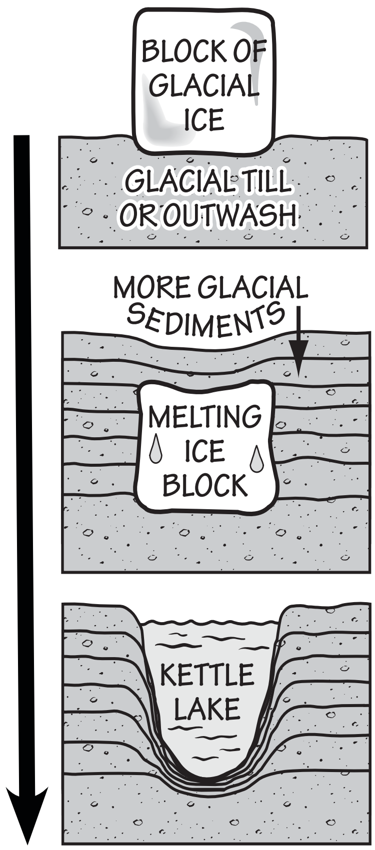

Figure 6.4: Steps in the formation of a kettle lake.

Erratics **are often distinctive because they are a different type of rock than the bedrock in the area to which they've been transported. For example, boulders and pebbles of igneous and metamorphic rocks are often found in areas where the bedrock is sedimentary; it is sometimes possible to locate the origin of an erratic if its composition and textures are highly distinctive. Anyone who has tried to till a field or garden in the Midwest is familiar with rocks like this.**

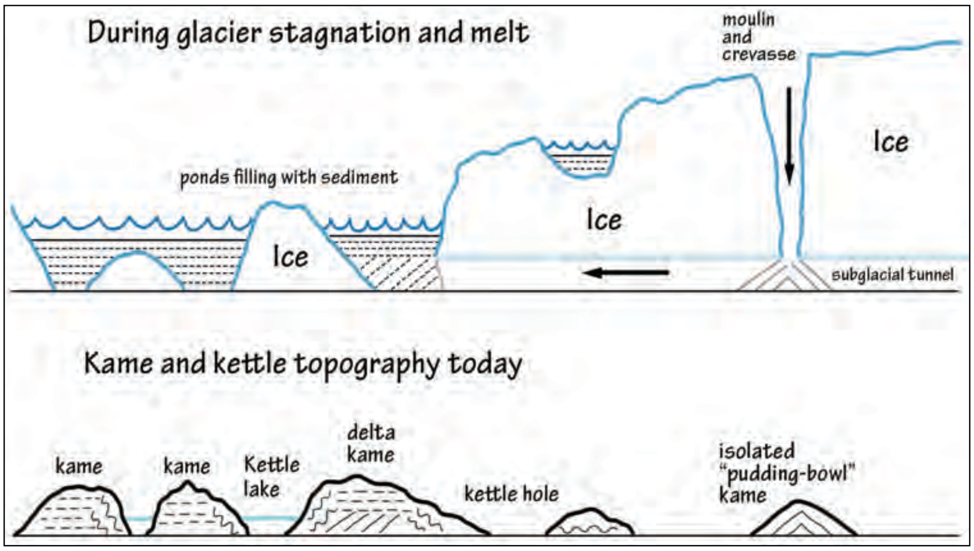

Figure 6.5: Glacial sediment deposits and the resulting hills called kames.

Periglacial Environments

Though a few areas in the Midwest were never covered by the ice sheet, the entire area felt its effects. The portion covered by the ice sheet was scoured and covered with glacial deposits; the area south of the ice sheet has its own distinctive landscape and features because it was next to the ice margin. This unglaciated but still affected zone is called a **periglacial zone**.

> **The average annual air temperature in a periglacial area is between -12° and 3°C (10° and 37°F). Though the surface of the ground may melt in the summer, it refreezes in the winter.**

There are a variety of features associated with a periglacial zone that also provide clues to the extent of the most recent ice sheet. In the tundra-like environment of a periglacial zone, **aeolian**, or windblown deposits are common. Sand dunes and **wind**-transported sediments are found in former periglacial areas and in glacial lake bottoms of the Midwest.

The **permafrost** associated with the periglacial area, in which the ground is frozen much of the year, can cause mass movement of sediment. When the surface layer of the permafrost ground thaws, it is full of moisture. This water-heavy layer of **soil** may move rapidly down a hill in a process called **solifluction**.

Physical **weathering** of the bedrock is magnified in the periglacial environment because of the freeze-thaw cycles associated with permafrost. When water enters the cracks and fissures in the ground and subsequently freezes, the ice wedges the cracks farther and farther apart (*Figure 6.6*). Freeze-thaw is important in any climate that vacillates above and below the freezing point of water. Because ice takes up more space than water, the pre-existing cracks and fractures are widened when the water freezes. Along ridges, rocks are eventually broken off as ice wedges continue to expand in joints and fractures. The boulders and blocks of bedrock roll downhill and are deposited along the slope or as fields of **talus**. Frost action also brings cobbles and pebbles to the surface to form nets, circles, polygons, and garlands of rocks. These unusual patterns of sorted rock are known as **patterned ground**. Solifluction and ice wedging are found exclusively where the ground remains perennially frozen, yet is not insulated by an ice sheet. Such conditions only occur in areas adjacent to ice sheets. While conditions like these existed in the Midwest at this time and led to the formation of patterned ground, any evidence was subsequently covered with glacial sediment or eroded away.

> ***Physical weathering* is the break-up of rock due to physical processes (such as erosion by wind, water, and ice) rather than chemical processes.**

wind • *the movement of air from areas of high pressure to areas of low pressure.*

permafrost • *a layer of soil below the surface that remains frozen all year round. Its thickness can range from tens of centimeters to a few meters.*

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

solifluction • *a type of mass wasting where waterlogged sediment moves slowly downslope, over impermeable material.*

talus • *debris fields found on the sides of steep slopes, common in periglacial environments.*

Ice Ages

last glacial maximum • *the most recent time the ice sheets reached their largest size and extended farthest towards the equator, about 26,000 to 19,000 years ago.*

Neogene • *the geologic time period extending from 23 to 2.6 million years ago.*

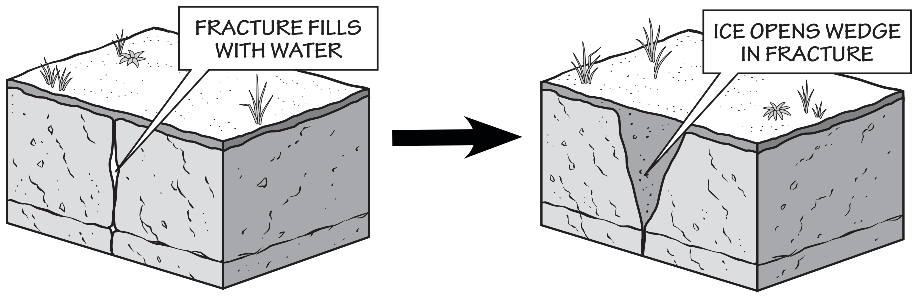

Figure 6.6: Physical weathering from a freeze-thaw cycle.

Ice Ages Over Time

As discussed in Chapter 9: Climate, for much of Earth's history there have not been persistent ice sheets in high latitudes. Any time that the world is cool enough to allow them to form is called an "**ice age**." We are therefore living in an ice age right now! The current ice age began about 34 million years ago when ice sheets were first forming on Antarctica, followed by Greenland at least 18 million years ago, and finally on North America, which defined the beginning of the Quaternary period (about 2.6 million years ago). When most people use the phrase "the ice age," however, they are referring to the **last glacial maximum** that saw much of North America and Europe covered in ice thousands of meters / feet thick, while many kinds of large, wooly mammals roamed the unfrozen portions of those continents.

Age of the Quaternary

In 2009, scientists at the International Commission on Stratigraphy voted to move the base of the Quaternary period to 2.6 million years ago, bumping it to 0.8 million years earlier than the previous date of 1.8 million years ago—a date set in 1985. They argued that the previous date was based on data that reflected climatic cooling that was only local to the region in Italy where it was first observed. On the other hand, the 2.6 million year mark shows a global drop in temperature, and it includes the entirety of North American and Eurasian glaciation, rather than dividing it between the Quaternary and the earlier *Neogene* period.

Glaciers 6

Ice Ages

The Quaternary period is divided into two epochs. The earlier **Pleistocene** encompasses the time from 2.6 million to 11,700 years ago, including all of the Quaternary up until the most recent episode of glacial retreat. Most of the glacial features in the Midwest were created during the Pleistocene, because by the beginning of the **Holocene** 11,700 years ago, the glaciers had already retreated from much of the area.

Ice on a Schedule

The enormous continental glaciers that define an ice age are so large that their extent is most directly affected by global trends, while mountain glaciers are much more susceptible to local and short-term changes in climate. Continental ice sheets advance and retreat in cycles that last tens of thousands of years, controlled to a large extent by astronomic cycles.

Astronomic Cycles and Ice Sheets

The cyclical movements of ice sheets seem primarily to be caused by specific astronomic cycles called *Milankovitch cycles*, which change the amount of light the Earth receives, particularly when comparing the summer to the winter. The cycles, predicted through principles of physics a century ago, are related to the degree of tilt of the Earth, the Earth's distance to the sun, and the point in the Earth's revolution around the sun that the Northern Hemisphere experiences summer. When the cycles interact such that there are cool summers at high latitudes in the Northern Hemisphere (milder rather than extreme seasonality), glaciers can accumulate and thus advance. The cyclicity of glacial-interglacial advances was about 40,000 years from before the start of the Quaternary until about a million years ago. For reasons that aren't clear, however, the cycles changed to about 100,000 years. If not for human-induced climate change, we might expect glaciers to cover the Midwest again in about 80,000 years!

Scientists continue to debate the particular causes of the onset of glaciation in North America over two million years ago. Movement of the Earth's tectonic **plates** may have been a direct or indirect cause of the glaciation. As plates shifted, continents moved together and apart, changing the size and shape of the ocean basins. This, in turn, altered oceanic currents. Mountain building, which occurred when continents collided, erected obstacles to prevailing winds

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

Ice Ages

Wisconsinian glaciation • _the most recent interval of glaciation, which occurred during the Pleistocene, 85,000 to 11,000 years ago._

Illinoian • _a period of glaciation that occurred during the Pleistocene, 191 to 131 thousand years ago._

and changed moisture conditions. The freshly exposed rock from the rising of the Himalayas also combined with atmospheric carbon dioxide through chemical weathering; this consequent decrease in levels of atmospheric carbon dioxide was at least partially responsible for global cooling. Finally, the presence of continental landmasses over one pole and near the other was also a major factor enabling the development of continental glaciers.

While they have advanced over and retreated from the Midwest many times during the Quaternary, each advance, called a glacial period, scrapes away and reworks much of what was previously left behind, making it difficult to reconstruct the precise course of events. The two most recent glaciations, the **Wisconsinian** and the **Illinoian** stages respectively, are relatively well understood, while researchers believe there have been approximately 10 previous Midwestern glacial periods that are generally lumped together as "**Pre-Illinoian**." After all that ice, it's little wonder most of the Midwest has been worn nearly flat!

Seeking Detailed Records of Glacial-interglacial Cycles

When glaciers advance over the land, the historical rock records are largely erased with each glacial advance. Therefore, to investigate the details of any associated climate change we must seek environments that record climate change but are preserved. Since the 1970s, the international Deep Sea Drilling Project has provided a treasure trove of data on coincident changes in the ocean, preserved in sediments at the ocean bottom (*Figure 6.7*). In the 1980s, coring of ice sheets in Greenland and Antarctica provided similarly high-resolution data on atmospheric composition and temperature back nearly one million years (*Figure 6.8*). The data from these programs have revealed that the Earth, particularly the Midwest, experienced dozens of warming and cooling

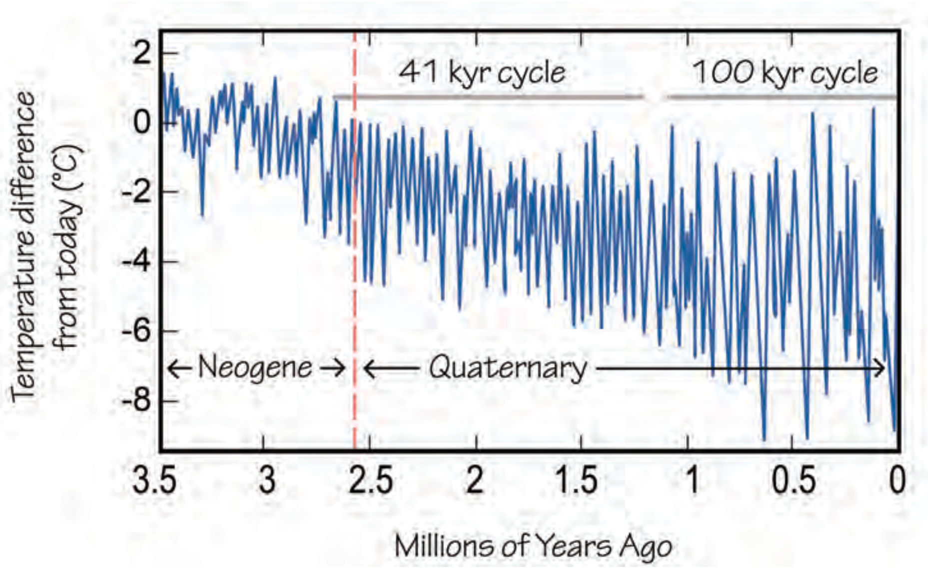

Figure 6.7: Ocean bottom temperatures from 3.6 million years ago to present, based on chemical analyses of foraminifera shells. Notice how the amplitude of glacial-interglacial variations increases through time, and how the length of cycles changes.

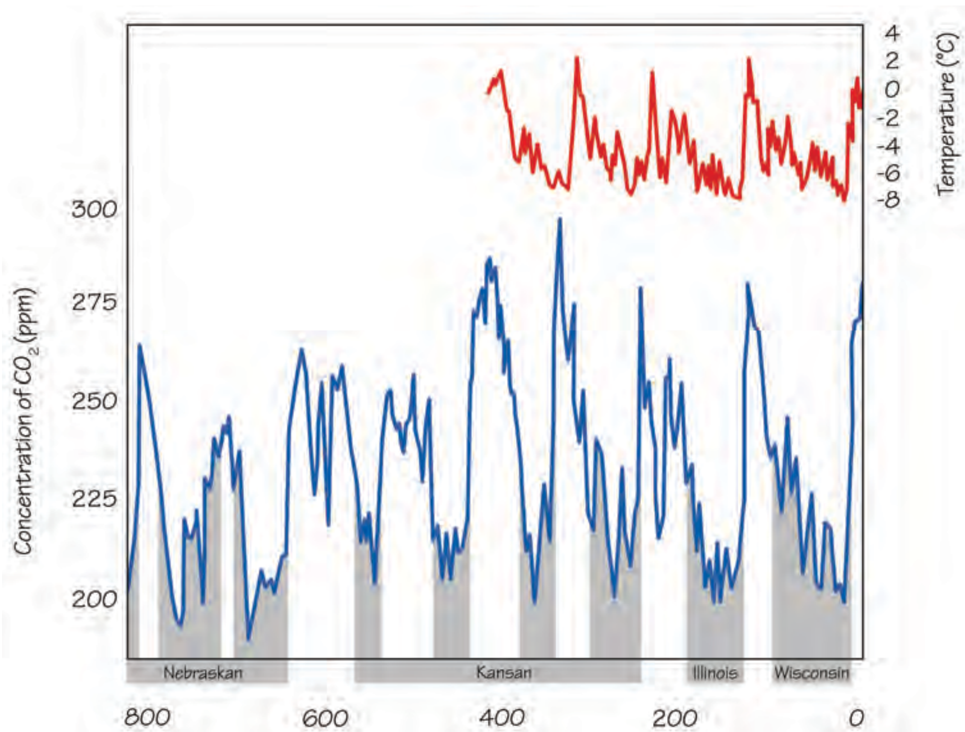

Figure 6.8: Atmospheric temperature and carbon dioxide concentrations from an ice core taken in Vostok in Antarctica and CO_2 data from several cores. Midwest glacial deposits are represented in gray at the bottom. Note that Kansan and Nebraskan deposits represent more than one glacial advance.

cycles over the course of the Quaternary period. Most of the earlier and less extensive Pleistocene glacial advances that occurred in the Midwest have been completely erased on land and so were unknown before records from deep-sea cores and ice cores revealed them.

From the Pleistocene to the Present

A cooling climate triggered the start of a series of glacial advances shortly before the Pleistocene began. The most recent glacial period, prior to the present **interglacial** period, began 65,000 years ago and affected the Midwest until about 10,000 years ago. Initially, the ice that covered the Midwest spread from a single **dome** located in northern Canada over the Hudson Bay. Approximately 20,000 years ago, this ice sheet reached its maximum extent, reaching as far south as northernmost Kansas and Kentucky (*Figure 6.9*).

The formation of glaciers comes from the precipitation of water that originates from the evaporation of ocean water. Thus, significant glacial build-up ties up water in ice sheets, causing a sea level drop. During the Pleistocene glacial advances, the sea level dropped an estimated 110 meters (360 feet)!

Pleistocene

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

ice dome • *the spreading center of an ice sheet.*

Pleistocene

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

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

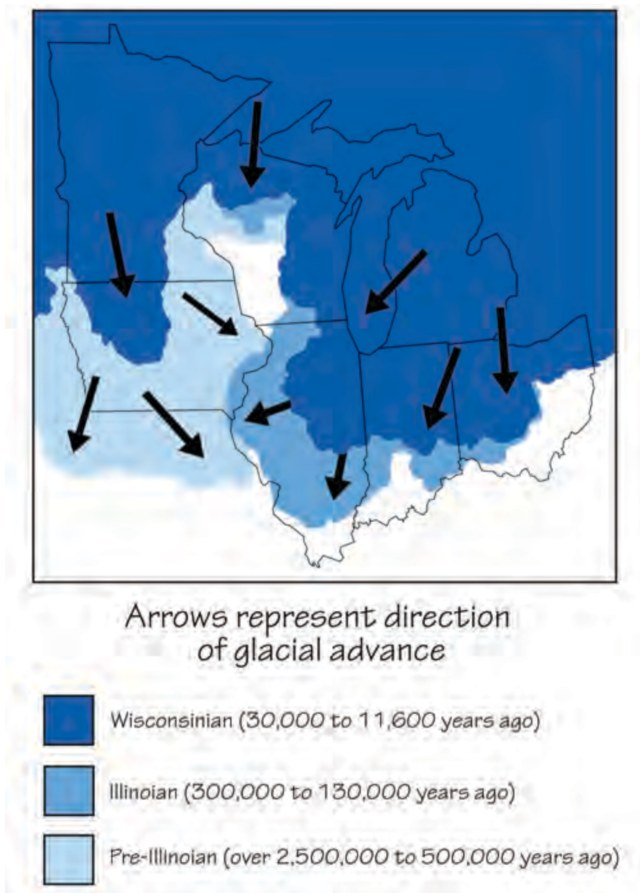

Figure 6.9: Glaciers flowed south during glacial advances; each advance differed slightly and left different sets of deposits.

By 18,000 years ago, the ice sheet was in retreat because of a slight warming of the climate. Though the ice sheet alternately moved forward and melted backward, overall it was on the retreat. Even during glacial advance, the glacier was always melting at its fringes. During times of glacial retreat, the ice sheet was not actually flowing backwards: the glacier continued to flow forward, but it was melting faster than it was advancing.

Rebounding of the Crust

The ice sheets could exceed two kilometers (1.2 miles) in thickness. The enormous weight of all of that ice over the continent depressed the **crust** into the **asthenosphere** (the uppermost part of the **mantle**) just as the weight of a person in a canoe causes the boat to ride lower in the water. When the person steps out of the canoe, the buoyancy of the canoe allows it to once again rise. As the ice sheet retreated from the Midwest during the current interglacial period, the crust rebounded, and it continues to do so today. The equilibrium achieved between the crust and mantle is known as **isostasy** (*Figure 6.11*). This rebound is thought to be a cause of infrequent, but occasionally severe, seismic activity in the Midwest.

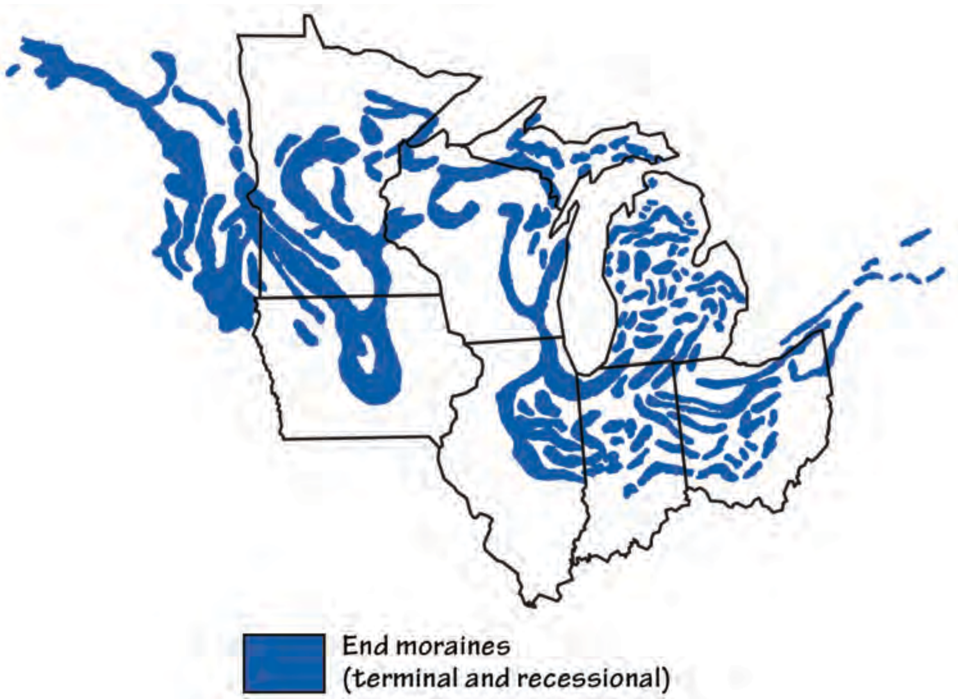

Figure 6.10: In addition to other deposits, glaciers resulted in moraine deposits through the Midwest, in some cases adding topographic relief to otherwise flat terrain. The moraines help define the extent of glacial advances.

The *Iowa Pleistocene snail* was abundant throughout the Midwest during much of the Pleistocene epoch. At one time it was only known from the fossil record and thought to have gone extinct after the last glacial maximum, but it was discovered alive and well in 1955. It survives today scattered among a few dozen algific talus slopes in five counties in Iowa and one in Illinois. It is currently classified as an endangered species.

Iowa Pleistocene snail* (Discus macclintocki), *found only in specific types of karst habitats. Adult shell width about 7 mm (0.25 inch).

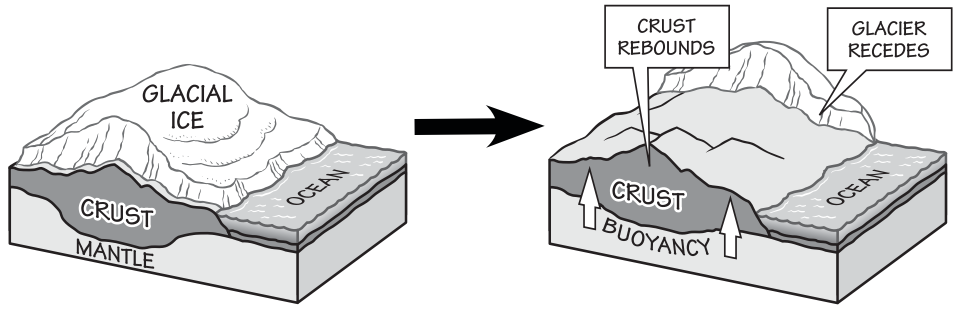

Figure 6.11: Through isostacy, glaciers push the crust down, and, when they melt, the crust rebounds upward.

The Great Lakes

The Great Lakes are a prominent geologic feature of the Midwest and include three of the five largest lakes in the world. In fact, they contain 21% of the world's fresh water. And 20,000 years ago, they did not exist. At that time, the ice sheets extended well past where the lakes would come to be prior to glaciation. The Great Lakes were actually river valleys that had been scoured and deepened repeatedly by the numerous ice advances during the Quaternary period. Many sizable glacial lakes were formed at the edge of the melting glacier, yet they no longer exist today or have significantly shrunk in size. As the glacier retreated and the basins filled with glacial runoff, the still-forming lakes drained southward, eventually into the Mississippi River (*Figure 6.12*).

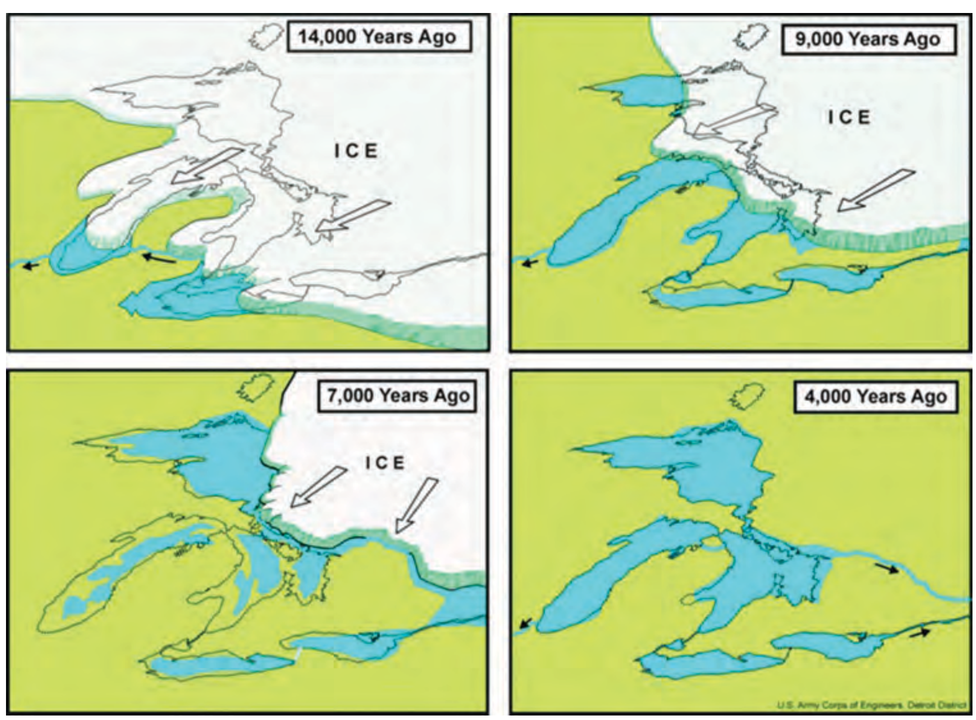

Figure 6.12: Glaciers over the Midwest retreated over the course of 10,000 years after the Last Glacial Maximum, leaving behind the Great Lakes, among other features.

The Loess Hills

The Loess Hills of extreme western Iowa, extending into northwesternmost Missouri, are named after a glacial deposit formed of windblown rock flour: **loess**. This type of glacial feature is found in only a few places on Earth. Loess deposits are found in parts of Wisconsin, Minnesota, Illinois, and Iowa, but the loess hills in Iowa represent the most prominent of all the loess deposits. While these hills form only a very narrow, 320-kilometer (200-mile) long, north-south band immediately east of the Missouri River **floodplain**, they are an important part of the story of the glaciation of the Midwest (*Figure 6.13*). The hills stand more than 60 meters (200 feet) above the surrounding low farmland and often display very sharp profiles, having been cut away into steep bluffs. They were formed during several glacial/interglacial cycles when glaciers ground down the bedrock. Then, as the ice retreated, meltwater deposited the fine sediments in expansive mudflats. When the mudflats dried, strong westerly winds blew the sand into great dunes, and the finest material (silt and clay) was carried farther in massive dust clouds. The dunes were eventually stabilized by vegetation and matured into the hills, but the loose material of the hills can still be easily eroded and carved. Slumping, mudslides, and undercutting caused by wind and water have produced steep slopes and a landscape of narrow ridges.

floodplain • *the land around a river that is prone to flooding.*

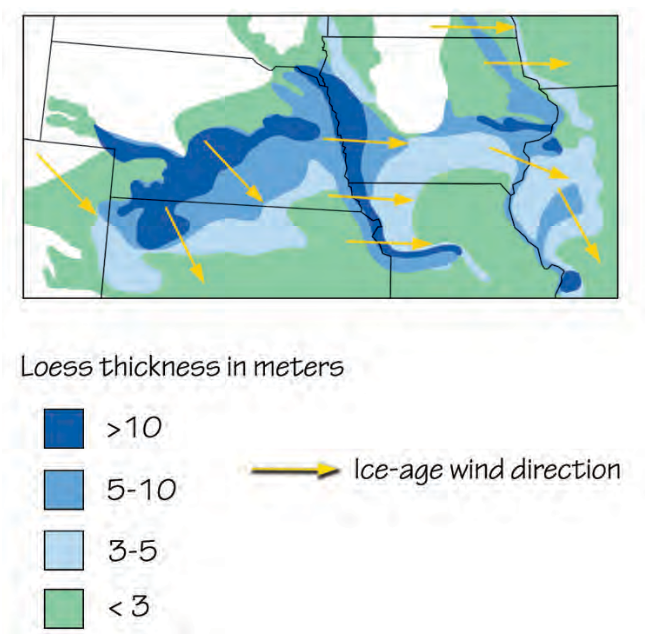

Fig 6.13: Thickness of loess deposits in Midwest.

Much of the soil throughout the Midwest is composed, in part, of sediment blown from the huge mudflats on the banks of the ancient Missouri River, which was a major channel for floods of glacial meltwater.

karst topography • *a kind of landscape defined by bedrock that has been weathered by dissolution in water, forming features like sinkholes, caves, and cliffs.*

Driftless Area

The Driftless Area, also known as the Paleozoic Plateau, is located around the upper Mississippi River valley where Minnesota, Wisconsin, Iowa, and Illinois meet. It is a place that beautifully contrasts with the surrounding glacial landscape because the Driftless Area was completely missed by the advancing ice during the Pleistocene. Its deep valleys, steep bluffs, and high hills stand in stark relief to the flat plains surrounding it, and it is suggestive of what the rest of the Midwest might have looked like before glaciers leveled it. The Driftless Area's topography is largely controlled by the water flowing through it, which has been carving into its rock for millions of years. Other creeks and rivers in the Midwest have been following their current courses for a few tens of thousands of years at most—orders of magnitude less time in which to shape their landscapes. As they scraped over the area, the ice sheets covered river valleys and filled them with sediment, forcing water to flow around their margins, effectively shoving the rivers out ahead of them. Much of the Missouri, Ohio, and Mississippi Rivers outline the farthest extent of ice sheet advances. This underscores the importance of glaciers to the Midwest: the borders of several states, defined by these rivers, are the direct result of glacial action!

The Driftless Area is an example of **karst topography**, a kind of landscape defined by bedrock that has been weathered by dissolution in water, forming features like sinkholes, caves, and cliffs (*Figure 6.14*). Here, cold underground lakes create a kind of natural air conditioning that cycles air into cracks and caves in the rock where it is cooled by the water before returning to the surface. This unique geologic phenomenon, coupled with cliffs that block much of the sunlight, make microhabitats that are tens of degrees cooler than the surrounding area just yards away. These habitats, called algific talus slopes, tend to occur only on the northern slopes of hills where they receive very little sunlight, and they are scattered across the Driftless Area. Furthermore, they do not occur anywhere else on Earth. They are home to unique flora and fauna, many members of which are usually only found much farther north, and some of which are no longer found anywhere else. In short, in many ways the Driftless Area is like a time capsule of the ancient Midwest.

Figure 6.14: Cave of the Mounds near Blue Mounds, Wisconsin.

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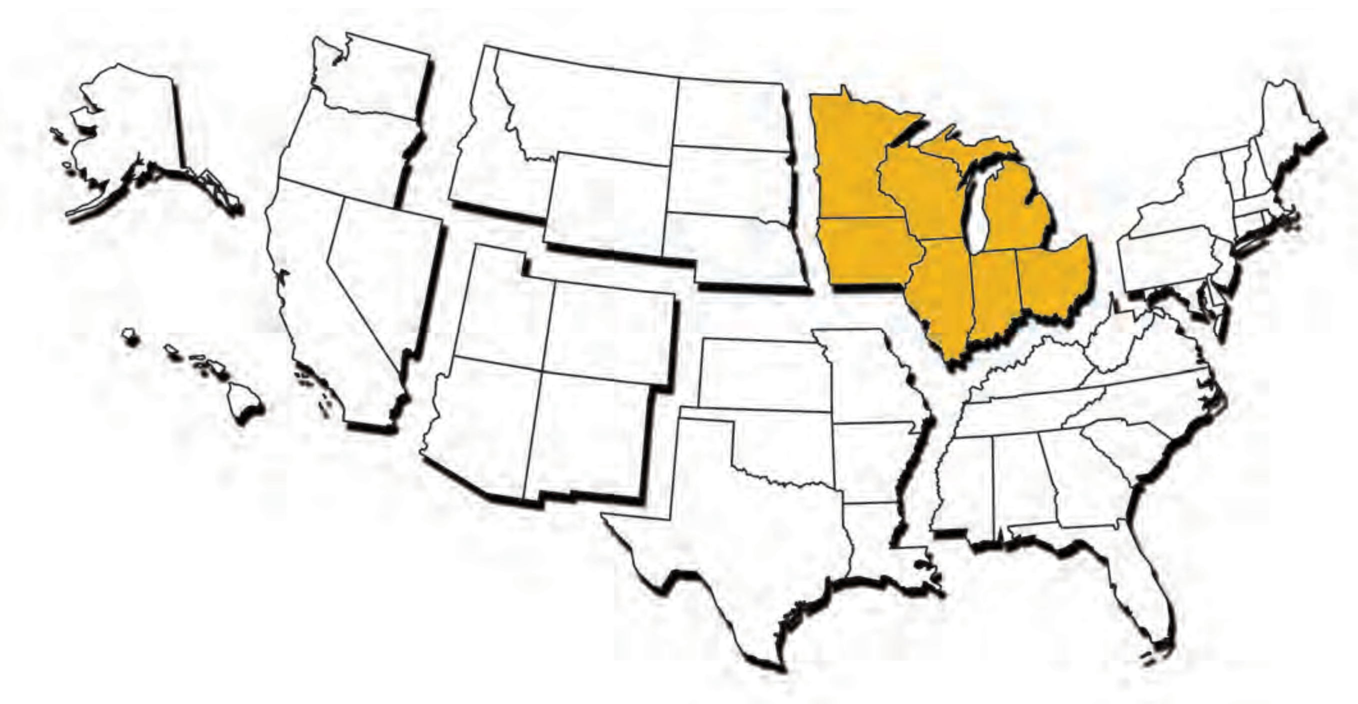

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On the back cover: Blended geologic and digital elevation map of the Midwest. Each color represents the age of the bedrock at the surface. Adapted from Barton, K.E., Howell, D.G., Vigil, J.F., *The North America Tapestry of Time and Terrain*, US Geological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