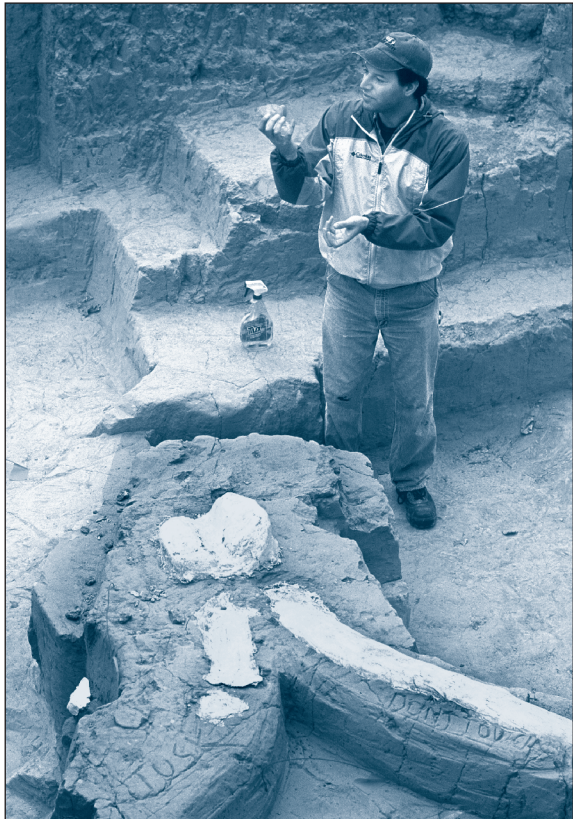


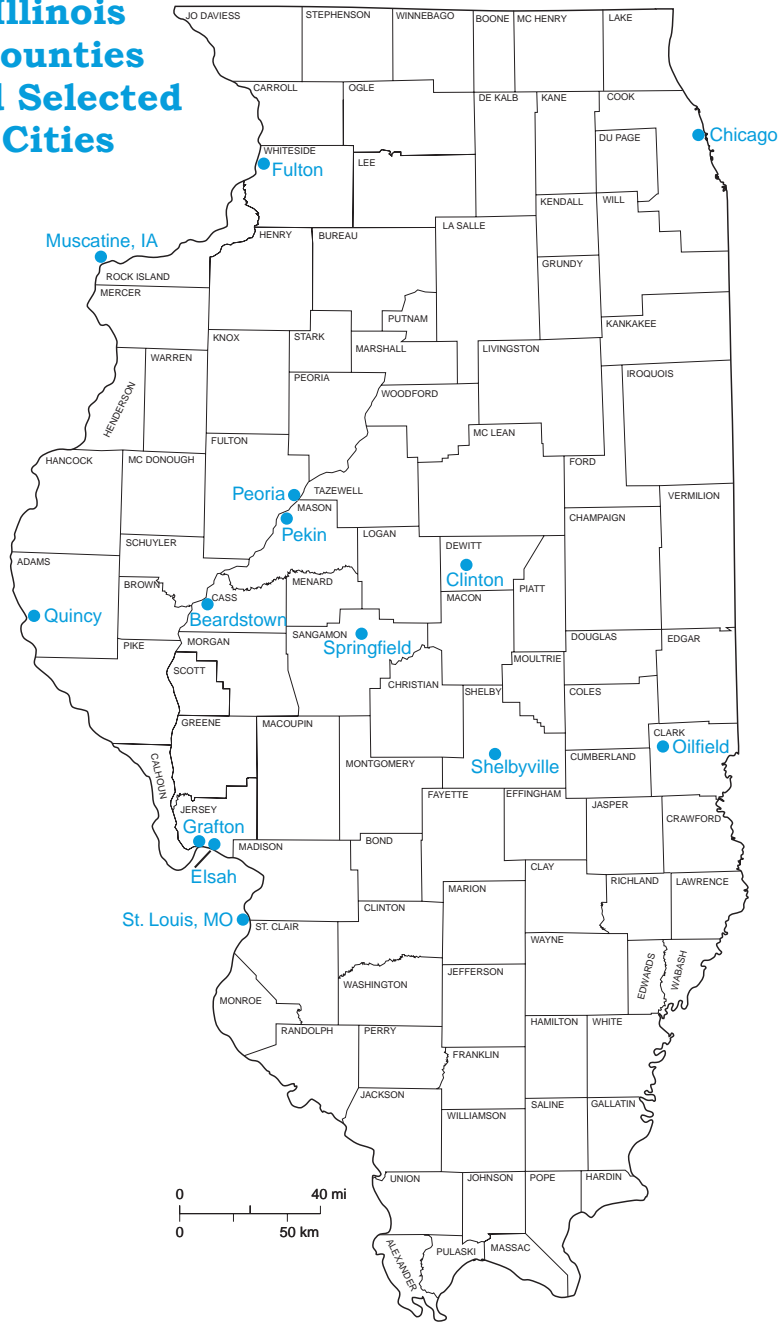


# Illinois' Ice Age Legacy

Myrna M. Killey



# Illinois Counties and Selected Cities



*Cover photographs (clockwise from upper left): Looking across the meltwater channel in the northern half of the Marseilles Morainic System in northern Illinois; Camelback Kame, along Deerpath Trail, Glacial Park, McHenry County Conservation District; ISGS geologist explaining the depositional environment of the tusks and teeth of a fossil woolly mammoth discovered in loess deposits on Principia College campus, Elsau, Illinois; the view from the top of Camelback Kame. (Moraine channel and woolly mammoth photographs by Joel M. Dexter; Camelback Kame photographs by Cheryl K. Nimz.)*



# Illinois' Ice Age Legacy

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**Myrna M. Killey**

**Geoscience Education Series 14    2007**

Illinois Department of Natural Resources  
**ILLINOIS STATE GEOLOGICAL SURVEY**

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# Foreword

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A varied and fascinating geology is buried beneath the relatively flat Illinois plains. A well driller boring down into the earth in Illinois passes through many different layers of soils, sand and gravel, pebbly clay, and silt before hitting bedrock. These varied deposits and the shape of the bedrock surface on which they rest are due to huge continental glaciers that repeatedly advanced and retreated across Illinois in the last 1½ million years.

Much of what we take for granted in our daily lives—soil, water, and minerals, the resources that nurture all life and sustain our society—is the legacy of these glaciers.

A great deal of Illinois' economy and well-being depends on the riches we have in the deposits, or drift, left by the glaciers.

- Illinois' rich agricultural soils developed in the windblown loess and till left by the melting glaciers.
- Much of our drinking water is pumped from aquifers of glacial sands and gravels.
- The sand and gravel essential to every building and road project was left by runoff from the glaciers.
- The diversity of our forests, prairies, and wildlife habitats depends on the different deposits and landscapes left by the retreating glaciers.

The importance of glacial drift was obvious to the writer Ignatius Donnelly back in 1883. He wrote of the drift covering much of North America:

It is our earth. It makes the basis of our soils; our railroads cut their way through it; our carriages drive over it; our cities are built upon it; our crops are derived from it; the water we drink percolates through it; on it we live, love, marry, raise children, think, dream, and die; and in the bosom of it we will be buried.

*—Ragnarok: The Age of Fire and Gravel*

Awareness of glacial deposits is important for yet another reason—preserving a safe and healthy natural environment for ourselves and our children. As citizens, we face many crucial health and environmental issues that involve landscapes composed of glacial deposits:

- keeping our drinking water, rivers, and streams free of contamination;

- protecting ourselves against floods, earthquakes, and erosion of soil and beaches;
- siting landfills, agricultural facilities, and low-level radioactive waste disposal sites safely;
- reclaiming land contaminated by previous generations;
- maintaining natural areas and wetlands for habitat and recreation.

As citizens, finding local solutions to these problems requires a basic understanding of these glacial materials and how they were formed.

This book introduces you to the legacy of glaciers in Illinois: the ways geologists study and learn about them, the history of the many glaciations, and descriptions of the deposits they left behind. I hope, when you next look out over the landscape of our state, that you'll see more than the relatively flat landscape around you and realize that much of what affects your daily life is a legacy of the massive glaciers that once covered Illinois.

—William W. Shilts, Chief  
Illinois State Geological Survey

# Acknowledgments

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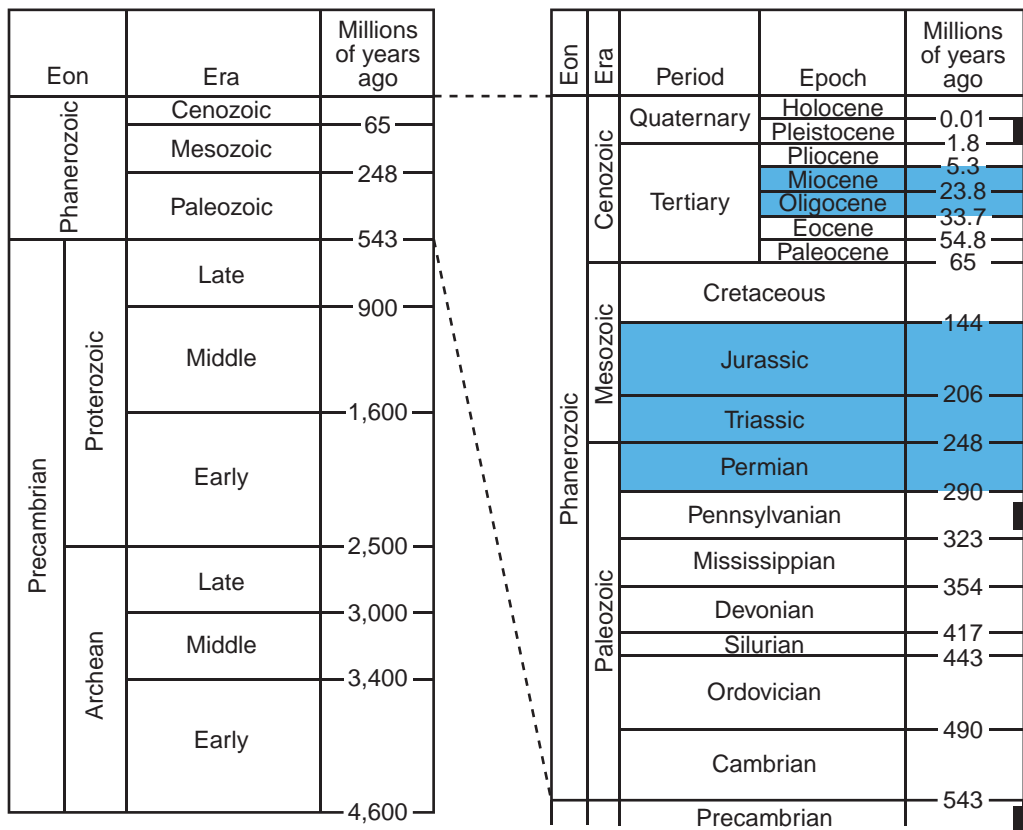
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# The Great Ice Age and Its Importance

Although the Earth is calculated to be roughly 4.6 billion years old, the face of most of Illinois is quite young—mere thousands of years old (fig. 1). Due to various climate changes about 1.8 million years ago, immense sheets of ice, called glaciers, flowed outward from centers of snow accumulation in Canada (fig. 2). (Some sources say these climate changes occurred 2.5 to 3 million years ago, but that is still only yesterday in geologic time.) Eventually, the glaciers crept far enough south to invade what is now Illinois. In time, the climate warmed again, and the ice sheets melted back. Such episodes of ice advance and withdrawal occurred several times.



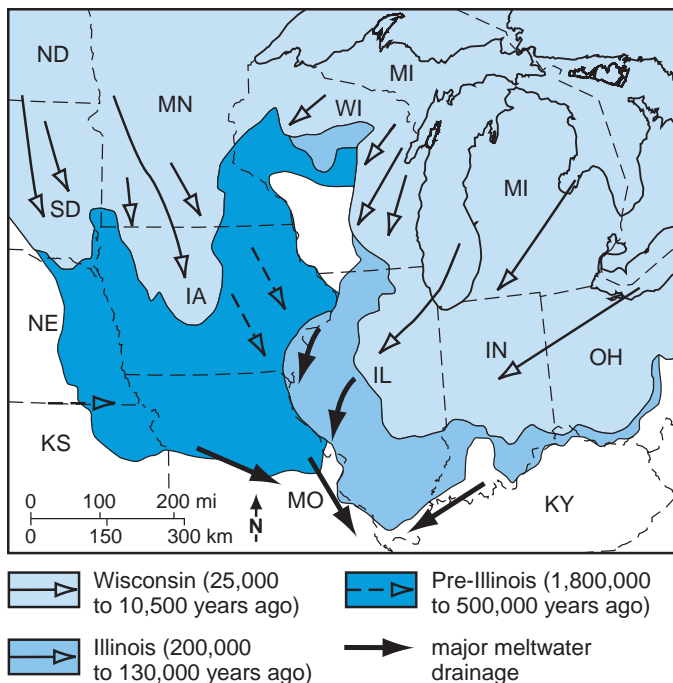
**Figure 1** Geologic time scale showing how recent and short-lived the Great Ice Age of the Pleistocene was in comparison to the age of the Earth. Blue shading indicates periods and epochs for which no deposits are known in Illinois. Small black rectangles indicate times of major ice ages. Based on the Geological Society of America 1999 *Geologic Time Scale* (Palmer and Geissman 1999).



**Figure 2** Glaciers spread southward into the Midwest from the northwestern and northeastern centers of ice accumulation in west-central and eastern Canada.

Imbedded in each successive glacier were immense amounts of ground-up rock debris gouged out of the *bedrock* (italicized terms are defined in the glossary) in Canada and the northern United States as the glacier slowly pushed southward. As the last glacier to reach Illinois melted and left behind the final load of rock debris, the land that emerged looked far different from the preglacial landscape. Hills and valleys on the old rock surface had been buried, new ones had formed over them, and a thick mantle of ground-up rock debris—called *glacial drift*—lay over most of the land.

These continental glaciers affected Illinois in several ways. First, rock debris was deposited by glaciers that came from both the northwestern and the northeastern centers of ice accumulation in Canada (figs. 2 and 3). Second, drainageways for meltwater from the glaciers converged here from the northeast, north, and northwest (fig. 3). Third, the



**Figure 3** The southern limits of major glacial advances into the Midwest. Major meltwater drainageways converged here from the northeast, north, and northwest (Prior 1991).

continental glaciers spread farther south in Illinois than anywhere else in the United States (37°30' N latitude; fig. 3).

Although the last glacier disappeared from Illinois between 14,000 and 13,000 years ago, to the geologist, glaciers are very recent visitors to the state. Of the approximately 4.6 billion years of Earth history (fig. 1), the *Quaternary*, which began with the Great Ice Age and continues to the present, makes up only about the last 0.03% of that history! The time spanned by the Great Ice Age alone is called the Pleistocene Epoch. Geologists prefer to use the term Quaternary because certain geologic processes affecting sediments deposited during the Great Ice Age are continuing on the landscape today.

## “Quaternary”: What Does It Mean?

The term Quaternary (pronounced Quat-ter'-nah-ree") is a relic of the earliest attempts to subdivide the geologic record and establish a time classification scheme for the rocks and sediments observed at the Earth's surface. But, if we still use the term “Quaternary,” or “fourth,” what happened to Primary, Secondary, and Tertiary?

Giovanni Arduino, an eighteenth century Italian who studied the Alps and plains of Italy, based his classification scheme on the degree of metamorphism, structure, and hardening of rocks. Arduino observed that the core of the Alps consists of crystalline rocks; because these were obviously the first formed, he called them Primary. The flanks of those mountains are strongly deformed fossiliferous limestone and marble, and he named these strata Secondary. He classified the unlithified sediments of the plains as Tertiary and later alluvial (river) and lake deposits as Quaternary.

This scheme was useful for early studies and was applied elsewhere in Europe and America until the 1820s. As geologic understanding of other areas and mountain ranges grew, however, it became clear that all mountain ranges were not the same age and had not been formed in the same manner. The terms Primary and Secondary were, therefore, misleading and were eventually discarded. Attempts have been made to eliminate the terms Tertiary and Quaternary, but their use has persisted. The term Tertiary has come to refer to the often unlithified preglacial formations of the Cenozoic Era (fig. 1), and Quaternary labels the period from the beginning of the Ice Age to the present and the sediments deposited during this time.

Despite their geologically short visit, the glaciers left a rich legacy of natural resources that first supported Native Americans and later attracted Europeans to settle in what is now Illinois. Ice Age deposits also form the natural foundation for construction—houses, cities, factories, highways, bridges, dams, and other structures. We must understand the characteristics of these materials and how natural processes affect them in order to identify and avoid associated potential hazards, such as landslides and unstable slopes. Finally, much of the waste produced by our society is buried in Ice Age deposits. Clearly, it is important for us to learn as much as we can about these interesting and useful materials.

## Natural Resources

### Soils

Illinois' highly productive soils are one of the Ice Age's richest legacies to the state. The rich soils of Illinois grow enough crops to feed much of the nation. Many of these soils developed in *loess*, a wind-deposited silt that blankets most of the state (see p. 14). Loess is one of the best possible parent materials for soil development suited for agriculture. It is rich with a wide variety of minerals that crops need and has a uniform, medium *texture*—one that retains moisture but is neither as coarse grained and loose as sand and gravel nor as fine grained and sticky as clay. Loess contains no cobbles or boulders that can interfere with plowing, and it retains moisture well.

### Water

Water is our most essential resource. Rain and snow collect in lakes and streams or seep into the ground to form groundwater. Approximately 50 percent of the state's population depends on groundwater to supply its water needs. Glacial deposits contain significant groundwater sources, although amounts and quality differ from area to area. Where water-saturated, the numerous and widespread sand and gravel deposits throughout the glaciated area of Illinois provide water to wells in amounts ranging from small domestic supplies to large municipal supplies. Abundant groundwater supplies also help meet the heavy demand of large urban areas such as the greater Chicago region and the areas of southwestern Illinois that form part of the St. Louis metropolitan complex.



## Mapping Ice Age Deposits to Find Water

Over the years, many ISGS geologists studying groundwater resources have responded to requests for information about developing groundwater supplies for homes, farms, industries, and towns. Because much of the state is covered by Ice Age deposits and the bedrock that underlies large areas of Illinois yields little or no water, a knowledge of the water-yielding characteristics of the glacial deposits is extremely important.

For example, when an ISGS geologist receives a request for information to help a new homeowner in a rural area develop a groundwater supply and has to reply that there are no known sources of water at that new site, the geologist and the homeowner both realize how important it is to be able to predict the distribution of water-yielding deposits. Within the glacial deposits, the principal sources of water (aquifers) are the layers of sand and gravel. These deposits are often buried within or below tills. Anyone who has dug a shallow hole in beach sand on the shore of a lake knows that water moves very rapidly into that hole once the water level of the lake is reached.

A sand and gravel deposit that allows water to move rapidly from the deposit into a well is what the geologist and homeowner seek. When no sand and gravel deposits are present and the bedrock does not yield water, the homeowner may have to haul water or construct a large-diameter well. Water can move only very slowly through clayey glacial deposits. The large well diameter allows water to collect over a long period to meet the home's most minimal needs.

If the people purchasing rural properties are able to consult maps that show the thickness, depth, and extent of sand and gravel bodies, they would certainly be more likely to choose an area where they could get water. The same could be said for selecting a site for a new development or industry.

Detailed mapping of the glacial deposits in Illinois, therefore, is a very important mission of the Illinois State Geological Survey. More information about the importance and relationship of geological mapping to groundwater location and protection can be found in *Illinois Groundwater: A Vital Geologic Resource*. See *Land-Use Decisions and Geology: Getting Past "Out of Sight, Out of Mind"* to learn about how mapping glacial deposits can lead to better, more informed decisions.

## Sand and Gravel

In addition to storing groundwater, sand and gravel deposits provide excellent materials for numerous commercial and industrial uses, including concrete aggregate, construction fill material, road gravel, building sand, and molding (casting) sand. Sand and gravel deposits are evaluated by their thickness, extent, thickness of any overlying deposits (*overburden*) that must be removed to reach them, distribution of particle sizes, and the quality of the gravel for given uses. The most valuable sand and gravel deposits contain at least 25 percent gravel and can produce large volumes of coarse and fine aggregate of the right composition for use in concrete.

## Natural Gas

We generally think of natural gas (including “drift gas”) occurring in association with petroleum. However, some natural gas forms in glacial deposits through the decay of *organic matter* in buried soils, peats, and organic-rich silts. The gas is confined in these layers or in porous layers of sand and gravel by thick, overlying deposits of mixed clay, silt, sand, pebbles, cobbles, and boulders called *till* (till formation and properties are discussed on p. 12). Several billion cubic feet of drift gas have been used to heat homes in Illinois over the years; it is a significant economic resource.

## Peat

Peat is partially decomposed and disintegrated plant matter formed by the natural accumulation of plant materials in poorly drained areas such as bogs. The occurrence of peat in Illinois is spotty and localized, but peat is produced commercially in Lake and Whiteside Counties. (See inside front cover for map of Illinois counties and select cities.) Peat has horticultural uses as a soil conditioner to increase organic content, make clayey soils more friable (easily broken or pulverized), and increase moisture retention.

## Fill Materials

Many construction projects require fill materials to provide uniform foundation conditions for buildings. Most tills and clayey glacial deposits provide good fill materials, although all must be tested for their engineering properties to determine their suitability. Because they are widespread in Illinois, adequate quantities and quality of fill materials are usually found easily.

## Geologic Hazards

Most of the damage from the geologic hazards we face in Illinois, from earthquakes and landslides to flooding and coastal erosion, involves glacial deposits. Planning to prevent or minimize damage depends on understanding the physical properties of the deposits.

The tills that were deposited directly by the glaciers are the thickest type of glacial sediment in Illinois, and they directly underlie the comparatively thin loess cover across vast areas of the state. Tills were deposited beneath the glacier and later were overridden by glacial ice—in some areas, by several successive ice sheets. The great weight of the ice consolidated the mass of individual grains of various sizes and compacted them tightly together. When subjected to certain stan-

Standard types of engineering tests, these tills will behave similarly to rock. Engineers refer to this property as *overconsolidation*.

Many geologists, however, describe tills and other glacial deposits as “unconsolidated,” using the term in the sense of *unlithified*, because not enough geologic time has elapsed since their deposition for the processes of compaction and cementation to turn them into true rock. In addition, even the most dense and massive overconsolidated tills, if they are moist enough, can generally be cut with a knife, pick, shovel, or other field implement. In reading about Ice Age deposits, it is important to understand the different concepts each term is intended to convey according to its context.

## Earthquakes

Because many tills are compact, they behave much as bedrock does when they are subjected to *seismic* energy during an earthquake. However, uncompacted, unconsolidated materials such as sand and gravel or lake silts may lose coherence when shaken, especially when they are moist. When these sediments become saturated with water, the grains may lose contact with one another during an earthquake. If this happens, the sediments may become liquified. In this state, there is little grain-to-grain contact, and the grains float loosely in water. When liquified, sands and gravels and lake silts lose strength and no longer support buildings or other structures. Thus, the geologic materials of an area, the degree to which they are saturated, their behavior when subjected to seismic energy, and their proximity to an earthquake epicenter (the point on the Earth’s surface directly above the quake’s point of origin) must all be taken into account in determining how Ice Age materials may react during an earthquake. Earthquake tremors can also loosen earth materials that occur on otherwise stable slopes and can trigger landslides.

## Landslides

The causes of landsliding in Illinois are numerous, and landslides may involve bedrock, Ice Age deposits, or both. If glacial deposits occur along steep stream banks, road cuts, or other excavations, slumping and landsliding may result, especially after heavy or prolonged rains, which cause the sediments to become saturated and lose coherence.

## Swelling Soils

Some glacial deposits with large amounts of certain types of clay minerals expand when wet and shrink when dry. After repeated cycles of shrinking and swelling, small cracks open and fill with earth, leaves,

twigs, and other debris; during swelling cycles, pressure can build up against foundation walls of houses and other buildings and crack and tilt walls and floors. Similar behavior can result from the expansion and contraction caused by cycles of freezing and thawing of water in the pores of soils.

## **Subsidence**

In Illinois, most subsidence—a drop of the ground surface—takes place over underground coal mines. Ice Age materials are involved only to the extent that collapse of an underground mine roof causes the overlying earth materials, including glacial deposits, to subside, or sink.

*Karst terrain*, characterized by closed depressions, sinkholes, caves, and underground drainage networks produced by the action of water on limestone or *dolomite*, is also susceptible to sinking and sudden collapse. The shrinking and swelling cycles of some Ice Age deposits, the subsidence of soft glacial sediments when subjected to weight, and the settling of clays also can cause damage to building foundations and roads in ways that may mimic the effects of mine subsidence.

## **Floods and Coastal Hazards**

Because Ice Age sand and gravel and more recent floodplain deposits exist in our major river valleys, and because the Lake Michigan coastline also consists of glacial deposits, studying the properties of these sediments helps us understand their susceptibility to the erosional and depositional processes of river floods and coastal waves. During the Great Flood of 1993, for example, floodwater inundated towns and large areas of farmland in the river floodplains. In places, the water deposited great volumes of sediment, but, in others, water eroded support from around bridge abutments and building foundations. Over many years, erosion of beaches and shorelines and undercutting of lake bluffs by wave action has caused considerable damage to land and structures along Illinois' Lake Michigan coastline.

Many of us live, work, and play on Ice Age deposits every day but rarely think about their contributions to our daily lives. This booklet introduces the reader to the fascinating legacy left to Illinois by those massive ice sheets that covered the state so many thousands of years ago.

# What Happened during the Ice Age?

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*If you had been able to view North America from space during the Ice Age and to drastically speed up time, you would have seen an awesome sight. Centers of snow and ice accumulation would have appeared in Canada, and ice sheets would have spread rapidly outward from these centers until they covered much of the northern half of the continent (fig. 2). You would have then seen the ice fronts pulse back and forth across Canada and the midwestern states many times before finally receding to their present location. If you had looked closer as the ice melted, you would have seen huge streams of water flowing away from the front of the ice and down the major river valleys we know today.*

## Causes of the Ice Age

Although the reasons why the climate changed to conditions permitting the growth of continental glaciers are not fully understood even today, scientists think the following factors played key roles.

Segments of the Earth's outermost rigid, rocky shell (called plates) slowly but continuously shift their positions in relation to one another. These large-scale movements and resulting deformations of the Earth's crust are part of the concept of plate tectonics. As the crustal plates eventually reach configurations in which a substantial portion of the Earth's land area is located near the poles, they form barriers to the flow of warm winds and ocean currents from the tropics to the polar regions. Such an arrangement of continents cools the high latitudes and allows the buildup of snow, which eventually forms glacial ice. These movements of the Earth's plates could account for the three major glacial ages throughout Earth's history: the first one, about 700 million years ago (during late Precambrian time); the second one, about 300 million years ago (during the Pennsylvanian Period); and the third one, the Great Ice Age, starting about 1.8 million years ago (the Pleistocene Epoch of the Quaternary Period; see fig.1).

Within a single glacial age, the climate fluctuated from cold to warm and back many times, which accounts for the expansion and contraction of major continental glaciers. A great deal of evidence suggests that these climatic cycles are due to a combination of the variations in the shape of Earth's orbit around the Sun, the tilt of Earth's axis relative to the plane of Earth's orbit around the Sun, and the times of the year when Earth is closest to the Sun as it moves through its elliptical orbit. Periodically, these orbital variations combine to reduce the contrast

## The Present Is the Key to the Past

Even though we can find abundant evidence in the landforms and deposits of Illinois that continental glaciers invaded the state many times during the Great Ice Age, glaciers remain an exotic concept for most people. The nearest glaciers are mostly in remote areas thousands of miles from population centers. It is hard for most of us to imagine what it must have been like in Illinois 20,000 years ago when a vast lobe of ice extended across the northeastern quarter of the state.

The concept of a Great Ice Age was first proposed by scientists such as Louis Agassiz of Switzerland, who grew up in countries where glaciers could be readily observed. In 1837, Agassiz presented the idea that glaciers once covered much more of the landscape than they do today. He and others noted deposits on the lowlands of western Europe that were similar to those adjacent to glaciers in the Alps. These observations convinced Agassiz and others that deposits on lowlands in front of the Alps were formed by earlier, more widespread glaciers.

One of the best ways to understand the glacial landscape and deposits of the Ice Age is to study existing glaciers; doing so uses a fundamental principle in geologic studies: The present is the key to the past.

Modern glaciers lure scientists to Iceland, Greenland, Antarctica, Patagonia, the Alps, eastern Canada, and Alaska. Although no present-day glaciers are perfect models of the Ice Age glaciers that reached the midlatitude area of Illinois, study of modern glaciers has increased our understanding of the dynamics and complexity of glacial environments.

Geologists have been able to observe first-hand many of the processes occurring in modern glacial and *proglacial* environments and see the resulting landforms and deposits. Some of these processes take place very rapidly. Where one day there is a large lake dammed by ice or sediment, the next day there is only a barren lake bed with a channel cut through the former dam. On a sunny summer's day when melting is at its greatest, small glacial streams in the morning can become raging torrents rumbling with boulders by afternoon. As meltwater is added to debris that has melted out on the glacier surface, the mixture can become a muddy slurry that cascades off the ice front. On windy days, the sky may be filled with clouds of dust lifted from dry meltwater channels, eventually to be carried far from the glacier.

Because we cannot see directly beneath a glacier, what happens there remains something of a mystery. Only at the very margin of the glacier can we crawl into tunnels to observe what goes on under the ice. To infer what processes operate at the base of the glacier, geologists must rely on indirect observations from ice cores and seismic records. Long-term historical studies also have allowed scientists to infer what happens as glaciers expand, remain stable, or shrink through time. For example, over the last 50 years or so, geologists have been able to observe the landforms and deposits emerging from beneath the shrinking Burroughs Glacier in Alaska. These observations suggest models that might explain some of the landforms and deposits we see in Illinois. These models then must be tested against observable evidence in the landforms and deposits. Such studies often suggest ways the models need to be modified. By such cross-checking between concepts and observations, geologists improve their understanding of the glacial landscape and deposits.

For example, from modern glacier studies in Iceland and Antarctica has come the idea that when glaciers move over soft sediment rather than bedrock, the soft sediment may change shape as water is added to it. The result is a glacier moving over a bed of deforming sediment. Some geologists have suggested that the Ice Age glaciers in Illinois at times moved by such a process. The homogeneous tills we find in Illinois might be in part a result of sediment mixing in a deforming bed beneath the glacier rather than the result of simple melting at the glacier's base. Geologists are now studying the tills in Illinois to see whether the deforming bed hypothesis could account for the state's homogeneous till beds.

in temperature between summer and winter and to produce extended periods with cool summers. During these periods, the previous winter's snow does not melt completely, and ice and snow gradually accumulate in northern areas. The increased area blanketed by light-reflecting snow and ice helps to cool the climate further by reflecting more of the Sun's energy back into space; the growth of a continental ice sheet further reinforces the climatic effects that make it grow.

These cycles of climate variations occurred many times throughout the Pleistocene Epoch. Studies conducted over the last two decades indicate that, during the Ice Age, glaciers spread out and then receded on North America, perhaps as many as a dozen times, with many more minor pulses. Some scientists think that we are presently in the midst of another interglacial age (warm cycle) and that, within the next few thousand years, glaciers may yet again advance into the interior of North America. Complicating such a scenario is the warming of the climate that may result from the ongoing release of human-made pollutants (greenhouse gases) into the atmosphere.

## How Glaciers Formed

As the climate became cooler, snow that fell in northern regions during the winter did not completely melt during the summer. It did, however, recrystallize into granular ice. Over many hundreds of years, the snow and granular ice accumulated to such thickness that the lower layers, weighed down by the thick overlying snow and ice, recrystallized into solid ice. Eventually the ice became so thick (at its maximum, perhaps 8,000 to 10,000 feet thick in central Canada) that it began to deform and flow outward under its own weight. It is this flow that distinguishes glaciers from all other forms of ice accumulation. The building up and flowing outward continued for such a long time that the resulting glacier eventually flowed southward into Illinois. When the climate warmed enough so that the rate of melting in the summer exceeded the rate of spreading outward, the ice front stopped expanding and began to recede as the mass of ice itself gradually melted, a process known as *ablation*.

## Ice Age Evidence

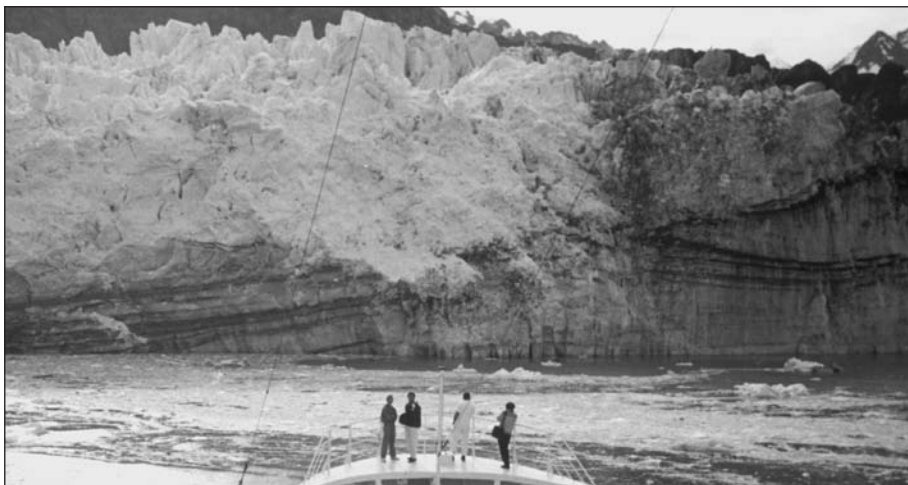
Illinois' present landscape bears witness to the presence of the massive continental ice sheets that covered the area many times over the past 1.8 million years and to the dynamic interplay of depositional and erosional processes associated with the ice. The evidence consists of the earth and rock materials blanketing Illinois' bedrock surface and the landforms that compose today's landscape.

## Rocks and Sediments Left Behind

Approximately 90 percent of Illinois is blanketed by layers of unlithified sediment. In places, this sediment is more than 400 feet thick, and it averages about 100 feet thick. We know this sediment was deposited by processes related to glacial ice because scientists have seen some of the same types of sediments deposited by glaciers in Alaska, Iceland, Greenland, Switzerland, South America, Antarctica, and elsewhere. There scientists today can study the processes responsible for depositing glacial drift.

Although a mental picture of a mass of pure, pristine blue-white ice covering our part of the continent is attractive, a look at glacial ice today (fig. 4) shows that, in fact, it contains rock debris that was plucked from underlying bedrock, ground up, and embedded in the lower part of the ice as it moved forward. The continental glaciers, massive as they were, must have been very dirty indeed to have left behind the immense amounts of sediment now overlying our bedrock.

**Till** Moving glacial ice gouges out, incorporates, grinds up, and carries along rock debris from clay-size particles smaller than the eye can distinguish, through silt (about the size of grains of flour) and sand-sized particles, to pebbles, cobbles, and boulders. Over broad expanses of Illinois, rock grains of all sizes are jumbled and packed tightly together in a deposit called till (fig. 5). Till was plastered onto the preexisting landscape at the base of the ice sheet as it slowly moved forward or was left behind as irregular layers when the glacier melted.



**Figure 4** Bands of sediment sheared into the ice can be seen on the face of this tidewater glacier in Glacier Bay, Alaska. (Photograph by Myrna M. Killey.)



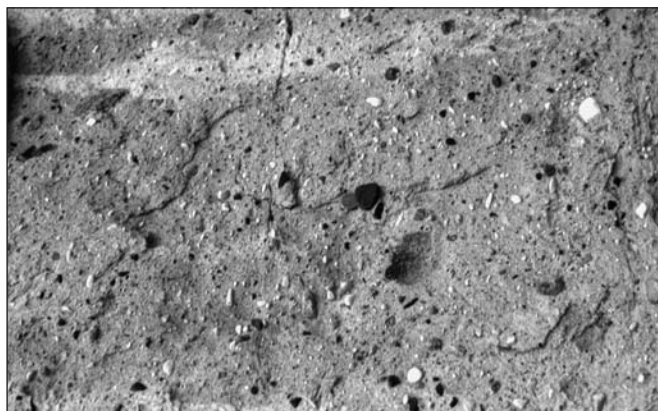
**Outwash** Other glacially deposited materials were sorted by size, indicating that some type of sorting agent—usually water or wind—has been at work on the sediments. It is easy to imagine streams of water pouring from the edge of the melting ice, first dropping (“washing out”) their loads of coarser, heavier materials such as gravel and sand (called *outwash*; fig. 6) near the ice margin but carrying the finer material such as silt and clay farther downstream. These outwash sediments can be seen in many of today’s sand and gravel quarries in Illinois.

## What on Earth Is “Diamicton”?

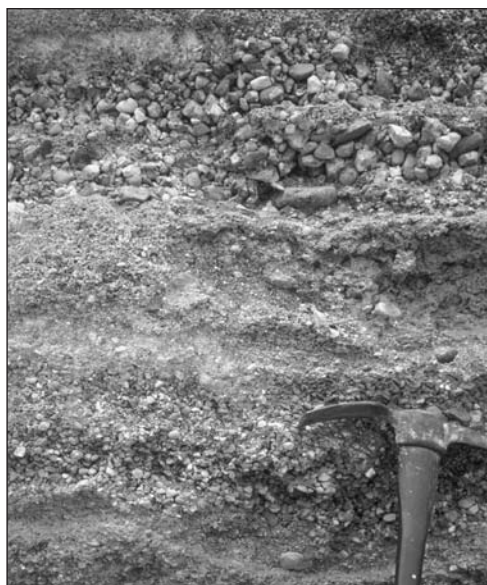
The word “till” has been used for many years to describe any glacially deposited sediment displaying a range of grain sizes from clay to boulders. Many geologists now restrict the term to mean only sediments consisting of a mixture of grain sizes deposited directly onto the landscape beneath the ice when the sheer weight of the overlying ice causes the base of the glacier to melt. The term “till,” therefore, implies a particular way that the sediment is deposited.

However, mixtures of water-saturated, till-like sediment can also be deposited in other ways. For example, deposits with a wide range of grain sizes can occur when saturated sediment gradually creeps down a slope and settles at its bottom; no glacial ice is involved. Even in a glacial environment, debris-laden ice at or near the glacier’s margin can melt and flow away from the ice as a slurry of sediment and water. Thus, it is not always possible to determine exactly how the jumbled mix of grain sizes (till-like material) we see today was deposited.

To describe a till-like mixture of grain sizes without implying anything about its origin, not even whether it was deposited by glacial ice, many geologists now use the term *diamicton*. Because the term till is still commonly used and is simpler to remember, however, we use till in this publication for all jumbled mixtures of grain sizes thought to be deposited by glaciers. Nevertheless, if you should hear someone use the term *diamicton*, you will know what it means.



**Figure 5** Till exhibits a variety of grain sizes packed tightly together. This photograph shows an area of till outcrop approximately 2 feet by 3 feet. (Photograph by Richard C. Anderson.)



**Figure 6** Outwash of sorted sand and gravel is illustrated in this outcrop from the “ridged drift” area of southern Illinois. (Photograph by Myrna M. Killey.)

Where we find a broad area of coarser (larger) grains such as gravel, we can be reasonably sure that the front of the ice once stood close by. We also know from drilling that layers of outwash commonly are buried beneath and often alternate with layers of till. Such sequences of layers of till and outwash tell us that glaciers came and went across the area several times.

**Loess** At times, especially during winter when glacial melting was greatly reduced, the sediment-choked beds of meltwater streams would often dry out enough that winds could pick up the finer particles of silt, clay, and fine sand and deposit them over the landscape. This wind-deposited material is called loess (fig. 7). We occasionally see the same process today when strong winds pick up loose soil from dry, freshly plowed, unplanted fields, blow it across the landscape, and create dust storms. Eventually the dust may be deposited as low ridges across fields and highways.

**Lake deposits** In some places, glacial meltwater was temporarily dammed between the ice front and morainic ridges (see fig. 12 on p. 17) and formed quiet-water lakes and ponds in which fine silt and clay (mud) settled out—just as occurs in many lake bottoms today. Eventually these lakes disappeared as the volume of meltwater lessened and stream erosion lowered the level of the lake outlets. Many



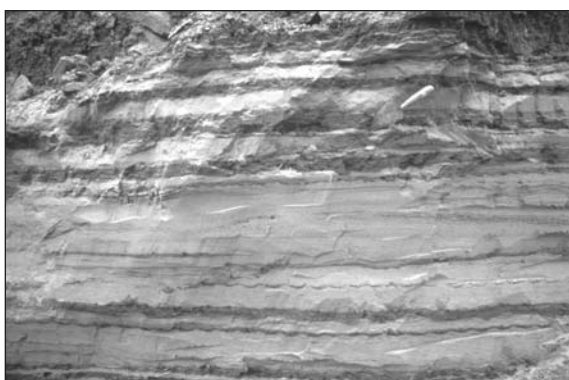
**Figure 7** Loess has a uniform grain size and tends to stand in vertical slopes, as shown. (Photograph by Joel M. Dexter.)

former lakes and ponds have been identified on today's land surface by their uniformly fine-grained deposits left in a very flat plain; these lake-deposited silts and clays are called *lacustrine* deposits by geologists. Some of these sediments show thin alternating layers, called *rhythmites*, that represent cyclical fluctuations in sediment deposition (figs. 8 and 9).

**Erratics** Boulders are scattered across Illinois (fig. 10); they may be seen piled in the corners of farm fields or used for landscaping. When we examine the boulders closely, we discover that many of them are *igneous* and *metamorphic rocks* quite unlike the *sedimentary rocks* that make up the bedrock of Illinois. These boulders are called *erratics* because of their erratic occurrence far from areas where igneous and metamorphic bedrock is exposed at the surface. But if they are unlike the sedimentary rocks found in Illinois bedrock, where did they come from, and how did they get here? It turns out that similar igneous and metamorphic rocks occur at the bedrock surface in much of Canada, Minnesota, northern Wisconsin, and Upper Michigan. The only way such large boulders could have been transported to Illinois naturally was by the continental gla-



**Figure 8** Rhythmites of interbedded silt and clay deposited in an ice-contact lake, capped by outwash sediment and loess, Jubilee Creek, Jubilee College State Park, northwest of Peoria, Illinois. (Photograph by C. Pius Weibel.)



**Figure 9** These layers of interbedded clay (dark layers) and sand (light layers) were deposited in a spit by longshore currents in ancestral Lake Michigan. (Photograph by Ardith K. Hansel.)



**Figure 10** This large igneous boulder is called an erratic because it is unlike the bedrock of Illinois. Erratics were carried from Canada and northern states into the Midwest by glaciers. (Photograph by David L. Reinertsen.)

ciers of the Ice Age, because no rivers existed that could roll such large boulders across such distances. Erratics may be somewhat rounded by abrasion during transport by the glacier.

**Scratches on bedrock** Although scratches on bedrock (called *glacial striations*) do not actually consist of earth or rock material left behind by the ice, some scratches (fig. 11) are additional evidence that continental glaciers advanced into Illinois. In several places, where bedrock is exposed at the ground surface, especially in limestone and dolomite quarries in northeastern Illinois, the bedrock displays a smooth, almost polished surface that bears numerous scratches, most of them oriented in a northeast-southwest direction. The most convincing explanation for this scratched and polished bedrock surface is that granite and other hard igneous and metamorphic rocks frozen into the base of the glacier abraded the underlying, softer bedrock as the ice dragged them along. The orientation of the striations tells us the ice generally moved southwestward across Illinois (fig. 3).

## Landforms Left by the Ice

Distinctive landforms typical of continental glaciation were left as part of the modern landscape. Although these landforms are discussed further in the chapter “The Illinois and Wisconsin Episodes,” they are



**Figure 11** Striations (scratches) on polished bedrock caused by rocks frozen into the base of a glacier that pushed relentlessly across the land surface, Fairmount Quarry, Vermilion County. A window in the till exposes the striated bedrock. (Photograph by W. Hilton Johnson.)

## Evidence for Multiple Ice Advances

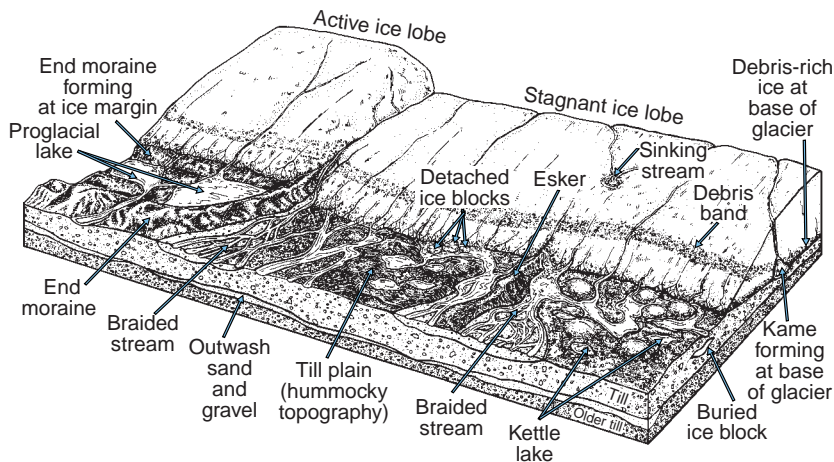
Giovanni Arduino's time classification, which placed alluvial (river) and lacustrine (lake) deposits in the Quaternary time period, provided the impetus for the initial classification of geologic features. This system was based on observations in the Alpine region of Europe where large erratics (boulders unlike the local bedrock) rested nearly 60 miles from their likely source in the Alps. Elsewhere, whalers had noticed rocks and boulders in icebergs breaking off the glaciers that covered much of Greenland. From these observations, some thought erratics resulted from drifting icebergs during a great flood (interpreted by some to be the Biblical flood). Thus, the boulders and sediments resulting from these supposed drifting icebergs were called "drift" and were thought to be deposited by water.

Natural scientists in the late 1700s and early 1800s, however, observed that erratics, scratches on polished bedrock surfaces, and ridgelike end moraines on valley floors could also be plainly seen in the vicinity of existing Alpine glaciers. The idea that glaciers once existed over a much broader area began to evolve.

Once the glacial origin of sediments in northern areas of North America and Europe was accepted, geologists quickly recognized that within these sediments were beds of plant remains, wood, and other organic deposits, as well as recognizable remains of soil horizons similar to those found in modern soils today. Geologists also found buried fossils, including shells, bones, and teeth of animals now extinct. All such discoveries pointed to warmer and glacier-free periods. As more and more places containing zones of weathering, old soils, and organic material were discovered within the sequence of glacial sediments, it became obvious that there had been many ice advances, each separated by a warming period during which soils formed and plants and animals lived on the land surface.

briefly introduced here because they are important evidence that continental glaciation took place in Illinois.

**End moraines** Huge, curved ridges of till outline where the outer margin, or end, of the lobe-shaped glacier once stood. These *end moraines* (fig. 12) were formed along the edge of the ice when the rate



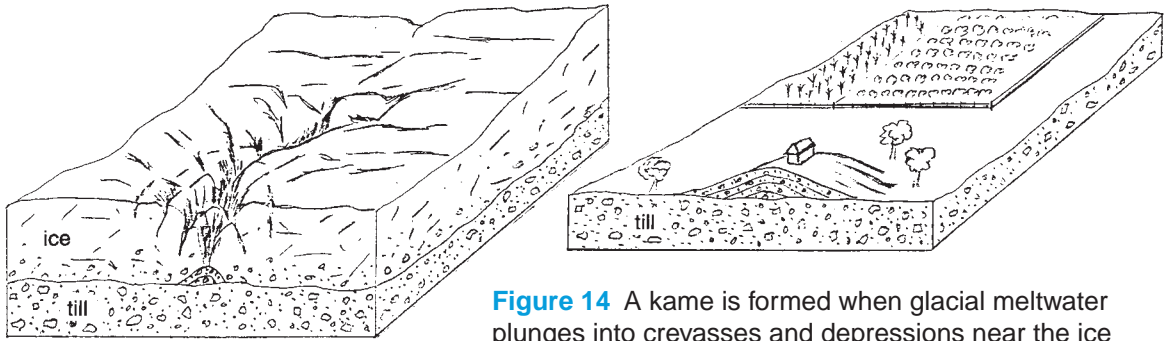
**Figure 12** Drawing of how a moraine forms.



**Figure 13** Looking west across an older landscape from the crest of the Bloomington Morainic System in northern De Kalb County, Illinois. (Photograph by Richard C. Anderson.)

of ice advance approximately equaled the rate of melting for a period of time, allowing the ice margin to remain stationary. The ice within the lobe kept moving forward, however, delivering more rock debris to the ice front, where it piled up. These end moraines (more commonly just called “moraines”) sometimes exhibit a hummocky land surface characterized by rounded knolls and depressions called knob-and-kettle *topography*. Examples of moraines that exhibit this kind of surface are the Marseilles, Bloomington (fig. 13), Valparaiso, and Shelbyville Morainic Systems (see fig. 35 on p. 56 for a map of moraines in Illinois and p. 63 for additional discussion).

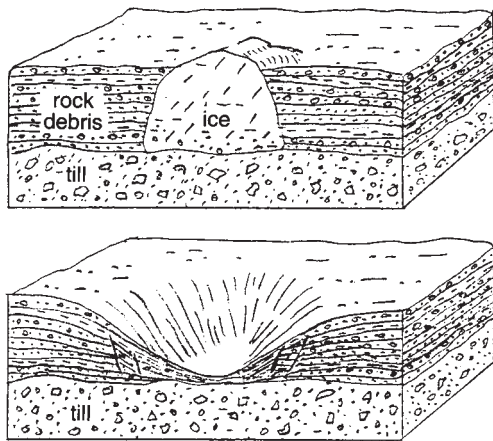
**Kames and kettles** Mounds of sand and gravel, called *kames*, formed when meltwater traveled in channels beneath the ice or plunged from the ice surface into *crevasses* near the ice front and deposited its load of sediment (figs. 14 and 15). As the glacier melted away, the sand and gravel gradually collapsed into a gentle mound on the landscape. Numerous examples exist in Illinois such as Blue Mound and Long Mound on the Macon-Christian County border. Several others occur in the “ridged drift” complex (described on pp. 53–54). Depressions on the landscape, called *kettles*, formed where blocks of ice—detached from the main ice sheet and surrounded by rock debris from the melting glacier—themselves finally melted (figs. 16 and 17). The depressions left on the landscape today may be swampy or dry. Dry depressions may hold water for a while after prolonged and



**Figure 14** A kame is formed when glacial meltwater plunges into crevasses and depressions near the ice front and deposits its load of sediment.



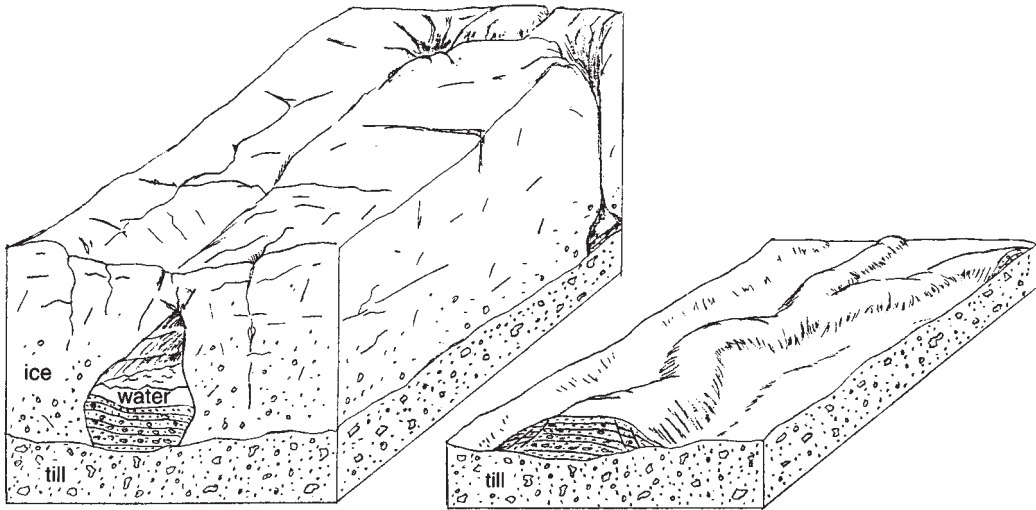
**Figure 15** A kame, a low mound composed of sand and gravel, in southern Champaign County. (Photograph by David L. Reinertsen.)



**Figure 16** A kettle is formed when blocks of ice become detached from the main glacier and are surrounded by rock debris from the melting glacier. When the ice blocks melt, they leave depressions on the landscape.



**Figure 17** A shallow kettle holds some water during wet periods. (Photograph by Wayne T. Frankie.)



**Figure 18** An esker is formed when a stream of meltwater carrying sediment and rock debris develops beneath or within a glacier. As the meltwater gradually slows, the rock debris is deposited. When the ice melts away, the sediment and rock debris are left as a long, narrow, winding ridge that marks the course of the former meandering subglacial stream. Small faults result from collapse of the layers of sediment along the sides of the ridge when the ice walls no longer exist to support them.

**Figure 19** A long, tree lined ridge of an esker. (Photograph by David L. Reinertsen.)



heavy rains, and deep kettles may actually contain lakes. Kettles can be found in the knob-and-kettle topography of some end moraines.

**Eskers** A type of glacial landform less commonly found in Illinois is an *esker*; a long, narrow, winding ridge of sand and gravel deposited by a stream of meltwater flowing at the base of or within a glacier (figs. 18 and 19). These streams carried sand and gravel and also meandered a little, just as some streams do today, as they wound their way at the



base of the ice toward the ice front. The sand and gravel were deposited as the meltwater stream gradually slowed and could no longer carry its load of debris. The ice then melted away, leaving these sediments in place to mark the course of the former subglacial stream. Several eskers occur along the course of the Kaskaskia River in Bond, Fayette, and Clinton Counties, and a group of small eskers exists on the back-slope of the Bloomington Morainic System in Bureau County. Because kames and eskers are easily accessible sources of sand and gravel, many, such as the Kaneville esker in Kane County, have been mined and no longer exist.

**Glacial lake plains** Exceptionally flat areas, called *glacial lake plains*, may occur between end moraines. These plains are the surfaces of lacustrine silt and clay deposited in the quiet waters of temporary meltwater lakes that were dammed between an end moraine and the edge of the retreating ice front. Examples include a large area in Grundy and southern Kendall Counties between the Marseilles Morainic System to the west and the Minooka Moraine to the east, and in central Douglas County between the Arcola Moraine to the south and the Pesotum and West Ridge Moraines to the north (see fig. 35 on p. 56 for a map of moraines).

### Other Ice Age Evidence

More evidence that much colder temperatures were once widespread across Illinois and the Midwest takes several forms, including fossils, pollen, *ice-wedge casts*, and *patterned ground*.

Every now and then, newspapers carry a story describing a new find of partial skeletons of mastodons or mammoths, usually in northeastern Illinois. These animals, close relatives of modern elephants, roamed



**Figure 20** An artist's conception of life near the margin of the Wisconsin Episode ice sheet about 14,000 years ago. Mastodons browsed on spruce, pine, and other plants that thrived in a cold climate. (Reconstruction painting by R.G. Larson, used with permission of the Illinois State Museum, Springfield, Illinois.)

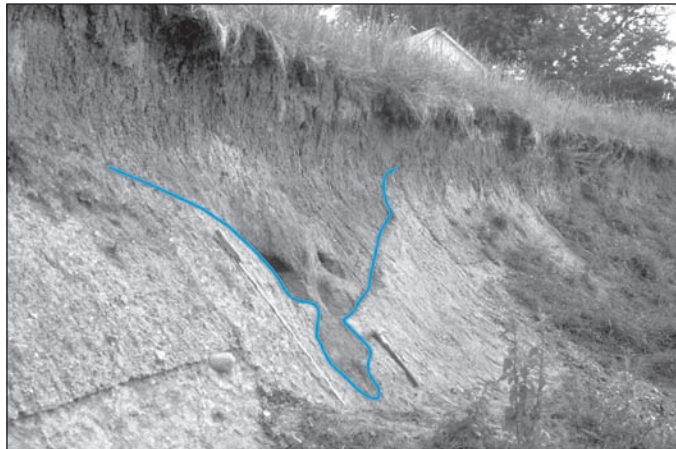
the open meadows, forests, and *tundra*-like Illinois landscape within a few miles of the glacier. Mammoths grazed on the grass and vegetation that existed on the tundra, and mastodons browsed on saplings in the partly forested landscape (fig. 20). As the climate became warmer and their environment changed, the mastodons and mammoths disappeared, becoming extinct about 7,500 years ago.

The existence of an Ice Age environment can also be demonstrated by examining fossil pollen, which is often found in the fine-grained sediments and peat deposited in glacial lakes. The fossil pollen indicates that, at the end of the last glaciation, much of northern and central Illinois resembled the forest and tundra landscape that exists today in northern Canada. Forested areas were dominated by spruce, pine, and sedge. The more open tundra-like areas were dominated by arctic, aquatic, and wetland plants. The fossil pollen in younger sediments shows widespread changes from species that thrive in colder environments to those that grow in warmer, drier conditions; those changes signal the time that the climate was becoming more like today's.

Finally, special features called ice-wedge casts and patterned ground have been found on the Illinois landscape. These features are also found in areas where *permafrost* exists today, suggesting that the Illinois landscape once had similar conditions.

### **Ice-wedge casts**

Sediment-filled fissures (fig. 21) known as ice-wedge casts formed when ice or hoar frost (tiny ice crystals) filled narrow cracks in sediment that resulted from thermal contraction at the ground surface. These features are most commonly found in the central and northern half of Illinois.



**Figure 21** A sediment-filled ice-wedge cast in east-central Illinois. (Photograph by W. Hilton Johnson.)



**Figure 22** Aerial photograph taken near Clinton in De Witt County, Illinois. The patterned ground surface (mottled surfaces) is typical of that in poorly drained areas where intensive frost action has taken place. Light and dark rectangles and strips are farm fields. (Photograph by W. Hilton Johnson.)

**Patterned ground** Polygonal patterns, known as patterned ground, develop on the ground surface in poorly drained areas where intensive frost action takes place. The polygons, best seen in aerial photographs (fig. 22), are outlined by slightly darker soils that accumulated in the swales (sunken areas) surrounding the polygons. Patterned ground is found in areas that had tundra-like conditions during the last major glaciation.

# Studying Ice Age Deposits

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*The prehistoric hunters who lived near the Ice Age glaciers left no records of the landscape they saw, so scientists must do the next best thing—study as much evidence as they can find about this fascinating chapter in Earth’s history. Advances in understanding the world around us must come through rigorous application of the scientific method—making observations, devising hypotheses to explain the observations, and then testing the hypotheses. Yet, in attempting to find out what happened during the Ice Age, creativity and imagination are also vital. A geologist with creativity and imagination can envision how things might once have been.*

## The Need to Know

Advances in science are often driven by the need to know something, but just as often they are driven by simple curiosity. Both curiosity and the need to know have been forces behind the desire to understand as much as possible about the Ice Age.

The need to know comes from society’s demand for water, sand and gravel, and other mineral resources; the need to dispose of waste in the safest possible environment; and the need to understand as much as possible about geologic hazards in order to lessen their effects. In the Midwest, drilling into the earth usually encounters glacial deposits before reaching bedrock. Deposits of sand and gravel can yield significant amounts of groundwater. Those near the surface can provide the raw materials for construction projects such as roads and buildings. Tills can be excellent natural repositories for holding waste. The economic and environmental importance of glacial deposits makes it necessary for us to understand and map their character, distribution, and extent.

In addition, curiosity kicks in: What must the area have looked like? How fast did the ice move? How many times did it come and go? How did it deposit materials in the sequences we see today? Can our growing understanding of these materials help us predict their depth, character, and occurrence in various places? If so, how can this understanding help us interpret and reconstruct the events of the Ice Age and possibly help us predict future climate changes?

## What Geologists See

Recognition that much of the Midwest had been covered by glaciers provided the basis for systematic study of the deposits and landforms left behind. Beginning in the 1860s, Illinois geologists, including A.H. Worthen and Frank Leverett, published comprehensive surveys of the state's geology. Since that time, geologists have built upon the observations and studies of these natural scientists and

- noted and mapped landforms, including their location, extent, shape, orientation, and relationships to one another;
- described the glacial deposits exposed in *outcrops* (such as in road and railroad cuts, creeks, stream banks, and mining excavations), including their color, texture, and vertical sequence from the lowest units to the uppermost unit that contains the modern soil, especially noting special features such as the remains of buried soils and lateral changes in sedimentary *facies*; and
- described the sequence and characteristics of the deposits brought to the surface by drilling and, where possible, studied the relationships of the deposits to one another and to the bedrock.

As they describe outcrops or drilling samples, geologists take samples and then

- analyze them for percentages of pebbles, cobbles, boulders, and the finer material that encloses these larger rocks;
- analyze the types and percentages of minerals in them;
- note and describe any fossils they contain; and
- make use of modern *radiometric age dating* and other techniques for age determinations, where possible, to arrive at estimates of actual ages for certain types of sediments and deposits.

## Deciphering the Ice Age Story

Observing landforms and earth materials can tell us much about the existence of glaciers in Illinois. Geologists also make use of well-established principles and sophisticated scientific techniques to learn more about glacial deposits. The most important of these are described.

## Age Dating

Geologists need to understand as much as possible about the rates at which geologic processes occur in order to assess the impacts these processes may have on human activities. For example, landslides may occur quickly, as a sudden slump or fall of rock or glacial material, or may occur slowly as a creep of saturated soil down a slope. Rates of stream and wave erosion in different kinds of geologic materials help determine whether it is safe to build in certain areas or what kinds of protective structures or techniques might help reduce damage to structures already built. Knowing something about the rates of soil formation and wind erosion helps people plan for conservation of this valuable resource. Many geologic processes take place gradually, including the advance and retreat of glaciers. Techniques have been developed that help geologists understand the ages when various materials were deposited by the glaciers covering Illinois and the rates at which these materials were deposited.

**Relative age dating** One of the basic principles geologists use to determine the ages of rocks and sediments relative to one another is the law of superposition. This law states that in any undisturbed sequence of sedimentary *beds*, or deposits, the bed at the bottom of the sequence was deposited first and is the oldest, and the bed at the top of the sequence was deposited last and is the youngest. Therefore, in a sequence of undisturbed glacial materials overlying bedrock, the one lying directly on the bedrock surface was deposited first, and each succeeding layer is younger than the one below it.

As an example, let's consider an outcrop where a bed of clay and silt underlies a glacial till; above the till is a sand layer. We see no evidence that these sediments have been disturbed. From the clay and silt, we can infer that a lake once covered the site. A glacier then advanced across the landscape and deposited the till. After the glacier retreated, sand was deposited, perhaps as a beach at the shore of a lake or as river *alluvium*.

**Radiometric age dating** In contrast to relative age dating, which tells us only that a layer of sediment or rock is older or younger than adjacent layers, radiometric age dating allows us to say with a degree of certainty how old organic material in a layer of sediment or rock actually is. An age is expressed in years and is calculated from the quantitative determination of radioactive elements and their decay products. Carbon-14 dating is one of the most useful techniques for dating Ice Age events occurring in about the last 50,000 years. Carbon-14 dating

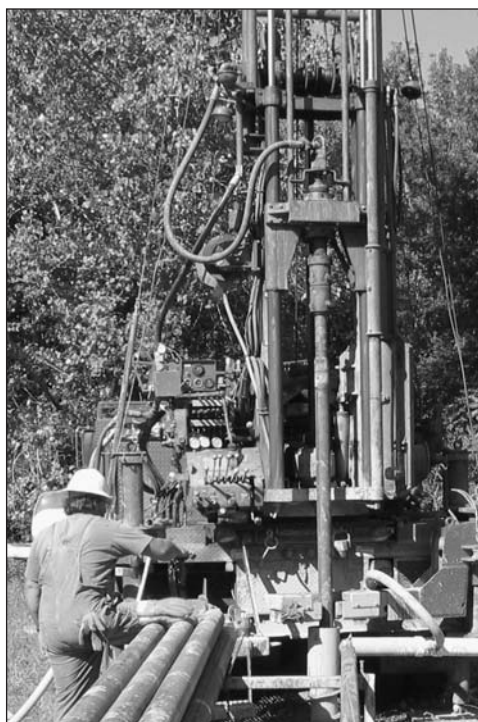
is based on the known, fixed rate of decay of radioactive carbon-14, which naturally occurs in the atmosphere. All living things contain carbon-14 in the same concentration as in the atmosphere. When the plant or animal dies, the exchange of carbon-14 with the atmosphere ceases, but the radioactive carbon-14 in the dead organism continues to decay. By measuring the amount of carbon-14 left in the wood, shell, peat, or bone, the age of the material and of the enclosing sediment can be estimated assuming the organic material has been left in place in its original sediment and not transported.

Other techniques not commonly used in Illinois, such as studying reversals of the Earth's magnetic field, have been used elsewhere to assign approximate ages to older glacial sediments. Through regional correlation with Illinois glacial deposits, some of our older glacial materials can be dated. More information about radiometric and other age dating techniques, magnetic reversals, plate tectonics, and related topics can be found in geology textbooks.

## Drilling

Tens of thousands of borings have been drilled into glacial drift to search for water or simply to understand the succession of geological units below ground (fig. 23). Depending on the needs of the client, drillers record the types of earth materials encountered. In some instances, they collect samples of the materials for study. Even though a drillhole can be likened to a mere pinprick on the broad surface area of Illinois, the records (logs) and samples from these holes provide a wealth of detailed information about what is beneath our feet. This invaluable information can be obtained in no other way.

In recent years, geophysical methods, such as seismic surveys, have been used alongside drilling to increase the amount of information scientists can obtain. Using seismic surveys, geophysicists measure the velocity of



**Figure 23** Geologists can interpret the glacially deposited sediments extracted from this borehole as part of a three-dimensional mapping project to understand the occurrence and distribution of aquifers in northeastern Illinois. (Photograph by Michael L. Barnhardt.)

sound waves traveling through different materials (fig. 24). These measurements show the variations in subsurface geology and help geologists interpret the distribution of deposits between test holes.

**Lithologic and mineralogical analysis** By analyzing the composition of glacial sediments recovered from outcrops and drillholes (fig. 25), geologists can usually determine the general path traveled by the ice. For example, because tills may contain igneous, sedimentary, and metamorphic pebbles similar to those at the bedrock surface in parts of Canada and northern states, the paths traveled by the ice can sometimes be traced back to areas in the north where these rock types crop out at the land surface. Geologists know that limestone composes much of the bedrock to the northwest of Illinois and that dolomite predominates to the northeast. By



**Figure 24** Seismic information provided by the ISGS landstreamer helps geologists refine geological interpretations of glacial materials based on borehole drilling. The geologists are placing geophones at specified intervals to detect the return of sound waves.

**Figure 25** ISGS staff examine cores from east-central Illinois at one of the many ISGS controlled drilling project sites.





comparing the ratios of limestone to dolomite pebbles in the tills, geologists concluded that tills with greater amounts of limestone pebbles were probably deposited by glaciers originating from the northwest, and tills with greater amounts of dolomite pebbles were probably deposited by glaciers originating from the northeast.

Similarly, by determining the types of minerals in the clay portion of till and knowing where shale (a type of bedrock) containing similar clay minerals occurs, geologists can determine the general areas traversed by the ice. For example, older tills in western Illinois contain significant amounts of a group of clay minerals that expand when wet; so do Cretaceous and younger rocks in western Iowa and Minnesota and eastern parts of North Dakota and South Dakota. Geologists can conclude, therefore, that these older tills in western Illinois were deposited by a glacier that originated in central Canada and took a southeastward path into the Midwest and western Illinois (fig. 3). In contrast, clayey tills in northeastern and east-central Illinois contain a great deal of the clay mineral called illite (named for Illinois). The Paleozoic shale bedrock of the Lake Michigan region and areas to the northeast contains a great deal of illite. Therefore, we can infer that these clayey tills were deposited by glaciers that traversed these northern and northeastern areas.

Sometimes the orientation and dip direction of pebbles and cobbles within a till (known as its *fabric*) can reveal the direction the glacier came from. Oblong pebbles and cobbles tend to be deposited with their long axes parallel to the direction of ice movement and dipping in the up-ice direction. Usually this orientation of pebbles is similar to that of bedrock glacial striations, which also parallel glacier flow. The orientations of these pebbles and cobbles can therefore be used to determine the direction of ice movement even where striations on rock surfaces are absent.

**Buried soils** In many places we can see the remains of a soil buried beneath layers of glacial sediment. Soils develop very slowly as geologic materials are exposed to *weathering*. Therefore, the most important thing about buried soils is that they record a climatic warm period between glacial cold periods. Sometimes the characteristics of the soil itself and the plant remains it contains can also tell us about the interglacial climate. And, of course, by using the principles of relative age dating, we know that the material in which the soil has developed is older than any overlying sediments and younger than the underlying ones.

## Putting It All Together

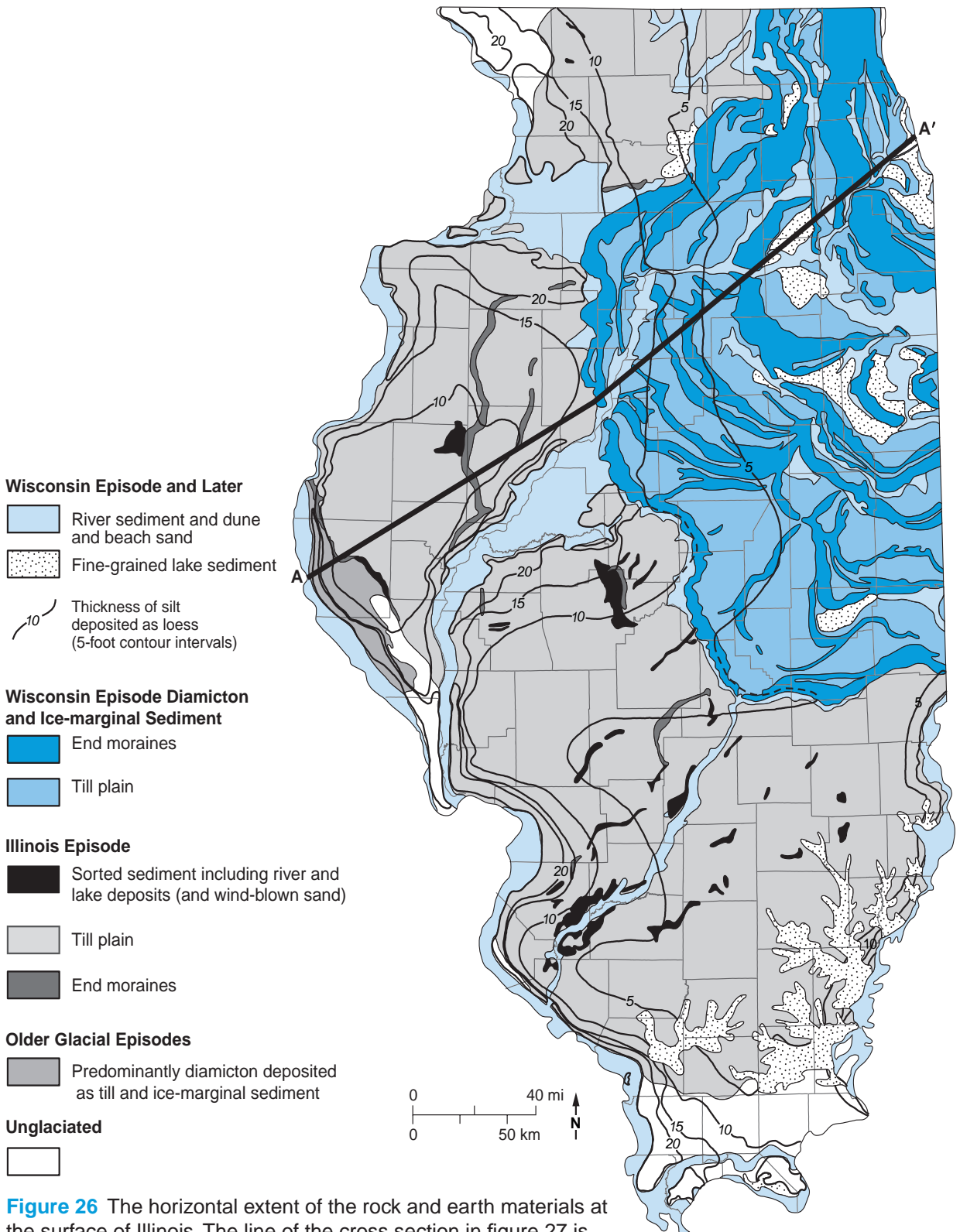
Early in the history of glacial studies in Illinois, geologists placed a heavy emphasis on describing landforms and using that description as the basis of their interpretation of the processes of glaciation. Many interpretations were also made from the materials exposed in outcrops. Later, as the value of borehole information became more apparent and the methods of analysis became more sophisticated, a more complete understanding of Ice Age events in Illinois emerged. The multitude of individual observations and analyses, considered independently, tell only about the individual sites described. However, geologists have been trained to observe how the earth materials at one outcrop are similar to those described at another and how vertical sequences of materials at one location are repeated elsewhere, often with only minor differences. It was then a short step to compile these observations and information from various locations into a coherent story that explained Ice Age materials in Illinois. This understanding of geology is continually being refined and improved by new facts, observations, and techniques.

## Telling the Story

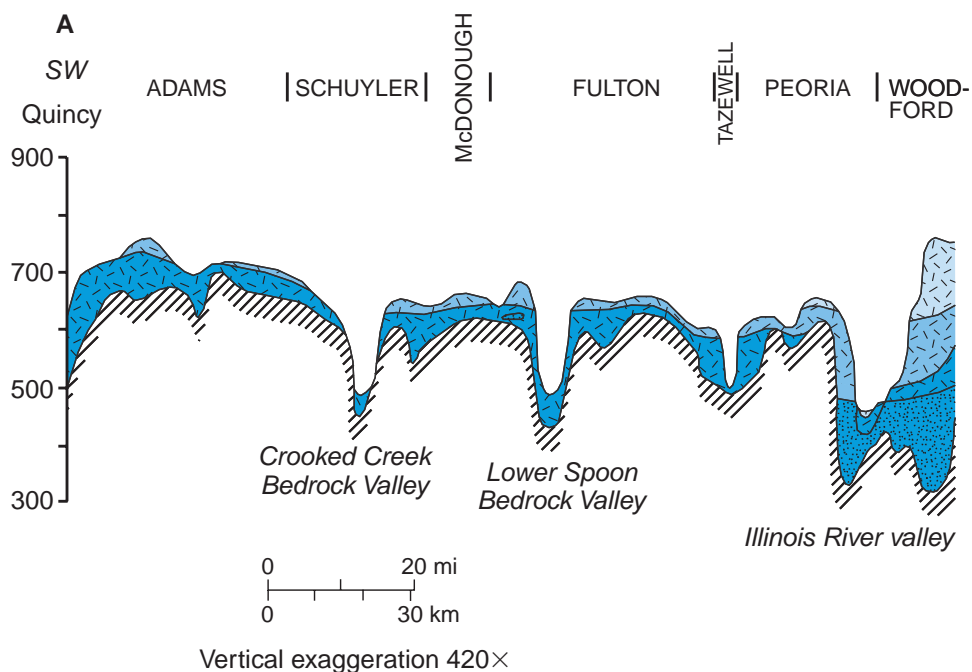
Geologists compile and present their observations and data in horizontal and vertical formats to tell the story of glaciation in Illinois. *Geologic maps* show the horizontal or *areal distribution* of various kinds of geologic units that occur across the landscape (fig. 26). *Cross sections* show the vertical sequence, extent, thickness, shape, and relationships among geologic units from the ground surface downward (fig. 27).

In addition, geologists analyze the data that have been collected over the decades from many sites in many states and assemble them into tables to show generalizations and draw preliminary conclusions for further research and publication. Such tables may display data about grain size, clay mineral composition, pebble orientation, and pollen percentages.

Altogether, over a century of geological investigations has revealed a great deal about the Ice Age in Illinois. We know about (1) the landscape that existed before the glaciers came, (2) the areas covered by the different glaciers, (3) the soils that developed during warm periods between advances of the continental ice sheets, and (4) the ways the glaciers deposited materials and created the landforms we see today.



**Figure 26** The horizontal extent of the rock and earth materials at the surface of Illinois. The line of the cross section in figure 27 is shown.



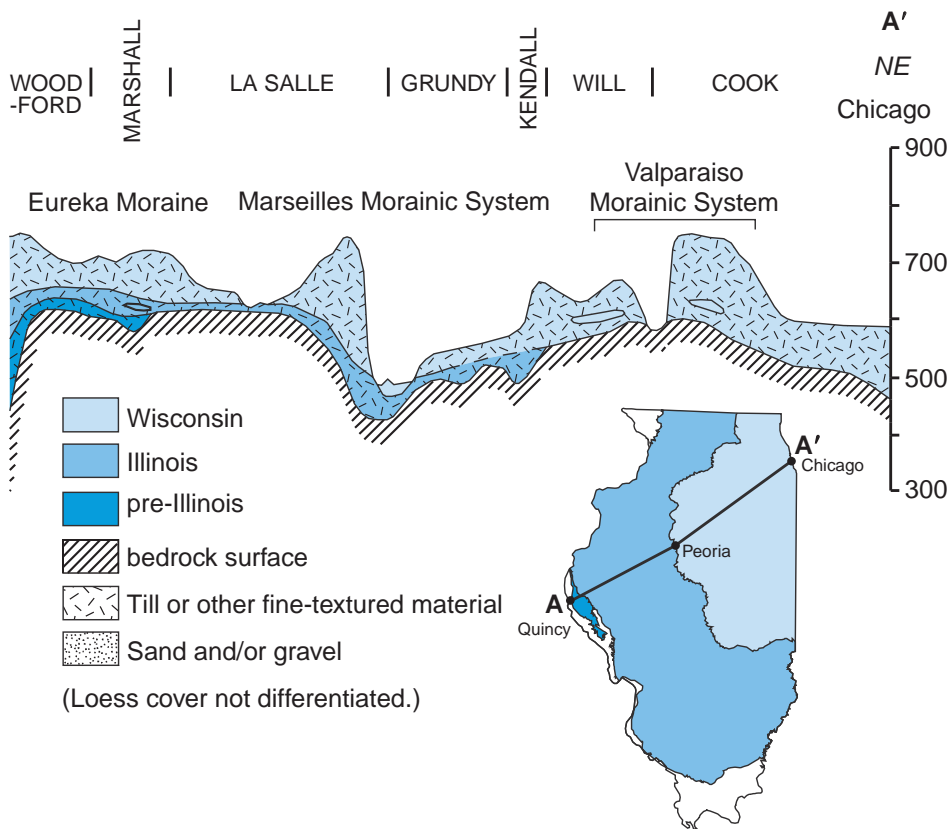
**Figure 27** Cross section showing the general vertical succession of pre-Illinois, Illinois, and Wisconsin Episode deposits in the subsurface along a line from Quincy on the west, through Peoria, to Chicago on the east.

## How to Read a Cross Section

There are many reasons why we need to know what is beneath the ground surface—searching for water and mineral resources and siting waste disposal facilities, among others. To visualize and understand the distribution of the layers below the ground surface, geologists construct cross section profiles of a vertical section of the Earth (fig. 27). The cross sections show what is known about the vertical sequence and lateral extent of rocks and sediment and provide the necessary third dimension across the area of interest. This area may be as small as a local factory site where the rate and direction of flow of some contamination infiltrating the ground must be determined for cleanup, or it may be as large as a state or even several states in order to achieve a regional picture of the extent and variability of major subsurface rock and sediment units. Cross sections are critical for interpreting the relationships among the various layers of sediment deposited across an area.

The vertical and horizontal dimensions on the cross section are drawn to different scales. The scale of a map indicates the proportion (expressed as a fraction or ratio) between the distance on the map and the corresponding actual distance of the land being mapped; for example, 1 inch on a map may correspond to several hundred feet, a mile, or tens of miles of actual distance. On the cross section in figure 27, the scale bar indicates that 1 inch on the map represents about 23.5 miles of actual distance.

Because the landscape in the Midwest is relatively flat, if the vertical scale of a map were the same as a horizontal scale, the hills and valleys would appear as



only very shallow bumps and dips, and the underlying *strata* could hardly be seen at all. To recognize Illinois landscape features and subsurface strata, the vertical scale is often considerably exaggerated.

Figure 27, for example, shows a generalized southwest-to-northeast cross section from Quincy to Peoria to Chicago. Perhaps the most striking feature of the cross section is that both the landscape and the bedrock surface are shown with steep slopes, deep valleys, and nearly vertical walls. The Illinois landscape across this area is not this rugged.

These apparently steep features are the result of intentional vertical exaggeration. On the cross section, 1 inch in the vertical direction represents almost 300 feet; 1 inch in the horizontal direction represents about 23.5 miles.

Now the following features can be easily noticed: (1) till and other fine-textured sediments predominate in the glacial cover over the bedrock; (2) most of the sand and gravel occurs in the deeper bedrock valleys; (3) the glacial cover is, in general, thicker between Peoria and Chicago than it is between Quincy and Peoria; (4) most of the additional thickness is due to deposits left during the last glaciation; (5) the bulk of the glacial sediment from Quincy to Peoria consists of pre-Illinoian deposits with a comparatively thin cover of Illinoian sediment; (6) Illinoian glacial deposits disappear toward Chicago; and (7) sediments of the Wisconsin glaciation directly overlie bedrock in eastern Illinois and the Chicago area.

# Before the Ice Age

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*Imagine exploring Illinois before the Ice Age. You would have roamed a landscape far different from today's. You would find hills and valleys, plateaus, and large rivers flowing westward through central Illinois and southward through north-central Illinois. Wouldn't it be fascinating to be able to take a picture of that ancient land surface and compare it to the surface that geologists today have portrayed through painstaking compilation of thousands of bedrock elevations from drill cores and samples?*

## Investigating Bedrock in Illinois Today

In Illinois and much of the Midwest, the term “bedrock” refers to the solid rock buried beneath the unlithified glacial sediment. Is the bedrock a flat surface composed of one type of rock? Or are there hills and valleys on a buried surface consisting of several different types of rock? How do we find out?

The first step is to go to where bedrock is exposed. Bedrock occurs at or very close to the ground surface in three areas of Illinois—the northwestern corner (Jo Daviess, Stephenson, and Carroll Counties), western Illinois (Adams, Pike, and Calhoun Counties), and the southern part of the state (Union, Johnson, Pope, Hardin, Alexander, Pulaski, Massac, and portions of Jackson, Williamson, Saline, and Gallatin Counties) (fig. 26). We have little difficulty believing that in these areas the landscape before glaciation probably looked similar to the way it does today. Elsewhere in the state, where the cover of glacial drift is thin, bedrock can also be seen in some road cuts, in the bottoms and banks of streams, and where erosion has removed the overlying glacial cover.

Most of the rest of Illinois, however, is mantled by glacial sediment ranging up to several hundred feet thick, and we might think there is little we could find out about the pre-Ice Age landscape. Over the years, however, many thousands of holes have been drilled through the glacial drift into bedrock in the search for water, oil, coal, and other resources or just to gather more detail for mapping. The records, or logs, of earth materials encountered in these drillholes provide the next step in investigating bedrock. Drillers' logs tell us about both the types of bedrock that underlie the glacial drift and their elevations above mean sea level (msl). By plotting the elevations of the buried bedrock surface and interpreting the bedrock surface between these locations,

geologists have been able to assemble a fairly complete picture of the landscape before the glaciers (fig. 28).

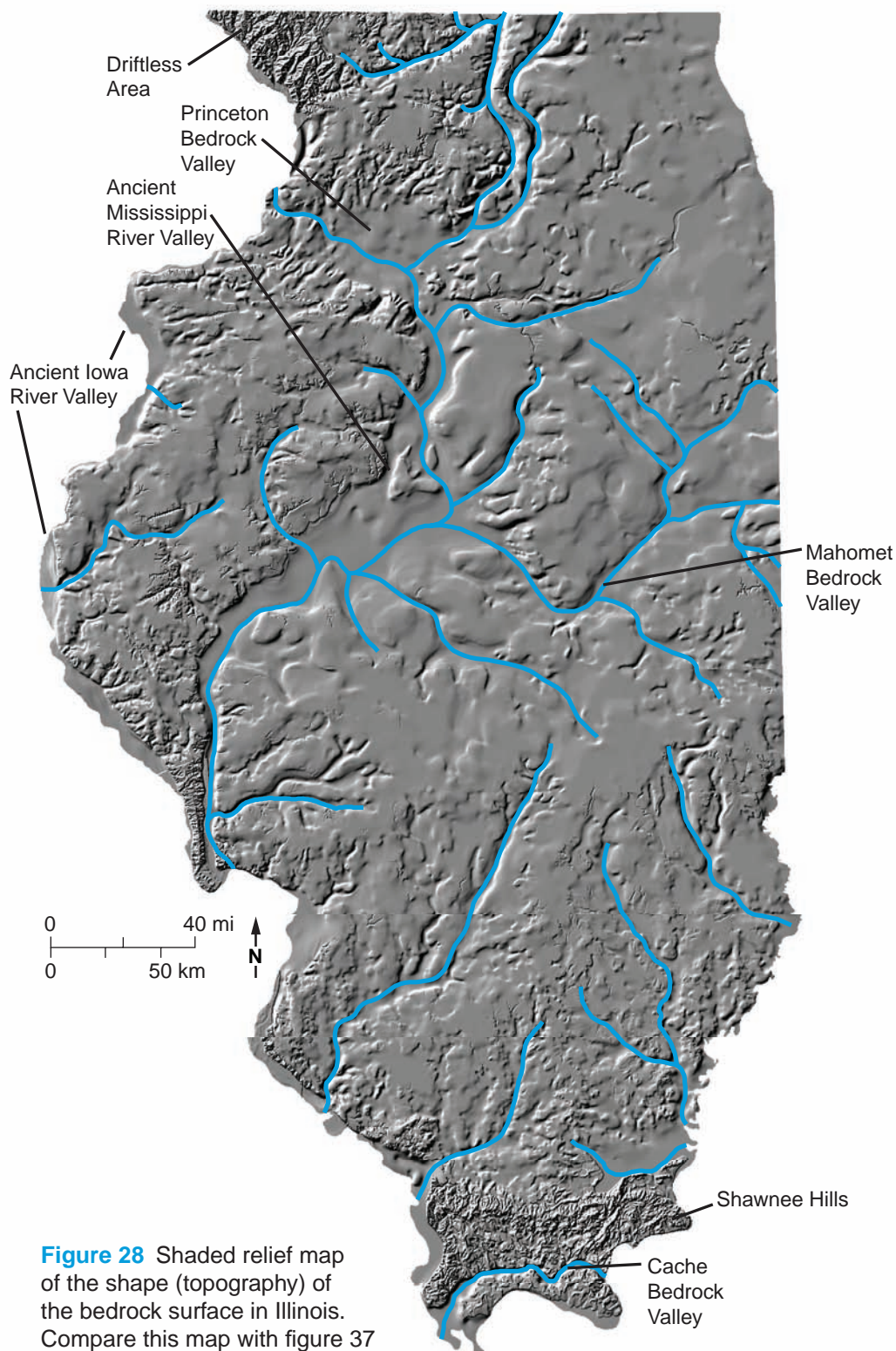
## Studying Buried Bedrock

Evidence from thousands of holes that have been drilled deep into bedrock tells us that beneath the glacial drift many layers of sedimentary rock from 2,000 to about 15,000 feet thick overlie a “basement” of ancient igneous and metamorphic rocks, mainly granite. These basement rocks extend deep into the Earth’s crust. None is exposed at the ground surface or even found at the bedrock surface anywhere in Illinois, although they can be seen in the Missouri Ozarks and in central Wisconsin.

The overlying sedimentary rocks, mainly shale, sandstone, limestone, coal, and dolomite (fig. 29), range in age from about 510 million years old (Cambrian) to 290 million years old (end of Pennsylvanian time) (fig. 1). Pennsylvanian age rocks are the youngest bedrock across most of the state. The sediments from which these rocks were formed were deposited in coastal swamps and shallow seas whose margins fluctuated across what is now Illinois. Over time, the sediments were gradually *lithified* by compaction and cementation. Later, Cretaceous gravel beds (about 144 to 65 million years ago) were deposited in extreme southern and western Illinois as part of an *embayment* (a deep indentation or recess of a shoreline forming a bay) that extended all the way from the present-day Gulf of Mexico to the southernmost tip of Illinois. Cretaceous sand deposited in a delta overlies the gravel. During Tertiary time, between about 65 and 1.8 million years ago, coastal plain and deltaic sediments were deposited at the extreme southwestern tip of the state.

## The Bedrock Landscape

Except for localized areas where glacial ice scoured the bedrock surface, this surface was primarily shaped by river erosion. A very long time intervened between deposition of Pennsylvanian age sediments (approximately 290 million years ago) and deposition of Ice Age sediments beginning about 1.8 million years ago (fig. 1). If other sediments were deposited during this time, they must have been eroded away, because no physical record of them remains. We must assume that erosion was the dominant process that affected the preglacial landscape during the intervening 288 million years. As with today’s landscape, the bedrock surface can generally be divided into uplands and valleys.



**Figure 28** Shaded relief map of the shape (topography) of the bedrock surface in Illinois. Compare this map with figure 37 on p. 62.



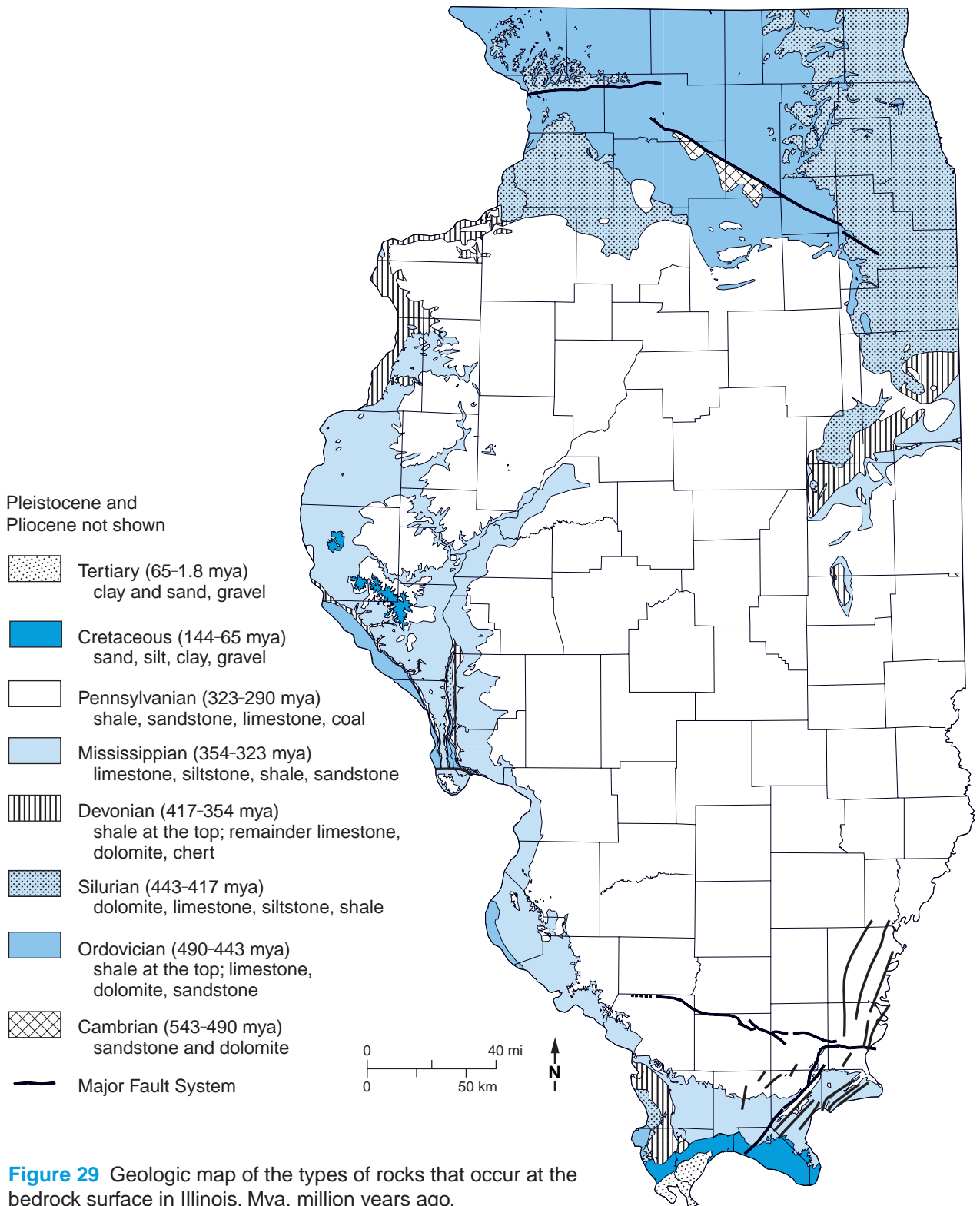
## Bedrock Uplands

Great mountain ranges of folded and faulted (broken) rocks never existed in Illinois, according to all available evidence. Instead, sedimentary rocks that were fairly resistant to erosion, such as limestone, dolomite, and sandstone (fig. 29), formed *cuestas* and uplands, especially in the northeastern, northwestern, western, and far southern parts of the state. The highest parts of the preglacial bedrock surface are still exposed in the state's northwestern corner and in the Shawnee Hills region of southernmost Illinois (fig. 28). There, the elevation of the bedrock surface is about 800 feet to more than 1,000 feet above msl. In western and northeastern Illinois, where bedrock is also dominated by limestone, sandstone, and dolomite, bedrock surface elevations of 600 to 800 feet above msl are common. Over much of the rest of the state, Pennsylvanian shale forms the bedrock surface. This shale was easily eroded and formed extensive areas of low elevations ranging from 400 to 600 feet above msl over much of the southern two thirds of the state.

## Bedrock Valleys

Considering the vast amount of time during which the bedrock surface was exposed to erosion, it is not surprising that a major drainage system developed on it. One of the most striking features of the preglacial landscape is a large valley system in central and east-central Illinois (fig. 28) known as the Mahomet Bedrock Valley. This valley enters the state from west-central Indiana and meanders westward to join the ancient Mississippi Bedrock Valley in Tazewell and Mason Counties. Generally these two valleys lie between 200 and 400 feet above msl. Much of the drainage of the continental interior in preglacial times converged into these and other major preglacial valleys in Illinois and then entered the embayment area that extended from the southernmost tip of Illinois to the present-day Gulf of Mexico. The Cretaceous and Tertiary sediments at the southern tip of the state (fig. 29) reflect the northernmost extent of these embayment sediments.

Other major drainageways on the bedrock surface include the ancient Iowa River (the present Mississippi River valley from the west end of Rock Island County to the mouth of the Illinois River) and tributaries to the Mahomet Bedrock Valley or the ancient Mississippi Bedrock Valley. Most of these drainageways also occur at elevations between 200 and 400 feet above msl. Parts of the bedrock valleys coincide with present-day river valleys and have been reoccupied by today's rivers, such as the lower Illinois and Kaskaskia Rivers. These well-established



**Figure 29** Geologic map of the types of rocks that occur at the bedrock surface in Illinois. Mya, million years ago.

ancient drainage systems were disrupted at various times and in various ways by the repeated advances of the continental glaciers. These disruptions are discussed in the following chapters.

## The Driftless Area

Jo Daviess County and parts of Stephenson and Carroll Counties are part of a larger area extending into southwestern Wisconsin, northeastern Iowa, and southeastern Minnesota that is called the Driftless Area because no glacially deposited sediments have been found to overlie the bedrock. Some evidence suggests that one of the oldest glaciers may have at least partially crossed the area. Some high-elevation sand and gravel (outwash) has been found, but if till was deposited there, it has been eroded or not yet found.

### Did You Know?

Charles Mound, the highest point in the state at an elevation of 1,235 feet above msl, is located in the Driftless Area.

The Driftless Area is a hilly, rugged landscape mantled only by loess and stream alluvium. Its driftless condition seems curious. The drift that surrounds this region proves that glaciers were present in the area at one time or another during the Ice Age. However, the bedrock surface in this area, ranging from about 800 to more than 1,000 feet above msl (fig. 28), is higher than the land surface anywhere else in the state. Because glacial ice seeks the path of least resistance as it moves, the ice was likely deflected by this high area. Although it is tempting to imagine the area as an island of rock surrounded by ice, it is more likely that ice moved past it from various directions at different times during the Ice Age but never completely surrounded it at any one time. Today, this rugged area shows us how other parts of Illinois may have appeared before the glaciers came.

# The Earliest Glaciations

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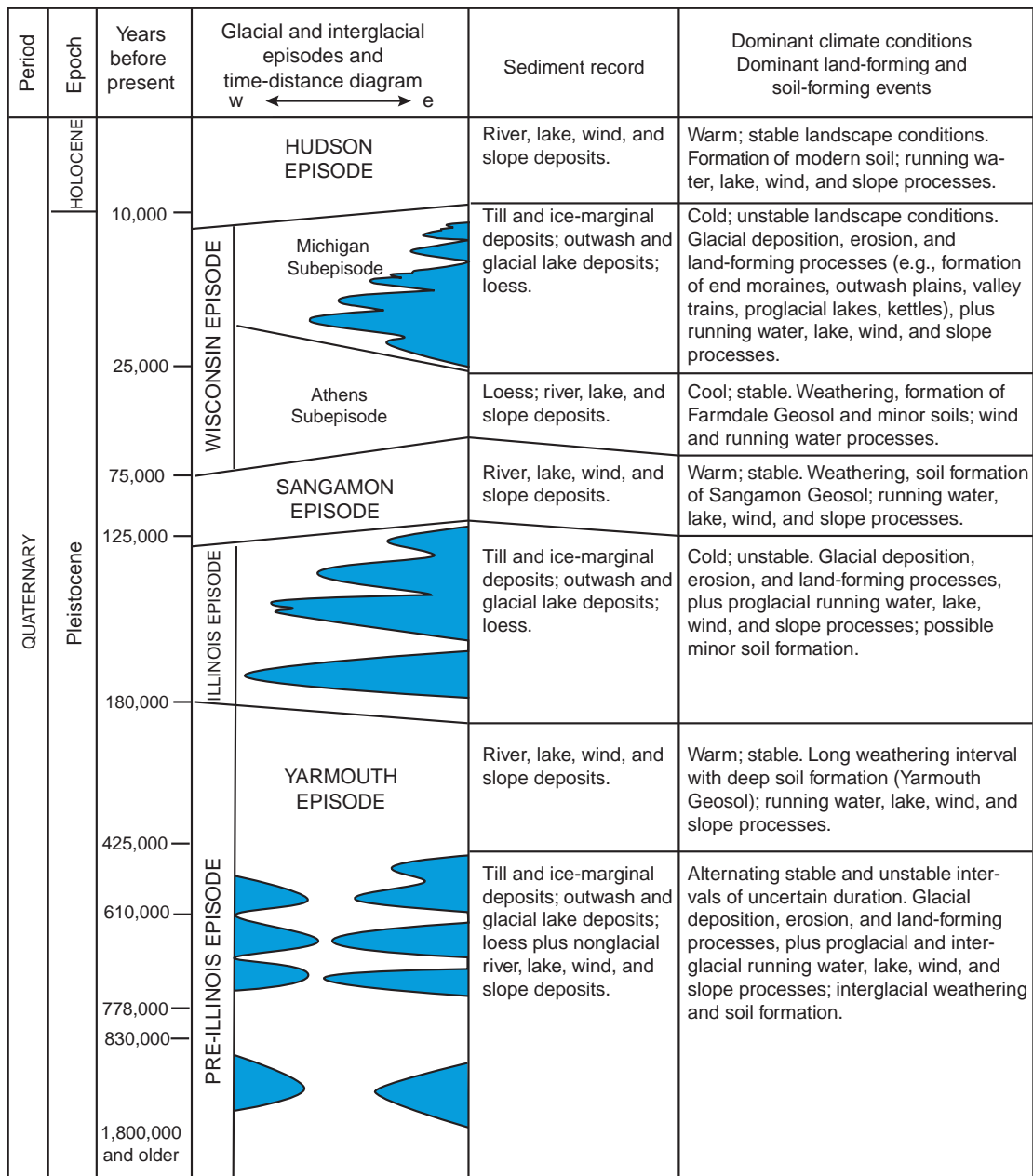
*Imagine standing on the bluffs of the ancient Mississippi River valley somewhere between what is now Peoria and Beardstown about 800,000 years ago. You might well have seen the leading edges of two vast continental ice sheets, one advancing from the northeast and one from the northwest, facing each other across the broad river valley.*

## Deciphering the Earliest Glaciations

Early study and classification of glacial deposits and ancient buried soils led geologists to propose that there were four major glaciations in North America during the Ice Age: (1) the oldest glaciation, the Nebraskan, was followed by the Aftonian interglacial interval; (2) the second glaciation, the Kansan, was followed by the Yarmouth interglacial interval; (3) the Illinoian glaciation was followed by the Sangamon interglacial interval; and (4) the Wisconsin glaciation was followed by the present warm interval. These glaciations were named after the states where their deposits were first studied or are best exposed. Until the early 1970s, Illinois geologists recognized these classic four subdivisions of the Ice Age.

More recent studies of glacially deposited sediments in North America and Europe, especially cores of ocean sediments from the North Atlantic, revealed a much more complex picture; major glaciations occurred several more times than previously recognized. Many geologists now think that at least 7 and perhaps as many as 12 or even 15 continental glaciations occurred before the Illinoian and the Wisconsin glaciations in the continental United States. These estimates are based on ice core records from Greenland and Antarctica and oceanic records as well as analysis of mineralogical composition and physical characteristics of subsurface glacial sediments recovered from borings from one area to another, careful study of ancient soils that developed in these early glacial deposits, and techniques such as reversed magnetic polarity, amino acid racemization, and radiometric dating that can help date and *correlate* sediments from one place to another.

Because much work remains to be done to identify, characterize, and trace these early glacial sediments, they are not given formal names and are grouped together. Because they were all deposited before the Illinoian glaciation, these sediments are often referred to as pre-Illinoian sediments (fig. 30). When they have been characterized, dated,



**Figure 30** Timetable illustrating the glacial and interglacial events, sediment record, and dominant climate conditions of the Ice Age in Illinois. Blue areas illustrate the ice margin fluctuations during the glacial episodes.

and traced more precisely, these sediments will be correlated with sediments of similar ages elsewhere and assigned specific *lithostratigraphic* names.

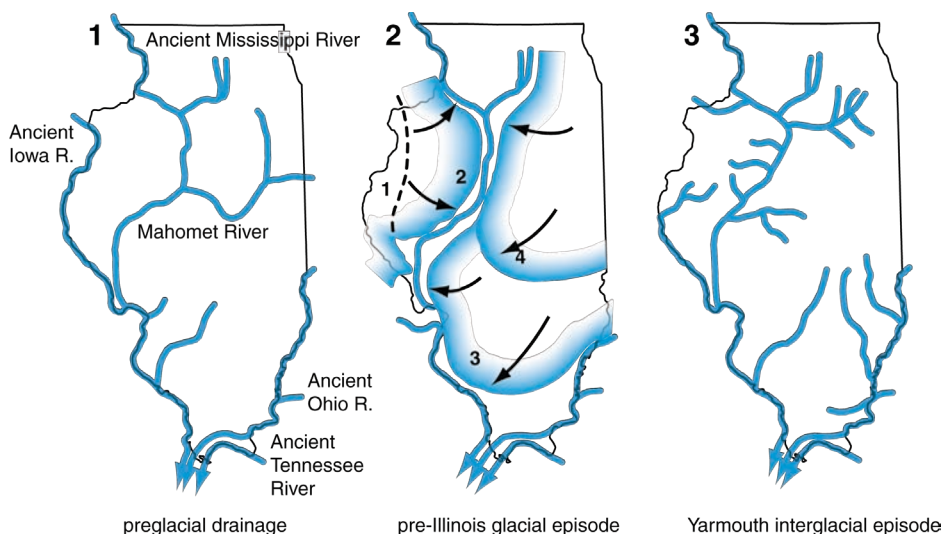
The sediments deposited by the first glaciers to enter Illinois have been severely eroded by running water and more recent glaciers. Today only scattered remnants of these sediments are found, generally buried beneath younger glacial deposits. Therefore, it is much more difficult to learn about these earliest glaciations than about the later Illinoian and Wisconsin glaciations. No distinct landforms have yet been identified that are composed of glacial sediments older than those of the Illinoian Episode.

## Origin of the Early Glaciers

In the absence of evidence such as distinctive lobe-shaped moraines that can indicate the direction of ice advance, we must rely directly on the sediments themselves to learn where the glaciers originated. In the deposits of these earliest Ice Age visitors, we find evidence for both northeastern- and northwestern-source areas (fig. 2 on p. 2; fig. 31, no. 2).

## Northwestern-Source Glaciers

Pre-Illinoian sediments can be found directly beneath the loess that blankets the land surface in a strip of western Illinois approximately 70 miles long (from Hancock County on the north to Pike County on the south) and from 2 to about 15 miles wide (from the Mississippi



**Figure 31** The extent of pre-Illinoian Episode glaciations and interglacial drainage in Illinois.

## Classifying and Naming Geologic Deposits and Times

Over the years, geologists have developed sets of terms to classify rocks and sediments. These classification systems help people communicate when discussing geologic history or referring to specific layers of rock and sediment (called strata). Because our understanding grows as new data become available and new ideas and techniques develop, classification systems are continually being modified. Commissions of geologists periodically review and modify the guidelines (called *stratigraphic codes*) for classifying geologic strata and time.

**Strata** Geologists describe the *lithologic* (physical) characteristics of strata that allow them to be mapped and traced regionally. A unit is named after a place where it is well exposed and the lithologic characteristics are typical (the “type locality”). For example, the Kankakee Formation (a bedrock formation) was named for the Kankakee River near the city of Kankakee, where the strata of the typical dolomite lithology crop out in the river banks. Such units are known as lithostratigraphic units. The basic unit in lithostratigraphic classification is the *formation*, which must be identifiable on the basis of easily recognized physical properties and must be widespread and thick enough to be mappable on a regional scale. A formation may be subdivided into smaller units called *members*, and several formations can be combined into larger units, called groups.

**Geologic time** Geologists have subdivided geologic time into various named intervals. For example, the Pleistocene Epoch (or Great Ice Age) is part of the Quaternary Period and is subdivided into smaller intervals, such as the Illinoian and Wisconsinan Ages, which are represented by deposits of different major glaciations.

Originally, the sediments of the Ice Age were not classified in the same way as bedrock. That is, formations and members of glacial sediments were not named. Instead, geologists named the major glaciations after the states (Kansas, Nebraska, Illinois, and Wisconsin) where deposits of those glaciations were well exposed. Endings of “-an” were added to the state names (except Wisconsin) when referring to the associated time, sediments, landforms, or the glaciations themselves. Between 1960 and 1970, geologists from Illinois were among the first to classify the Ice Age deposits into formations and members. They also subdivided the Quaternary Period into glacial and interglacial ages and subages on the basis of glacial and interglacial deposits, and applied adjectival endings to all these units (for example, Illinoian Age, Sangamonian Age, and Wisconsinan Age).

**New time classification** In the most recent stratigraphic code, geologists provided new guidelines for subdividing geologic time in cases where the sediment units on which the time is based are clearly *time-transgressive*, that is, when deposition of a single distinctive unit clearly began and ended earlier in one place than another (see sidebar, p. 57). Such is the case with most glacial and interglacial units. Radiometric age dating indicates that the last glaciation began earlier in Canada than it did in Illinois and ended in Illinois before it did in Canada. Recently geologists have introduced a modified classification system for Quaternary time in which glacial and interglacial intervals are referred to as episodes rather than ages. Episodes are sometimes subdivided into smaller intervals called subepisodes and phases. Unlike most time units in the present system, those in the new system do not have adjectival endings.

### Alternative time systems

Wisconsinan Age	Wisconsin Episode
Sangamonian Age	Sangamon Episode
Illinoian Age	Illinois Episode
Yarmouthian Age	Yarmouth Episode
pre-Illinoian ages	early glacial episodes

This publication uses the new terminology for classifying Quaternary time. But, if you should read somewhere about the Wisconsinan Age of glaciation, be assured that it refers to essentially the same time interval as the Wisconsin Episode.

River bluffs eastward; fig. 26 on p. 31). Because they are closer to the surface in this area, these sediments are generally more easily studied here than elsewhere. By means of samples taken from outcrops and drillholes, geologists can trace these sediments beneath younger deposits to the east. Glaciers coming from a northwestern-source area would have crossed Iowa before entering Illinois. Iowa geologists have determined that correlative deposits in their state have a predictable sequence, consisting of two distinct bundles of tills. The older, underlying bundle of tills was named the Alburnett Formation, and the younger, overlying bundle was named the Wolf Creek Formation. These deposits in the same sequence have been traced from Iowa across the Mississippi River and western Illinois nearly to the Illinois River (fig. 27 on pp. 32–33). There is no specific evidence as yet that the northwestern-source glaciers crossed the Illinois River (ancient Mississippi River) valley.

Sediments from northwestern-source glaciers are distinguished by more ground-up limestone (a rock composed of the mineral calcite that reacts readily with dilute hydrochloric acid) and small amounts of the clay mineral illite. The mineralogical composition of sediments from these northwestern-source glaciers contrasts with that of sediments from the northeastern-source glaciers.

## **Northeastern-Source Glaciers**

Although deposits of early northeastern-source glaciers have been eroded away in many parts of the state, they can be found deeply buried throughout parts of central and east-central Illinois, especially in some of the deeper bedrock valleys. Over the past 40 years, geologists have studied samples from thousands of drillholes that reached bedrock and have traced and correlated these earliest glacial sediments over broad areas. In a few places where bedrock is comparatively near the surface, such as in Vermilion County, pre-Illinoian deposits have actually been exposed in coal strip mines, such as can be seen in Kickapoo State Park.

As mentioned, northeastern-source sediments generally have a mineralogical composition that is different from that of the northwestern-source sediments. Pre-Illinoian tills in eastern Illinois generally contain large amounts of illite and more ground-up dolomite and dolomite pebbles than ground-up limestone and limestone pebbles. One till in eastern Illinois, however, is unique among the northeastern-source tills. Named the Hillery Till Member, it is a distinctive deep reddish brown and contains so much ground-up limestone that it reacts more strongly



than other northeastern-source tills when a drop of dilute hydrochloric acid is placed on it. This till is thought to have been deposited by a glacier advancing out of a source farther to the northeast and east than the Lake Michigan basin area, possibly out of the Lake Erie area, in which case it would have ground up some of the limestone bedrock traversed between there and eastern Illinois. Because of its distinctive color and composition, the position of the Hillery Till Member in the sequence of pre-Illinoian deposits in east-central Illinois is relatively well known so that when it is encountered, other (usually gray) tills above and below it can be identified and correlated according to their relative age and characteristics.

## Time Relationship between Pre-Illinois Deposits

We do not yet have the means to tell whether the glaciers entered Illinois from the northwest and from the northeast at the same time. The most commonly used radiometric age dating technique, carbon-14 dating, does not reach back far enough in time, and other techniques may not be precise enough. Nor does there appear to be any evidence that the tills of western Illinois are found in eastern Illinois or that they can be correlated to any tills there. So far, then, we do not know the time relationship between the pre-Illinoian eastern and western tills.

## Other Sediments

Our discussion of early glaciations has focused almost exclusively on tills because where we find till, we know that ice once covered that area. Tills are also widespread and are the type of glacial deposit most easily traced and correlated by texture and mineralogical composition in Illinois.

Nevertheless, logs of drillholes through glacial sediments record many beds of silt, clay, and sand and gravel interspersed within and between layers of till. Thick deposits of sand and gravel fill many parts of the bedrock valleys. These sediments indicate that glacial rivers sorted and deposited rock debris; coarser material was dropped closer to the ice front, and finer debris was carried farther downstream. Where we find sand and gravel within tills, we can hypothesize that they were deposited in a meltwater stream beneath or near the ice. These sand and gravel beds are of great importance because they are commonly saturated with water and can serve as *aquifers* that supply drinking water for communities, industries, farms, and households.

Deposits of sand and gravel generally do not have distinctive characteristics that can be correlated over long distances. However, experience has shown that if the tills above and below major sand and gravel beds can be traced and correlated from one region to another, the continuity of major deposits of sand and gravel lying between these tills can generally be evaluated, and drilling for water can be guided by this information. Locally, some sand and gravel beds may display certain characteristics, such as the presence of grains of a certain mineral, that can be used to correlate these bodies.

Undoubtedly, the most significant aspect of pre-Illinoian sand and gravel units is their thickness and extent in the major bedrock valleys, which makes them useful as potential sources of major water supplies for nearby communities. Perhaps the best-known example is the Mahomet Bedrock Valley, which was probably formed and occupied by a series of preglacial rivers and glacial meltwater streams (fig. 31, nos. 1 and 3 on p. 42). Up to 150 feet of sand and gravel fills parts of this broad valley. Elsewhere, in the deepest parts of the ancient Mississippi Bedrock Valley (fig. 28 on p. 36 and fig. 31, no. 1), a sand with abundant distinctive polished pink and red quartz grains occurs. Wherever pre-Illinoian outwash sands containing reddish quartz grains occur, they can probably be correlated to each other, thus providing one more clue to piecing together the story of the earliest glaciations in Illinois.

## **Ancestral River Systems**

After the earliest glaciations (fig. 31, no. 3), the ancient Mississippi River flowed along the west side of the Driftless Area in Illinois as far as Fulton in Whiteside County. From there, it followed a southeastward course to the present big bend of the Illinois River valley in Bureau County. With one exception, the river then essentially followed the present course of the Illinois River valley southward to its confluence with the ancient Iowa River at Grafton in Jersey County. The exception is the present, very young valley near Peoria and Pekin where the ancient Mississippi River valley lies a short distance east of the Peoria-Pekin area. This segment of the bedrock valley is called the Mackinaw Segment, named for the village of Mackinaw that lies above it.

Another ancestral river, the ancient Iowa River (figs. 28 and 31, no. 1), with headwaters in east-central Iowa, followed the present Mississippi River valley below Muscatine, Iowa, southward to its confluence with the ancient Mississippi River at what is now Grafton in Jersey County. Today, its valley is occupied by the modern Mississippi River.

Drilling logs show that the lowest parts of the Mahomet Bedrock Valley and its tributaries are filled with sand and gravel, lake silts, and even a few tills of the earliest glaciers to advance into Illinois. From this evidence, we can deduce that the filling of this major valley system began with these earliest glaciers.

## **The Yarmouth Soil: A Distinguishing Role**

A long interval of warmer climate called the Yarmouth Episode (fig. 30 on p. 41) occurred after the last of the early ice sheets melted away. The thick soil that developed on the pre-Illinoian deposits was named the Yarmouth Soil after the village of Yarmouth in Des Moines County, Iowa. Although in many areas this thick soil was at least partially *truncated* (planed off) by later glaciers, what is left can still be seen in outcrops in western Illinois and in samples from drillholes elsewhere in the state. Perhaps the most distinctive parts of the Yarmouth Soil formed where clay and silt slowly accumulated in low, wet, poorly drained areas of the landscape. Today these accumulations of weathered clay and silt are dark gray to black, massive, dense deposits that are called *gley* or *accretion gley*; in many areas, the Yarmouth gleys are overlain by sediments of later glaciations.

In areas where the Yarmouth Soil remains complete, it is well developed and about twice as thick as the Sangamon Soil discussed in the next chapter. The Yarmouth's thickness suggests lengthy and significant intervals of warm climate conditions contributed to its formation (fig. 30).

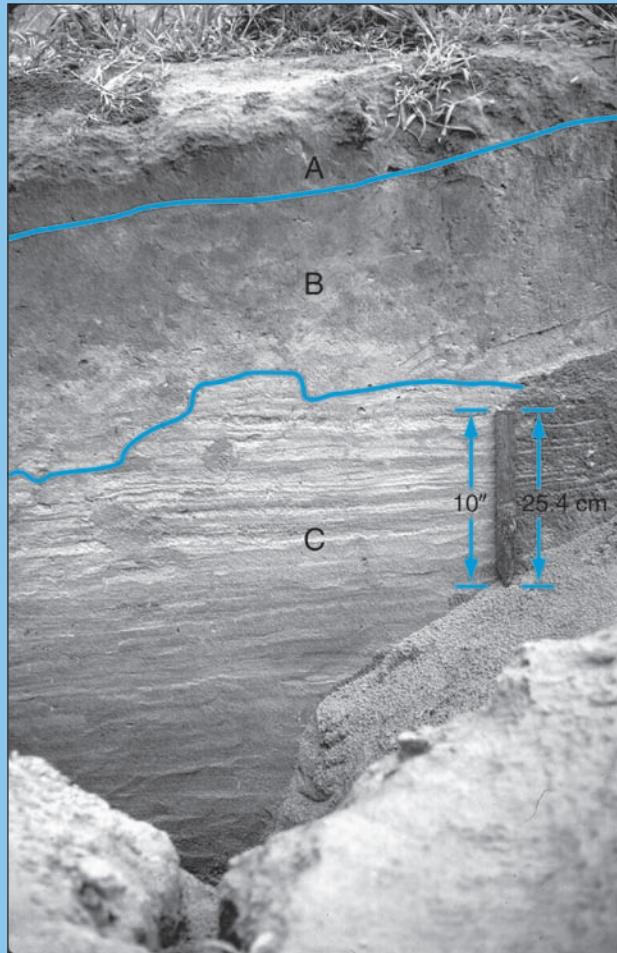
## **Finding Out More**

Most of our information about pre-Illinoian deposits comes from subsurface samples and logs. Many samples and cores from drilling in western and eastern Illinois have yet to be studied. In addition, excavations for construction of new highways may open up new exposures of glacial sediments to study, and cores from new engineering test holes frequently become available. Whenever and wherever such exposures or borings may occur in the future, geologists will study, describe, sample, and analyze them to learn how these new pieces of information fit into the puzzle.

## The Importance of Buried Soils

The word “soil” means different things to different people. To the average person, soil is the material at the ground surface in which plants grow. To the engineer, soil generally refers to all sediments that can be easily differentiated from rock. To the soil scientist, a soil is a sequence of zones of alteration in a sediment or rock (called the parent material). These zones, called *soil horizons* (fig. 32), result from weathering of the parent material. Weathering is exposure to the various chemical, physical, and biological processes that affect geologic materials at and near the Earth’s surface. The sequence of soil horizons is called the soil profile. The characteristics of the various soil horizons, briefly outlined here, that appear in old buried soils within glacial deposits can provide geologists with important evidence for climatic and other events that occurred as the soil was forming.

The upper part of a soil profile is the most intensively weathered because it is most exposed to surface processes. This top horizon



**Figure 32** Shallow soil profile showing A, B, and C horizons. (Photograph by Leon R. Follmer.)

is called the A horizon. It is generally the darkest in color because it contains the largest amount of decomposed organic remains. Below the A horizon in some soils is a subsurface horizon called the E horizon, which has the lightest color in the soil profile because the colored materials have been removed by leaching. *Leaching* is the process by which minerals dissolve and are carried downward by infiltrating water from snow and rain into the underlying B horizon. The B horizon is the zone of accumulation of clay particles (sometimes called claypan) carried down from the A horizon by infiltrating water. Beneath the B horizon is the C horizon, which generally is blocky, massive, and only slightly altered from the original sediment or rock. Untouched by weathering processes, the original parent material is called the D horizon. Unweathered rock, in contrast to sediment, is called the R horizon.

Soil horizons were first recognized and studied in the soils existing on today's land surface. When old soils buried within the sequence of glacial sediments were recognized, geologists realized that these soils also could reveal information about Ice Age events. Old buried soils indicate that warm intervals occurred between advances of continental glaciers and that the land surface was stable for a very long time—that is, little erosion took place, and no significant amounts of new sediment were deposited.

Often, the buried soil horizons we find are incomplete. Sometimes another continental glacier advanced and overrode the stable land surface represented by this buried soil and sheared off (truncated) part of the soil, leaving only the lower horizons in place. By tracing the overlying and underlying tills across the landscape, we can correlate exposures of an old buried soil from place to place because some exposures reveal a more complete sequence of soil horizons than others, and those tell us more about the nature of the warm interglacial interval during which it formed.

In Illinois, there are many similarities between modern soil and ancient buried soils, such as the types and characteristics of soil horizons. From these similarities, we can conclude that the topography and climate under which soils were formed during the warm interglacial intervals were similar to the conditions under which modern soils have formed in Illinois. The thickness of a buried soil and the degree of development of its soil horizons also tell us something about the length of the interglacial interval. Because we know how much time has passed since the retreat of the last ice sheet, we can get an idea of how long an earlier interglacial interval lasted by comparing the depth of alteration of the underlying parent material to the depth of modern soil development.

There are even places where a new soil developed on top of an old soil. For example, the Illinoian glacier never overrode the very old Yarmouth Soil in parts of Adams and Pike Counties in western Illinois, so during the warm interglacial interval that followed the Illinoian glaciation, the Sangamon Soil formed within sediments that had already been altered during formation of the Yarmouth Soil. In some places in the same area, no glacier overrode the Sangamon Soil, so modern soil formed in these earlier soils. A soil scientist can tell a great deal about the history of weathering and soil formation in such areas.

# The Illinois and Wisconsin Episodes

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*On a clear day about 200,000 years ago, if you had stood atop Bald Knob in Union County at more than 1,000 feet above sea level and looked toward the northeast, you might just barely have been able to see the edge of the Illinois Episode glacier on the horizon. And if, about 20,000 years ago, you had stood near where the tiny hamlet of Oilfield in Clark County is located today and looked northward, you would have seen a low ridge of bluish gray ice on the horizon, perhaps fading into a lowering dark gray sky to the north. You would have been looking at the front of the Wisconsin Episode ice sheet as it stood at its maximum southward extent. Today, the ridge of higher ground you can see against the horizon from this location is the end moraine of that glacier.*

The evidence of the last two major glaciations in Illinois—the Illinoian and Wisconsin glaciations—is much easier to interpret than that of the earlier glaciations, because the deposits of these glaciations are directly accessible over much of the state, and the landscape left behind can be studied in detail.

## Illinois Episode Glaciation

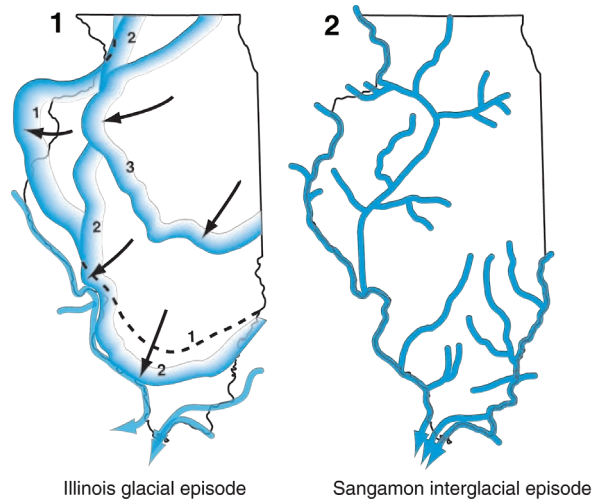
### Source Area

During the Illinois Episode, glaciers advanced southwestward out of the Lake Michigan basin from areas in the Great Lakes basin far to the northeast and east. We know the glaciers came from these areas (1) because the tills contain relatively high amounts of the clay mineral illite and the carbonate mineral dolomite, both of which are dominant in the rocks of the Lake Michigan basin area, (2) because of the direction of glacial striations, and (3) by the orientation of rock fragments (the fabric) within the tills.

### Extent of Illinoian Deposits

At the end of the long warm interval called the Yarmouth interglacial episode about 180,000 years ago (fig. 30 on p. 41), the climate again changed, and a continental ice sheet once more invaded the Midwest. During at least one of the three major advances of the next glacial episode (fig. 33, no. 2), the glacier extended farther south than any other major glacier in the continental United States; at its maximum extent, ice covered nearly 90% of Illinois. For this reason, this episode is called the Illinoian glaciation.

The extent of Illinoian sediments is easily traced because they occur directly beneath the loess blanket-ing most of the state. In the northeastern quadrant of Illinois, however, these glacial deposits are covered by deposits of later Wisconsin Episode glaciers or were eroded away by them. Illinoian sedi-ments extend from Stephenson and Win-nebago Counties on the Illinois-Wisconsin state line into the southern Illinois counties of Jackson, Williamson, Johnson, Saline, and Gallatin (fig. 26 on p. 31). These sediments also extend westward across the Mississippi River in the vicinity of Hancock and Adams Counties.



**Figure 33** The sequence of Illinois Episode gla-ciations and interglacial drainage in Illinois.

Over much of the southern part of the state, the Illinoian tills and as-sociated deposits average less than 50 feet thick. The surface of these deposits is usually deeply weathered, and end moraines are not appar-ent along their southern margin. From these facts we can speculate that perhaps the glacial deposits extend over such a large area because of a relatively rapid surge of ice that then stagnated and melted in place, rather than because of a continuous flow of ice that brought rock debris to the glacial margin and deposited it in an end moraine. Or perhaps the glacier stopped where it did only because the climate along the southern margin was warm enough to halt the ice advance or because the surging ice no longer possessed enough energy to override the bedrock cuestas of the Shawnee Hills area, which rise to elevations of 800 to 1,000 feet (fig. 28 on p. 36). Whatever the complete story may be, the great distance covered by Illinoian Episode glaciers remains as impressive evidence of climate fluctuations during the Ice Age.

### Ice Advances

Deposits of three major glacial advances have long been recognized in Illinoian Episode sediments (fig. 33). These deposits are classified as members of the Glasford Formation. The first major lobe of ice

to advance out of the Lake Michigan basin deposited silty tills. The relatively large amounts of expandable clay minerals in these tills reflect the erosion and incorporation of older loesses, soils, and sediments into the base of the advancing Illinois Episode glacier. It is not yet clear how far south this first lobe advanced, but it reached its maximum western extent in Iowa, crossing the ancient Mississippi River valley (fig. 33, no. 1). A brief warm interval of weathering must have occurred after this first Illinois Episode ice advance because a soil developed in these early deposits, although it is not as deep and widespread as the underlying Yarmouth Soil.

The ice of the second major lobe to enter the state during the Illinois Episode extended almost as far west as the first lobe and reached farther south than any North American Ice Age glacier (fig. 33, no. 1). The till deposits are sandier than those laid down during the first advance. They also have lesser amounts of expandable clay minerals and more illite than do the older and younger Illinoian tills. Apparently the ice of this advance also stagnated, or gradually melted in place, because the surface of these sediments is marked by the “ridged drift,” a system of elongate ridges and knolls, consisting largely of sand and gravel. Only a weakly developed, unnamed soil is found locally on this surface, where it is buried by younger Illinoian deposits, suggesting that a relatively short interval occurred between the middle and late Illinoian glaciations.

The last of the three major Illinois Episode glaciers to enter the state was not as extensive as either of the first two (fig. 33, no. 1). Only in central and northwestern Illinois do its deposits extend beyond the late Wisconsin Episode glacial boundary, but they can be traced beneath the overlying Wisconsin Episode drift. In general, these latest Illinoian tills are more variable in texture. In some areas, the till is fairly sandy; in other areas, where the ice overrode lake silts and incorporated them into the till, it is fairly silty. Of the three Illinoian tills, the youngest contains the largest amount of the clay mineral illite. In north-central Illinois, the last interglacial soil is recognizable in tills of the Winnebago Formation, formerly attributed to the Wisconsin Episode. These tills are now attributed to a late re-advance of the Illinois Episode.

## **Illinoian Landscape**

The loess-blanketed deposits of the Illinoian glaciation present a unique landscape known as the Illinoian till plain. In the southern third of Illinois, north of the Shawnee Hills area, this till plain is remarkably flat, interrupted only by southeast- or southwest-trending valleys and



low ridges. The flatness may be due (1) partly to the fairly low *relief* of the bedrock surface, which ranges from 400 to 600 feet above msl across broad areas (fig. 28 on p. 35); (2) partly to the nature of the ice, which was probably somewhat plastic and mobile enough to fill in low areas and subdue the remaining topography; and (3) partly to the glacier reaching so far south that it melted in place rather than advancing, retreating, and readvancing, which would have built up a rolling topography marked by moraines. Another process undoubtedly contributing to the flat till plain is *solifluction*, the slow, viscous, downslope flow of waterlogged sediment and rock debris. The essentially featureless parts of the Illinoian till plain contrast with the sharp ridges, greater relief, and generally uneven topography of the “ridged drift” area.

Interestingly, the land surface covered by till from the third Illinois Episode glacial advance in central Illinois (fig. 33, no. 1) has more relief than the surface covered by the older Illinoian tills. For one thing, the glacial margin is locally marked by morainal topography somewhat like the moraines of the later Wisconsin Episode advances. Another reason for its greater relief may be that streams flowing into the ancient Mississippi River valley during the following Sangamon interglacial episode dissected and eroded the landscape. Similar erosion by Wisconsin Episode and modern streams draining into the Illinois River drainage system probably also contributed to the greater relief in this area.

**The “Ridged Drift”** An interesting series of features on the southern part of the Illinoian till plain is collectively called the “ridged drift.” This extensive complex of ridges and kames is composed of sand, sand and gravel, silt, and gravelly till that trends northeast-southwest from the boundary of Wisconsin glaciation in Shelby County nearly to the Mississippi River in St. Clair County (fig. 26 on p. 31). The origin of the ridged drift is controversial. The ridges and knolls may have originated as eskers. Another possibility is that crevasses in the thin ablating ice may have been infilled with sand and gravel-laden meltwater, forming a series of kames and *kame terraces*. A third explanation is that the ice of the second major Illinois Episode advance may have been deflected westward by one or more lobes advancing simultaneously from farther east, possibly out of the Lake Huron basin. In this case, the ridged drift may have been formed in the area between the two ice lobes (called an “interlobate” area) in a complex coalescing of the ice margins during which this eastern lobe extended to the present Mississippi River valley from St. Louis southward. The deflected Lake Michigan lobe spread westward across what is now the Illinois River

valley and crossed the present Mississippi River valley into Iowa in the area from Hancock County to Carroll County.

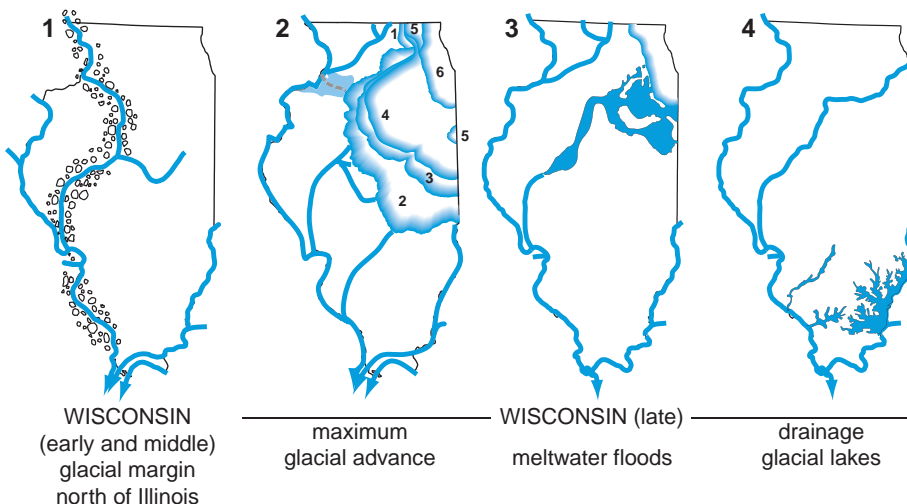
## Changing the Course of Major River Systems

When each of the Illinois Episode glaciers reached the bedrock valley near Princeton in Bureau County, the ice dammed the ancient Mississippi River (fig. 33, no. 1). Evidence indicates these diversions were only temporary, however, and following each blockage meltback of the glacial front permitted the river to resume its former southeastward course (fig. 33, no. 2). This course was maintained until the Wisconsin Episode glacier entered the area (fig. 34, no. 2). By the close of the Illinoian glaciation, the Mahomet Bedrock Valley in east-central Illinois had been completely filled with sediment.

## After the Illinoian Glaciation

Another major interval of warm climate and soil development took place after the last of the Illinoian ice sheets melted away. The soil that developed during this interglacial interval is called the Sangamon Soil after Sangamon County, Illinois, where it was first described.

The Sangamon Soil is one of the most thoroughly studied buried soils because it is so widespread. It has been traced westward into the Great Plains region, southwestward to Texas, and eastward to Ohio. In Illinois, it typically shows development of soil horizons, just as modern soil does, and it often has a strong reddish brown color. In poorly drained areas, it exhibits a greenish gray to black, dense, massive,



**Figure 34** The sequence of Wisconsin Episode glaciations and interglacial drainage in Illinois.

mucky character just as the older Yarmouth Soil does. Although much of the Sangamon Soil in northeastern Illinois was apparently truncated or completely removed by overriding Wisconsin Episode glaciers, elsewhere in the state it is well preserved and serves as an excellent identifiable marker bed. A marker bed has characteristics that are distinctive enough to be traceable over long distances in the subsurface and, thus, can serve as a *stratigraphic* reference.

## The Wisconsin Episode

In the early and middle parts of the Wisconsin Episode, glaciers did not advance into Illinois; we can deduce this because we find no tills left by these glaciers in Illinois. Sediments in Illinois from this interval are loesses and river, lake, and slope deposits (mainly silt).

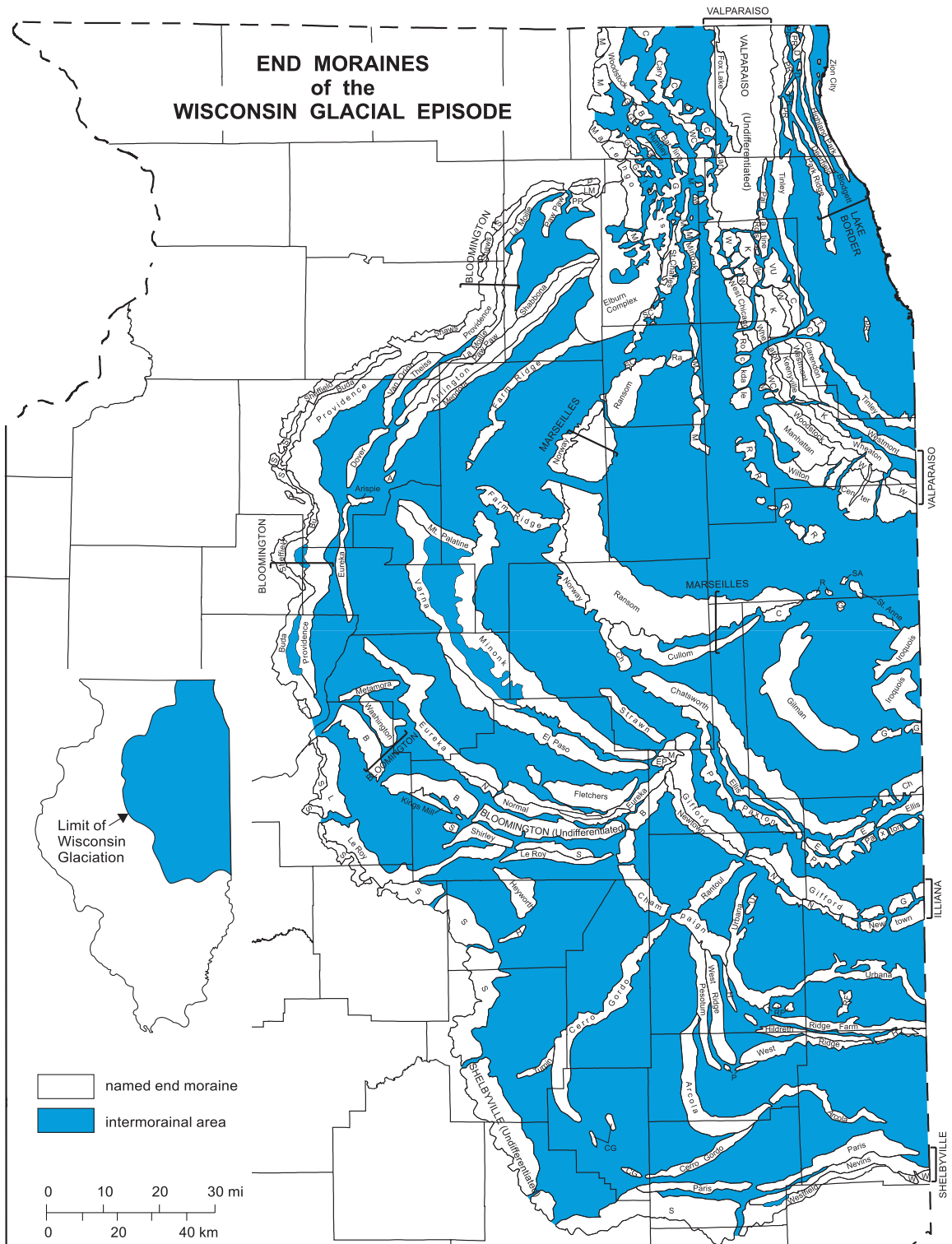
A unique sediment that helps to distinguish Wisconsin Episode sediments from older underlying deposits is a thin, distinct, and widespread organic silt deposit called the Robein Member. The Robein Member is the most widely radiocarbon-dated marker bed in Illinois. Samples have generally yielded ages from 28,000 to 20,000 years before present, well within the time of the Wisconsin Episode (fig. 30). In drilling logs, mention of a black silt or a similar sediment gives geologists a needed signpost to determine the relative age of sediments above and below it. The Robein Member, in combination with the greenish gray, poorly drained Sangamon Soil on which it rests, provides the unique marker that separates Illinois and Wisconsin Episode deposits both in outcrop and in the subsurface.

## Source Area

The Wisconsin Episode glaciers also entered Illinois from the Lake Michigan basin, as indicated by rock striations, the mineralogical composition of the sediments, the fabric of pebbles and cobbles within the tills, and the orientation of the end moraines (fig. 35). The clay mineral illite, found in the shales of the Lake Michigan basin, dominates the clay portion of all the Wisconsin Episode tills, and ground-up dolomite and numerous dolomite pebbles and cobbles from the Silurian age bedrock in northeastern Illinois also point to the northeast-southwest path taken by the ice.

## Deposits

Wisconsin Episode deposits occur at the ground surface in the northeastern quadrant of Illinois, and the margin of these deposits is marked by a prominent end moraine. These sediments, currently assigned



**Figure 35** Wisconsin Episode moraines arc across northeastern Illinois and indicate the positions of temporary stationary ice fronts as the ice margin retreated.

to the *Wedron Group*, are exposed in many road cuts, rock quarries, sand and gravel pits, and creek banks. Because they are comparatively young, these deposits have been only slightly altered by weathering and erosion. Wisconsin Episode deposits give us the most complete and easily studied clues to what happens before, during, and after the advance of an active continental ice sheet.

## When Did the Wisconsin Glaciation Happen?

A unique feature of the Wisconsin glaciation in Illinois is that this ice advance occurred recently enough that carbon-14 radiometric dating can be used to date materials deposited then. This method can reliably determine the age of organic matter as old as 50,000 years. Thus, in addition to being able to date these beds of till, sand and gravel, and lake silts and clays in relation to each other using the law of superposition, where organic matter occurs, we can sometimes bracket the actual time that the sediments were deposited.

### Time-Transgression

Time-transgression means that a layer of sediment with distinctive characteristics was deposited in an environment that shifted geographically with advancing time. Consequently, the age of the deposited layer varies from place to place.

For example, consider the area of the last glaciation. We know that the Wisconsin glaciation began earlier in Canada than it did in Illinois and ended in Illinois before it did in Canada. As we know from radiometric age dating, the Wisconsin Episode ice began advancing into northeastern Illinois about 25,000 years ago, reached its southernmost extent near Shelbyville about 20,000 years ago, and then finally melted back into the Lake Michigan basin between about 14,000 and 13,000 years ago. Therefore, the earliest Wisconsin Episode till was deposited in the Chicago area some 5,000 years earlier than it was deposited at Shelbyville. Near Shelbyville, till was deposited over about a 2,000-year span. At Chicago, tills may have been deposited over about a 12,000-year span. Wisconsin Episode till was deposited about 5,000 or 6,000 years later in the Chicago area than it was at Shelbyville. For these reasons, deposits such as the tills of the last glaciation are said to be time-transgressive.

For example, wood found in a zone of organic silt just beneath Wisconsin Episode till deposits in northeastern Illinois has been dated to about 25,000 years before present. This tells us that ice began to advance into the state at about that time, because the organic silt underlies till deposited by the Wisconsin Episode ice. At the farthest southward advance of that ice, near Shelbyville, wood has been found beneath the till that dates to about 20,000 years before present. We infer, then, that it took approximately 5,000 years for that glacier to reach its maximum extent. In abandoned beaches of Lake Michigan, where the lake level was higher as the ice front was retreating into the lake basin, wood has been found that dates from 14,000 to 13,000 years ago. Thus, in Illinois, the deposits of the Wisconsin Episode that contain wood and other organic material

are anchored in time, and we know that the glacier deposited its load of rock debris in Illinois over a period of about 12,000 years (between 25,000 and 13,000 years ago).

## Clues from Wisconsin Episode Sediments

In exposures of these deposits from the most recent ice advance, we not only can see the sediments themselves but also find clues as to how they were deposited. Till that is dense, massive, and overconsolidated was deposited directly at the base of the ice and compacted by the weight of the glacier moving over it. Till-like sediments that are neither massive nor overconsolidated may have flowed off the ice as a muddy mass. Layered (bedded), fine-grained sediments were probably deposited in a lake bed; thin layers (rhythmites) of clay, silt, and sand

### Ice Age Dust Clouds

For tens of thousands of years, as glaciers crept into the Great Lakes and headwaters of the Mississippi and Missouri Rivers, those rivers carried vast quantities of meltwater and sediment to the Gulf of Mexico. Melted at their base by the heat of the Earth and on their surface by the Sun, the glaciers issued forth first trickles, and then torrents that carved and flooded the river valleys to the south. At times the meltwater floods reached from bluff to bluff across the valleys. When floodwaters receded, they left barren, sediment-covered islands and temporarily empty stream channels exposed to winds. These sediment surfaces dried quickly.

In the brisk, dry, winter winds, sand grains began to move, accumulating first in ripples and then in small migrating dunes that moved across the land surface. The sand grains in turn kicked up smaller silt- and clay-sized grains that rose into the turbulent air and were suspended and carried downwind in dust clouds. The clouds moved the suspended silt far downwind, much like the dust clouds that occasionally rise from freshly plowed spring fields today. As the dust clouds traveled away from their source in the big river valleys, moved by winds that usually blew from the northwest, the largest particles fell first as clouds dispersed and winds dissipated. The finest particles were carried tens of miles.

As the dust cloud passed, the silt settled to the ground. Trees and grasses slowed the wind near the ground and trapped the dust. Most of the time, the dust accumulation was almost imperceptible, but gradually deposits thickened. On average, less than 1/25 inch fell each year in the areas closest to the valleys where deposition was fastest. Elsewhere, the dust fell even more slowly. It took almost 1,000 years for about 3 feet of dust to accumulate. Not only did the dust accumulate slowly, it also probably accumulated at variable rates. Some of the dust storms may have been heavy and dark and may have lasted for weeks. But mostly the dust fell gradually.

Near the Mississippi and Illinois River valleys, this wind-blown dust, called “loess” by geologists, is over 100 feet thick in places (fig. 36 on p. 60). Farther from these valleys, the loess is thinner. Much of southern Illinois is covered by at least 5 feet; western Illinois has more, about 10 feet on average. Loess is thinnest in northeastern Illinois where the glaciers stood while the loess accumulated elsewhere.

Eventually the climate warmed, the glaciers retreated, and dust deposition ceased. The upper part of the loess now began to be weathered into the silty topsoil and subsoil that form the fertile fields of Illinois. Illinois owes the richness of its soils to these ancient dust storms.

indicate cycles of deposition. Vertically graded and sorted sediments indicate that sediments were carried and deposited by running water of different velocities. For example, a sequence of layers that goes from coarse sand and gravel to fine sand indicates the sediments were carried by water that gradually slowed down. Faster moving water can carry both coarse- and fine-grained material. As the water slows, it can no longer carry the coarser grains, which settle out first.

Because the sediments from older glaciations may have been weathered or partially eroded, overridden, and compacted by younger ice sheets, many of these depositional clues are missing, buried, or dis-

## What Loess Tells Us

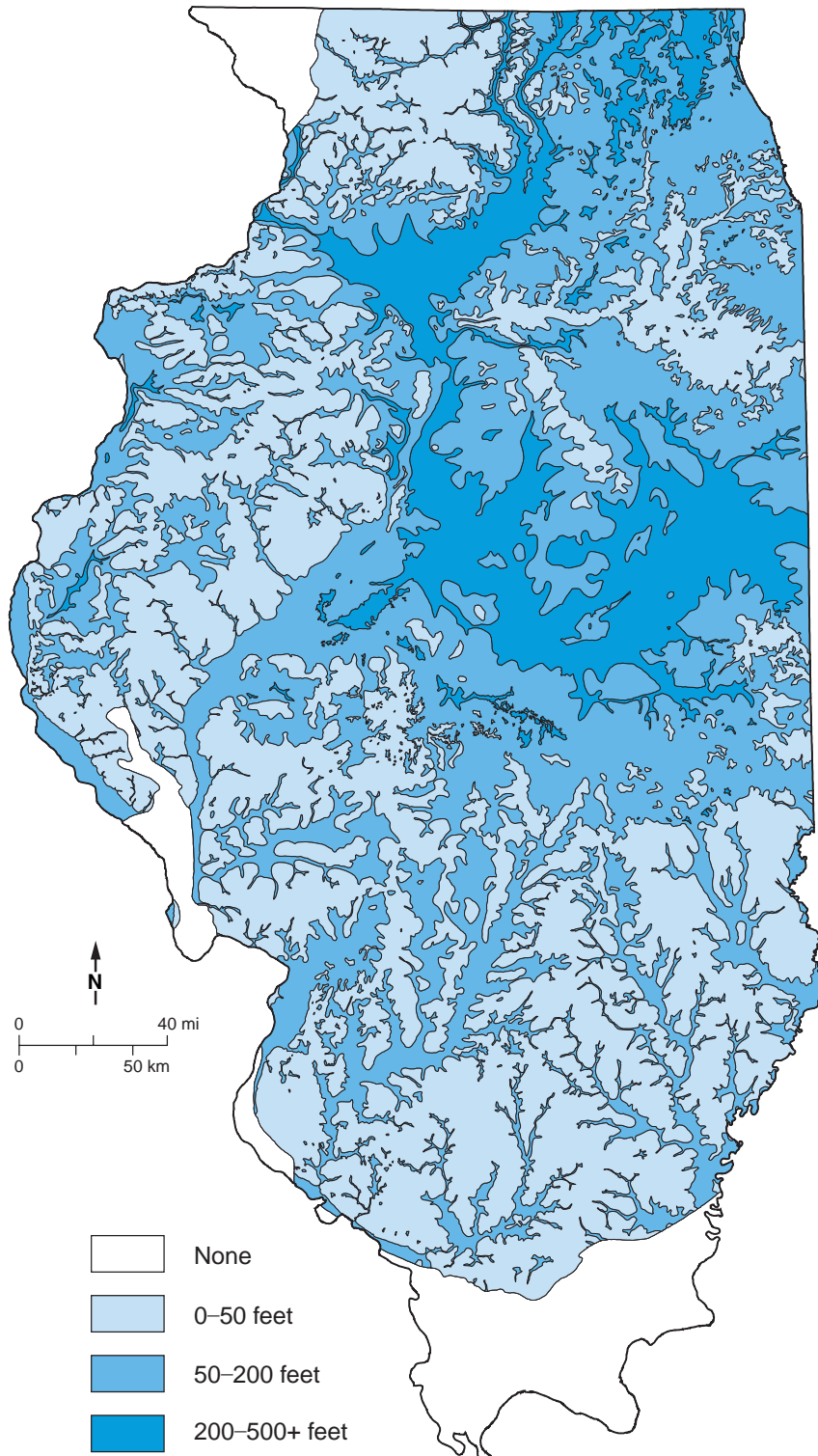
In its mineral composition, loess records the changing composition of the debris carried by its source valleys. The most dramatic change in mineral composition records a time about 20,500 years ago when the glaciers flowing from the Lake Michigan basin reached the Illinois River near Peoria, blocked the river, and diverted the ancient channel of the Mississippi River to its present channel along the west side of the state (fig. 34, no. 2 on p. 54). Huge floods, probably from temporary lakes held back in the glacier-dammed river valley, broke loose and filled the valleys to the south deeper than they have ever been filled in historic times. The fine sediment in the valleys was picked up and carried along with the wind. When it fell from the passing dust clouds, the dust gradually buried and preserved snails, wood, pine and spruce needles, and traces of grasses. These fossils are found today. In the dust deposits are also found the burrows of ground squirrels and crayfish and the traces of roots and burrowing worms and insects. During periods of slow accumulation, the dust was altered by weathering.

The record of loess accumulation during the last glaciation in Illinois tells us that, from about 50,000 to about 12,500 years ago, our big rivers were carrying glacial meltwater. The earliest meltwater carried debris that was reddish due to the red sediment entering the headwaters of the Mississippi River from the Lake Superior area. This sediment, when picked up and redeposited by the wind, became the reddish brown loess called the Roxana Silt deposited between about 50,000 and 28,000 years ago.

Between about 28,000 and about 25,000 years ago, the glaciers retreated into the Great Lakes basin, loess accumulation slowed, and weathering and soil-forming processes kept up with the accumulation for a while. A distinct weathered zone from that time (the Farmdale soil, fig. 30 on p. 41) is found in the loess near the source valleys. But, about 25,000 years ago, the glaciers re-advanced and emerged from the southern end of ancestral Lake Michigan. The renewed pulse of meltwater carried yellowish brown and gray debris, and the new loess that resulted, the Peoria Silt, was yellowish brown in color. Similar loess was deposited along the Illinois, Wabash, Ohio, Mississippi, and Missouri River valleys. About 12,500 years ago, loess deposition ceased along the Mississippi River valley. Today the Peoria Silt can be traced from Minnesota to Louisiana and from Nebraska to Ohio.

Loess deposits from several earlier glacial episodes are also present in deposits along the big rivers of Illinois. In places near the river valleys, loess can be seen in deep stream valleys or quarries that have cut through younger sediments. Near Collinsville in southwestern Illinois, three older loesses offer silent witness of earlier cycles of the Ice Age during which glaciers sent forth ice tongues and spewed meltwater torrents, and winds blew dust clouds across the land. The weathering of soils in the upper surfaces of the buried loesses tells of warm periods like that of today that intervened only to be followed by another frigid glacial episode that buried the soils with more loess or debris from the advancing ice.

Study of the loess deposits of Illinois offers insights into past climate changes, the advance and retreat of glaciers, the composition and formation of soils, the effect of erosion on the stability of ancient landscapes, and the plant and animal life that inhabited the past landscapes of Illinois.



**Figure 36** The drift that blankets Illinois becomes thinner east of the major river valleys in the state.



torted. Therefore, the evidence for determining how they were deposited is often much less clear, as well as less accessible, than that of more recent or modern glaciers. Nevertheless, the processes responsible for the compaction, layering, and sorting that we see in sediments exposed at the ground surface today were likely the same for the older, more deeply buried sediments from earlier glaciations.

## **Glaciers Change Major River Systems**

During the Wisconsin Episode advance, the Mississippi River was permanently diverted westward to occupy the valley of the ancient Iowa River along the west side of what is now Illinois, a course it still follows (fig. 34, no. 2 on p. 54). Its former valley, known as the Princeton Bedrock Valley (fig. 28 on p. 36), was buried by drift, including a great thickness of outwash sand and gravel. The great torrents of glacial meltwater flowing away from the ice contributed to the widening and deepening of the Mississippi River valley.

## **Recognizing Wisconsin Episode Deposits**

As with the deposits of earlier glaciations, it is the layers of tills and marker beds deposited during the Wisconsin Episode glaciation that are traceable and that can be correlated across long distances. Wisconsin Episode tills can be distinguished because they occur above the easily recognized Sangamon Soil or the Robein Member marker bed (mentioned on p. 55); because they are exposed in many road cuts, stream banks, and quarries; and because they have distinctive colors, grain sizes, and mineralogical compositions. Three bundles of tills have been distinguished. The oldest (lowest) generally exhibits a unique pinkish brown color and is fairly sandy, the next is gray and siltier, and the uppermost till is also gray but very clayey, as a result of the ice gouging out shale and lacustrine sediments in the Lake Michigan basin area.

Like the tills left by earlier glaciers, those of the Wisconsin glaciation contain some sand and gravel beds that serve as aquifers, supplying water for many individual households, farms, and small communities throughout the northeastern quadrant of the state.

## **Landscape Differences between These Last Two Glaciations**

If you look carefully at both the topography of the Illinoian till plain and the topography of the landscape in northeastern Illinois (fig. 37), where the younger Wisconsin Episode deposits underlie the loess, you

## Surface Topography Map

Five main landscape areas are recognizable.

1. The very flat floodplains of the Mississippi, Illinois, Wabash, and Ohio Rivers and the Green River and Havana lowlands are represented by large gray areas of little to no contrast between light and dark. The higher elevations are referred to as upland areas.

2. The most complex patterns of light and dark appear in the rugged unglaciated areas of northwestern Illinois, southern Illinois, and the narrow peninsula of land between the Mississippi and Illinois Rivers; these hilly areas have been subject to erosion since well before the Ice Age. Intricate patterns of light and dark near the major river valleys represent areas where streams in small valleys flowing into main river valleys have dissected the landscape.

3. Across much of the southern third of the state, north of the rugged unglaciated hills, are tree-like branching drainage patterns. These denritic patterns developed by erosion after the melting of the Illinoian glaciers about 125,000 years ago.

4. The northeast quadrant of the state is broader and flatter than elsewhere, except for the major river floodplains. Visible in this quadrant are the curved moraines with interspersed flatter areas and less well-developed stream valleys.

5. In western Illinois between the Mississippi and Illinois Rivers is a striking parallel pattern of east-northeast to west-southwest drainage. This pattern may be related to the crevasse patterns that developed on the wasting Illinoian ice. The valleys may later have been deepened by meltwater running off the Wisconsin glacier as it stood at its maximum extent.



**Figure 37** This map is based on the map of Luman et al. (2003) generated from Digital Elevation Models (DEM) with vertical exaggeration and shading added. The map shows the landforms of Illinois as if the sun were shining from the northwest at about  $30^\circ$  above the horizon. The vertical dimension has been exaggerated 20 times in order to show detail better.

will see some striking differences. For one thing, you can see evidence of a longer period of erosion and dissection of the land surface (for example, well-developed drainage patterns) on the Illinoian till plain because this land surface was exposed to these processes for a much longer time. For another, the flat Illinoian till plain contrasts with the end moraines, formed of till, that arc across northeastern Illinois (fig. 35 on p. 56) and record the pulsations, or short-interval advances and retreats, of the Wisconsin Episode ice front. This pattern of curved moraines distinguishes the Wisconsin Episode landscape from other landscapes of the state. It is easy to imagine the curved outer ends, or edges, of the ice lobes where the ground-up rock debris was carried to form these ridges.

Wisconsin Episode end moraines may stand 50 to 100 or more feet above the flatter, slightly undulating surface of the *till plain* between them. The end moraines may be a few to several tens of miles long and from one-half to several miles wide (fig. 35 on p. 56). Glacial lake plains are usually several miles in length and width. Kames and kettles may be several tens to a hundred feet across. Kames rise a few tens of feet above the surrounding landscape and may be somewhat isolated on till plains. Kettles are depressions of somewhat lesser depth below the surrounding landscape. Both can often be found as part of the knob-and-kettle topography of some end moraines.

## **Sediments Other Than Till**

Like the deposits of the earliest glaciations, those of the Illinoian and Wisconsin glaciations contain numerous *lenses* and beds of sand and gravel, as well as beds of silt and clay. The sand and gravel beds may serve as aquifers, supplying water for municipalities, industry, farms, and households. In some areas, extensive beds of sand and gravel, probably deposited by meltwater in front of the advancing glacier, underlie the Illinois and Wisconsin Episode deposits. These deposits serve as major water sources for some communities.

## **After the Wisconsin Glaciation**

As the climate again warmed, the Wisconsin Episode ice retreated from Illinois for the last time, about 14,000 to 13,000 years ago, although it remained active for another 3,000 to 5,000 years north of Illinois. Modern soil began forming across the landscape, and other geologic processes such as erosion and deposition by wind and water continued. As the ice front melted back into the Lake Michigan basin, meltwater periodically ponded between the ice front and the moraines

bordering the lake; several successively lower lake stages formed before the level of modern-day Lake Michigan was reached. As the ice margin continued to recede northward, Lake Michigan and the other Great Lakes gradually began to assume their present configuration.

## **Glacial Meltwater Floods**

As the Wisconsin Episode glacier stood building the broad belt of moraines that rim the southern end of Lake Michigan, its meltwater flooded into the Kankakee and Fox River valleys (fig. 34, no. 3, on p. 54), which could not contain such large volumes of water. The meltwater floods pouring down the valleys were so great that they ripped up and carried slabs of bedrock along with them. Meltwater floods also scoured some of the deposits laid down by previous glaciers. Long bars of rubble that accumulated along the floods' courses remain visible today. Rubble and slabs of bedrock below the ground surface in the valley indicate that those floods were just the last of a series that began earlier in the Wisconsin Episode.

## **Glacial Lake Sediments**

Glacial meltwater continued to pond between moraines and the ice front, even after the ice had retreated well back into the Lake Michigan basin. Lake sediments were deposited across what is now the greater Chicagoland area, and the city of Chicago is built on a glacial lake plain. The existence of beaches, bars, and spits attests to former lake shores. The higher ground now occupied by the village of Blue Island actually was an island in a lake.

In the southeastern part of the state, so much outwash was deposited by meltwater coming down the Wabash River that the valley could not contain it all. Water backed up into the valley's tributaries, creating lakes in which up to 20 feet or more of silt and clay accumulated.

## **Sand Dunes**

Broad areas of outwash provided material that was picked up by the wind and was redeposited, resulting in tracts of sand dunes along the middle Illinois River valley, along the Mississippi River valley (especially in Rock Island, Mercer, and Henderson Counties), in the Green River and Havana lowlands, and along the Kankakee River valley in the eastern parts of Kankakee and Iroquois Counties. We know this process took place shortly after the deposition of the outwash and the waning of the meltwater floods because most of the dunes are now anchored in place by vegetation.

## Are We Still in the Great Ice Age?

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Researchers who study modern climate change are delving deeply into evidence left from the Ice Age. Cores of ocean sediments and of relatively undisturbed ice from Greenland and Antarctica are being studied intensively to determine the mechanisms responsible for rapid climate shifts during the Great Ice Age. There are no definite answers to this question. As we now know, during the Ice Age, Illinois repeatedly alternated between cold glacial climates and warm interglacial climates that were often warmer than today's climate. Research into the causes of Ice Age climatic change may also shed light on the combined impact of natural climate change and human influences on climate.

Much research must yet be done in order to answer all of the questions remaining about past glaciations in Illinois. Understanding more about these glaciations and the reasons behind their occurrence will aid in answering the question of whether or not we are still living in the Ice Age.

Ongoing study of Ice Age deposits allows scientists to continue to add to the store of knowledge about the nature and extent of these deposits. As understanding of the Ice Age deposits and processes grows, we can map the deposits more accurately, heighten public awareness of potential geologic hazards, and use the land and its mineral and water resources more intelligently for ourselves and for future generations.

Two ISGS publications that illustrate how geologic information can improve these types of societal decisions are *Illinois Groundwater: A Vital Geologic Resource* and *Land-Use Decisions and Geology: Getting Past "Out of Sight, Out of Mind."*

## For More Information

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These publications provide general information about glacial geology and its implications for society.

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# Glossary

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Definitions are based on a variety of sources. The *Glossary of Geology*, fourth edition, published by the American Geological Institute, was especially useful.

**ablation** The processes by which snow or ice is lost from a glacier, including melting, evaporation (sublimation), and wind erosion.

**accretion gley** *See* gley.

**alluvium** Sediment eroded from adjacent areas and deposited by running water in and along rivers and streams.

**aquifer** A saturated sediment or rock that is porous and permeable enough to be useful as a source of water and that provides a generally sustainable yield of suitable quantities of groundwater.

**areal distribution** Refers to the geographic area over which a rock or sediment unit occurs, either buried or exposed at the surface.

**bed** A layer of sediment or sedimentary rock. *See* strata.

**bedrock** The solid rock that underlies unlithified sediment of glacial and other origins.

**correlate** To tie together similar types of geologic structures or formations in separate locations on the basis of physical characteristics and stratigraphic position.

**crevasse** A deep, nearly vertical crack in a glacier or ice mass caused by stresses resulting when the ice moves over an uneven surface.

**cross section** A diagram or drawing that shows the sequence of rocks and sediment layers as they occur in a vertical plane; commonly drawn from the ground surface down to some selected depth, such as the bedrock surface.

**cueta** A ridge with a gentle slope on one side and a steep slope on the other.

**diamicton** A general term for unsorted, unstratified rock debris composed of a wide range of particle sizes; use of this term carries no suggestion about how such debris was formed or deposited.

**dolomite** A sedimentary rock (calcium magnesium carbonate) similar to limestone (calcium carbonate) and especially common in the bedrock of northeastern Illinois.

**drift** *See* glacial drift.

**embayment** A deep indentation or recess of a shoreline that forms a bay.

**end moraine** A ridge formed by the accumulation of glacial drift at the edge of a glacier. In Illinois, most end moraines are composed predominantly of till.

- erratics** Boulders and other rock fragments transported by glacial ice from their place of origin to an area where the bedrock is different.
- esker** A long, narrow, sinuous ridge of sand and gravel deposited by a melt-water stream flowing upon, within, or beneath a glacier that is melting away.
- fabric** The preferred orientation and dip direction of elongate pebbles within a till. Fabric can be used to determine the direction of ice movement.
- facies** The characteristics of a rock unit that differentiate it from surrounding units and usually reflecting the conditions of its origins.
- formation** The basic unit of lithostratigraphic classification. A formation must be identifiable on the basis of easily recognized physical properties and widespread enough to be mapped at a regional scale. A formation can be divided into smaller units, called members, where these, too, are recognizable and mappable. Formations can also be combined into groups when useful and appropriate.
- geologic map** A diagram or drawing on a horizontal plane of part of the Earth's surface showing by means of lines, colors, symbols, and orientation the distribution of selected features such as particular surface or subsurface units or rocks or sediments.
- glacial drift** A general term for all rock material carried and deposited by glaciers or glacier meltwater.
- glacial lake plain** A large flat area underlain by fine-grained sediment that was deposited in a lake formed by ponded meltwater from a glacier.
- glacial striations** A series of long, generally straight and parallel scratches or furrows on a bedrock surface that were caused by the dragging and scraping of rock fragments that were frozen into the base of an overriding glacier; striations are usually oriented in the direction of ice movement. Glacial striations are also formed on erratics (rock fragments) transported by the ice.
- gley or accretion gley** Sediment that has accumulated (accreted) slowly in low, wet, poorly drained areas of the landscape; gley is often dark gray to black, massive, and dense.
- group** The major lithostratigraphic unit next higher in rank than a formation; a group consists of two or more associated and adjoining formations having significant lithologic features in common.
- horizons** Zones of successively greater alteration that develop in a geologic material upon exposure to the physical and chemical processes of weathering.
- ice-wedge cast** A vertical wedge of sediment (or cast) that filled a crack in frozen ground formerly filled by an ice wedge; the wedge of ice was water that had frozen in a narrow crack that was produced by thermal contraction in permafrost.

**igneous rock** Igneous rocks are formed by the cooling of molten rock, called magma.

**kame** A low, steep-sided hill or mound composed mainly of poorly sorted sand and gravel that was deposited by meltwater plunging into crevasses and depressions near the front of a glacier.

**kame terrace** A terrace-like ridge consisting of stratified sand and gravel deposited by a meltwater stream between a melting glacier or stagnant ice lobe and a higher valley wall or lateral moraine. The ridge is left standing after the disappearance of the ice.

**karst terrain** Characterized by closed depressions, sinkholes, caves, and underground drainage networks produced by the action of water on limestone or dolomite, karst terrain is also susceptible to sinking and sudden collapse.

**kettle** A shallow basin- or bowl-shaped depression on the landscape formed when a large block of ice became detached from the main glacier; the ice block was gradually buried by outwash from the retreating ice and left a depression in the outwash when it eventually melted.

**lacustrine** (“lac” is French for “lake”) Formed or deposited in a lake.

**leaching** The dissolution and removal of soluble minerals by water from rain and snow that infiltrate downward through a soil.

**lens** A geologic deposit with surfaces that converge toward each other; a lens is thick in the middle and thins out toward the edges.

**lithified** Changed over time from a loose sediment into a coherent and solid rock by means of cementation, compaction, and compression.

**lithologic** The physical character of rocks or sediments, including mineralogical composition, grain size, color, and structure.

**lithostratigraphic** Pertaining to the classification of rock and sediment that is based solely on lithologic similarities within a unit and on lithologic differences between adjacent rock or sediment units.

**loess** (pronounced “luss”) Windblown dust; a widespread, homogeneous, massive, unconsolidated but slightly coherent, fine-grained deposit that blankets much of today’s Illinois landscape. In Illinois, loess deposits range from about 100 feet thick on the east sides of major rivers to less than 5 feet over much of the eastern half of Illinois.

**member** A lithostratigraphic unit of subordinate rank; a recognizable and mappable subdivision of a formation.

**metamorphic rock** Those rocks changed in composition, mineral content, texture, or structure by the application of heat or pressure; they originally may have been sedimentary, igneous, or other metamorphic rocks.

**organic matter** Biologically derived materials (for example, wood, shells, peat, and bone) containing carbon as an essential component, usually bonded with hydrogen.

**outcrop** Part of a glacial deposit or bedrock that is exposed and visible at the Earth's surface.

**outwash** Stratified sand and gravel that was washed out from a glacier by meltwater streams and deposited in front of, or beyond the margin of, an active glacier.

**overburden** Sediment or rock that overlies an economically useful deposit and that must be removed prior to mining that deposit.

**overconsolidation** Sediment that is more consolidated than would be expected from the existing overlying sediments. In the case of tills, overconsolidation resulted from compaction by the extremely heavy glacier overriding the sediment.

**patterned ground** Ground surface having polygonal or circular patterns that develop in poorly drained areas subject to intensive frost action; the patterns are defined by contrasting soils.

**permafrost** Soil or rock at or near ground surface in arctic or subarctic regions that has been continuously frozen for a long time.

**proglacial** Immediately in front of, or just beyond the outer edge of, a glacier; proglacial refers to lakes, streams, deposits, and other features produced by or derived from glacial ice.

**Quaternary** (pronounced Quat-ter'-nah-ree') The name for the period from the beginning of the Ice Age to the present and the sediments deposited during this time.

**radiometric age dating** A method for calculating the age of a specimen by measuring the amount of radioactive element remaining in the specimen. The method is based on the known, fixed rates of nuclear decay of certain natural elements, such as carbon-14 and potassium-40.

**relief** The general unevenness of the Earth's surface. The vertical difference in elevation between hilltops and valleys of a given region. A region showing little variation in elevation has low relief.

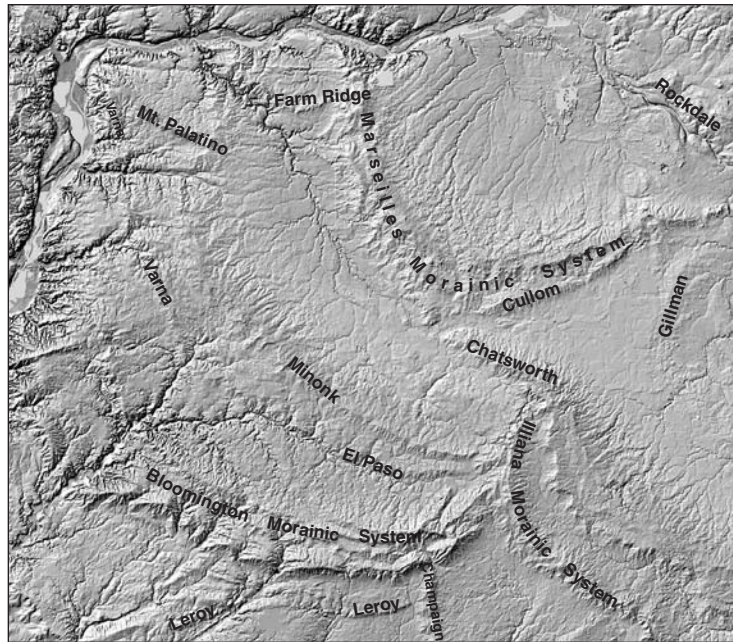
**rhythmites** A repetitive succession of rock or sediment units in which the layers indicate a frequent and predictable pattern of the same sequence of conditions. No thickness or time (for example, seasonal variation) is implied by this term.

**sedimentary rock** Those rocks formed by the compaction and cementation of sediment or by the precipitation of dissolved minerals from salt or fresh water.

**seismic** Pertaining to a vibration in earth materials that may be induced artificially or by an earthquake. Seismic methods used in investigating the subsurface include the generation, reflection, refraction, detection, and analysis of elastic waves in the earth.

**soil horizons** *See* horizons.

- soil** The unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants.
- solifluction** The slow, viscous, downslope flow of waterlogged sediment and rock debris; solifluction especially occurs in regions underlain by frozen ground that acts as a downward barrier to water percolation.
- strata** Single and distinct layers, or beds, of sediment or sedimentary rock that are easily distinguishable from layers above and below them.
- stratigraphic, stratigraphy** The systematic definition and description of major and minor natural divisions of rocks and their arrangement according to composition, distribution, correlation, and mutual relationships.
- stratigraphic code** A set of guidelines developed by a commission of geologists to aid in communication when referring to the layers of rock and sediment and to geologic history. Periodically updated and modified, the code contains guidelines to follow when classifying deposits and time.
- texture** The size, shape, and arrangement of the component particles of a sedimentary deposit such as till.
- till** Unsorted, unstratified rock debris composed of a wide range of particle sizes that was deposited directly by and underneath a glacier.
- till plain** A gently rolling ground surface underlain by till deposited beneath a glacier. It is usually bordered by end moraines.
- time-transgressive** A deposit that varies in age according to its geographic position; reflecting a depositional environment over a period of time during which the ice advanced and withdrew across a particular geographic area.
- topography** The general shape of a surface, such as the land surface, including its relief and the position of its natural and human-made features.
- truncate** To scrape off or plane off the top portion of a buried soil or other deposit by an advancing glacier.
- tundra** A treeless level to undulating plain that is characteristic of arctic and subarctic regions. It usually has a marshy surface that supports a growth of mosses, lichens, and numerous low shrubs; it is underlain by a dark, mucky soil and permafrost.
- unlithified** Sediment that has not been changed into a coherent and solid rock.
- weathering** The process of physical disintegration and chemical decomposition whereby earth and rock materials are changed in color, texture, composition, firmness, or form upon exposure to the atmosphere.



**Back cover photograph:** Curved moraines, intermorainal areas, and river and stream valleys from central Illinois (adapted from the map by Luman et al. 2003). For location, see figure 35 on p. 56.

The Geoscience Outreach Program of the Illinois State Geological Survey uses many channels to inform the public about the geology and mineral resources of the state and the results of the Survey's research projects. The Survey distributes nontechnical publications, offers sets of rock and mineral specimens to Illinois schools and educational groups, presents lectures and exhibits, responds to inquiries, conducts workshops for teachers, and leads field trips. The program's full-day field trips, each given in widely separated areas of the state, offer teachers, students, and the public the opportunity to learn about the geologic processes that shaped the land and formed the rocks and glacial deposits.

The outreach program is specifically designed to assist in the teaching of earth sciences and to help citizens understand how the research programs of the Illinois State Geological Survey protect the environment and strengthen the economy of Illinois.

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This information may be provided in an alternative format if required. Contact the IDNR Clearinghouse at 217/782-7498.

