# How the Ice Age Shaped Indiana

**Jerry Wilson**

Published by Wilstar Media, www.wilstar.com
Indianapolis, Indiana

Previiously published as *The Topography of Indiana: Ice Age Legacy*,
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Second Edition

For Aaron and Shana
and
In Memory of Donna

## Introduction

During the time that I have been a science teacher I have tried to enlist in my students the desire to understand and the ability to reason. Logical reasoning is the surest way to overcome the unknown. The best aid to reasoning effectively is having the knowledge and an understanding of the things that have previously been determined or discovered by others. Having an understanding of the reasons things are the way they are and how they got that way can help an individual to utilize his or her resources more effectively.

I want my students to realize that changes that have taken place on the earth in the past have had an effect on them. Why are some towns in Indiana subject to flooding, whereas others are not? Why are cemeteries built on old beach fronts in Northwest Indiana? Why would it be easier to dig a basement in Valparaiso than in Bloomington? These things are a direct result of the glaciers that advanced southward over Indiana during the last Ice Age.

The history of the land upon which we live is fascinating. Why are there large granite boulders nested in some of the fields of northern Indiana since Indiana has no granite bedrock? They are known as glacial erratics, or dropstones, and were formed in Canada or the upper Midwest hundreds of millions of years ago. They were carried to their present locations by the glacial ice sheets.

The comprehension of time by the human mind cannot do justice to the vast eons of geologic time. How long would it take a sea to build 13,000 feet of sediment on its bottom? In one person's lifetime, the amount of sediment that would accumulate would hardly be measurable. Yet Indiana has between 3,000 and 13,000 feet of sedimentary rock underlying its glacial drift, the youngest layer being more than 300 million years old.

Most science textbooks do not, and probably should not, lend themselves to a detailed discussion of Indiana's topography. The texts do cover the effects of the Ice Age, but only to a limited extent.

I have searched for supplemental resource materials to fill in the gaps, but I find these sources scattered and sketchy at best. Therefore, I decided to compile as much information as I could find on the subject into a form that I could use during my lesson on Indiana's geology and how it relates to the Ice Age. This book is the result.

I have relied on the knowledge that I have derived from lectures by experts, from the many books I have read over the years and on maps, the Internet, and other publications. Some of these are listed in the resources section at the end of this book. I have wandered Indiana to get a first-hand view of some of the effects of glaciation. Although I find that some authors differ on such things as the dates of the glacial advances, the precise naming of the ancestral Great Lakes, and the extent of their coverage, I have tried to find as much common ground as I could, and use corroborating research when possible. When two authors differ on a certain point, the author who has the more recent publication was used as the primary reference.

In addition to its use as a supplement for classroom teachers, I hope this book will be of use to those who just like to take in the countryside of Indiana. Visitors to the state and residents who want to visit Indiana's wonders of nature may find this book helpful in understanding why Indiana's geologic features look the way they do. From the falls of Clifty Creek to the sand dunes of Lake Michigan. Indiana has more geologic features worthy of a tourist's attention than most people may think.

## Pre-Glacial Indiana

Picturing the Ice Age, some people imagine tribes of cave men out hunting woolly mammoths or saber-toothed tigers. That might not be far from a true image of ice age life, but only as it existed near the end of the vast stretch of time that is known as Earth's last great Ice Age.

The Ice Age lasted more than two million years. And during that time, there were at least four major glacial advances in the northern hemisphere. But between the ice advances, the climate may not have been much different than it is today. Also, prior to the last advance, which ended about 10,000 years ago, pre-human society was not advanced enough to have gathered in tribes and used tools for the purpose of hunting large animals. Early humans did not start using tools until roughly 50,000 years ago, in Africa.

Back in what was to become Indiana, human ancestors may or may not have existed at the end of the Ice Age. There are various hypotheses that have been put forth that try to explain where North American inhabitants came from and when they first came. The verdict is still out as much more study is needed. Humans as old as Cro-Magnon Man, the human that dwelled in caves and hunted for a living, probably never existed in what is now Indiana.

What can be said for sure is that more than two-thirds of the state owes its landscape to the activity of the vast ice sheets of the last great glacial advance. Before the ice sheets encroached, more than two million years ago, Indiana, and much of the Midwest, was a maturely-dissected low plateau. It contained numerous hills, what are called knobs, separated by broad valleys. Indiana's landscape was similar to the present topography of Kentucky and Missouri. And, in fact, all of Indiana's landscape was very similar to what one would currently find in the southern third of the state. The last ice sheet never advanced as far south as the present-day Ohio River, which marks the southern boundary of Indiana. The southern limit of that ice sheet ran on a wavy line connecting present-day Terra Haute, Edinburgh, and Richmond. At least two of the earlier ice sheets advanced farther south, but none as far as Evansville, Bloomington, or New Albany. So the southern Wabash Valley and the valleys of the East Fork White River and Muskatatuck River were all spared the encroachment of the ice sheets. Drainage patterns in Southern Indiana were changed enormously by the glaciers of the Ice Age, however.

Another clue as to what most of northern and central Indiana might have looked like prior to the Ice Age comes from Wisconsin. One might think that, being much farther to the north, Wisconsin would have been completely covered by ice sheets during the Ice Age. But an area of central Wisconsin known as the driftless area, because it lacks glacial debris known as drift, was spared. Some geologists speculate that the highlands of northern Wisconsin may have deflected the ice lobes around the driftless area. The driftless area includes the Wisconsin Dells, a region of the state marked by magnificent cliffs carved into the bedrock by rapidly-flowing streams.

Although bedrock is close to the surface in the southern third of Indiana, it is deeply buried beneath glacial drift north of a Terra Haute to Richmond line. As the vast ice sheets descended from what is now Canada, they scraped up pieces of the bedrock, soil, and any other debris in their path. This debris was deposited over the northern two-thirds of Indiana as the ice melted. This can easily be seen in road cuts. Along Interstate-64 in southern Indiana, horizontal layers of limestone, sandstone, and shale can be seen. On the other hand, road cuts through the hilly regions of west-central Indiana show only a conglomeration of pebbles, larger stones, sand, and clay. This mixture is glacial drift.

There are a few unusual regions of western Indiana, especially near Delphi, where limestone bedrock does come to the surface, even though it was glaciated. These rock layers are unusual in that, unlike the bedrock of southern Indiana, they are tilted, sometimes at a steep angle. Tilted bedrock is usually associated with mountain-building forces originating deep within the earth. But there are no mountains in Indiana and there is no hint that there ever were. So these tilted rock layers poking out of the surrounding glacial drift remained a mystery until the 1920s when E. R. Cumings and R. R. Shrock investigated. The outcroppings were part of a rock dome formed as coral reefs in an ancient sea. Many of these fossil reefs have since been found throughout Indiana, Michigan, Illinois, and Wisconsin. They formed during the Silurian Period, 400 million years ago, when Indiana was covered by a warm inland sea. The sea stretched from present-day Labrador southward into the Midwest.

At the time, the ancestor of the North American continent was in the tropics, straddling the equator. It was just prior to the time when all the land masses of the earth were connected together, forming one large supercontinent known as Pangaea. About 180 million years ago, Pangaea began to break apart. Through the process of plate tectonics, the various land masses that broke away from Pangaea moved to their present-day locations, forming the arrangement of continents familiar to everyone today.

It might not be too apparent, but Indiana's bedrock has something in common with the rock layers of the Colorado Plateau in Arizona and the Ozark Mountains of Missouri. All three areas are described as plateaus, meaning they are uplifted regions underlain by rock layers that are horizontal and parallel to each other. There is little tilting and folding of the rock. Southern Indiana is a low plateau, meaning there has been very little uplift. The Ozark Mountains are not true mountains at all, but an eroded plateau. But the land there has been uplifted much higher than the land of Indiana, so erosion has resulted in much more prominent relief in Missouri. The Colorado Plateau is much higher elevation than either Indiana or Missouri, but the landscape there is stark. Both Indiana and Missouri get plenty of annual rainfall. The landscape of both regions is typical of wet-climate erosion. Arizona, by contrast, has a very dry climate. Dry-climate erosion of a plateau typically results in canyons, mesas, spires, and arches. So the wetter the climate and lower the elevation the gentler will be the landscape.

Since the Precambrian Era ended over half a billion years ago, much of what is now North America, including Indiana, has been invaded by inland seas several times. Deposition of sediments in the seas eventually led to the formation of layers of sedimentary rock. These rock layers form the bedrock of Indiana. The basement rock of Precambrian age, called the craton, consists of compressed igneous rock, mostly granite. This nucleus of Precambrian rock does not cut the surface anywhere in Indiana or the lower Midwest. It does break through the surface in northern areas of Minnesota and throughout Canada. There, it is called the Canadian Shield. In Indiana, the craton is buried beneath sedimentary rock layers ranging between 3,000 and 13,000 feet thick.

The age of Indiana's bedrock that breaks the surface ranges between 450 million and 300 million years old. The Ordovician shale and limestone that occur as outcrops in the southeastern part of the state contain many fossils. The younger rock layers that are exposed in the southwestern region of the state consist mainly of shale, sandstone, and limestone. They are of Pennsylvanian and Mississippian age, about 300 million years old, and therefore contain deposits of coal. Much of the south-central region of the state is underlain by 340-million-year-old limestone. This rock is mined for use as building material. The Empire State Building in New York City is constructed of Indiana Limestone. But since Indiana does not contain bedrock any more recent than 300 million years old, no dinosaur fossils are found in the state. Dinosaurs did not arrive in force until about 225 million years ago.

About 300 million years ago, Indiana was in a tropical environment. The abundant plant life, mostly ferns and tree ferns, led to the formation of peat bogs as dead plant material accumulated to a depth of many feet within the marshy areas. Peat forms as a result of compaction and anaerobic decay of plant matter. It is the first step in the long process of coal formation. Lignite, the lowest grade of coal because of its high moisture and sulfur content, forms from the further compaction of peat as more layers of sediment are deposited on top of the peat bog. Later, as more sediment accumulates over the lignite, and as heat and pressure increase, the lignite is transformed into bituminous coal. The coal deposits of western Indiana are of this type. Anthracite is a metamorphic coal formed by continued compression and compaction of bituminous coal. It is the highest grade of coal, composed of almost pure carbon. There are very few anthracite deposits remaining in North America, and none in Indiana.

As landscapes go, Indiana is very flat. There is a variation in elevation of no more than 600 feet from the highest point in the state, near Richmond in the east, to the lowest point near the confluence of the Wabash and Ohio Rivers in the southwest. Yet, going from east to west across southern Indiana, the ages of various rock layers at the surface vary by about 150 million years. That corresponds to a vertical accumulation of sedimentary rock of 7000 feet. How, then, can 7000-feet worth of bedrock exist at the surface in various places across the state?

Although the layers of the bedrock are parallel, and they appear to be completely horizontal as one would expect of any plateau, the rock layers are actually tilted slightly. The bedrock is arched upward along an axis running from southeast to northwest. This is a huge anticline, a bedrock formation consisting of an up-fold along an axis. Very large, regional anticlines are termed arches. This anticline is called the Cincinnati Arch, because the axis runs through southwestern Ohio, near Cincinnati. Imagine placing several blankets on a bed so that they are flat and parallel to each other. The blankets represent layers of sedimentary rock. Slide a baseball bat underneath the blankets. This creates a deformation of the blanket layers that approximates the appearance of an anticline. Now, suppose that months of sleeping on top of the blankets with the baseball bat underneath, discomfort notwithstanding, has warn large holes in the top few blankets, exposing the ones beneath. The same thing happens with rock layers in an arch. Southern Indiana is on the western slope of the Cincinnati Arch. Weathering and erosion have removed the youngest rock layers from the central region of the arch, in eastern Indiana, exposing the older layers beneath. These younger layers are still intact in the western part of the state. Thus bedrock at the surface gets younger moving from east to west across southern Indiana.

It is easy to understand that younger layers of bedrock overlay older layers; sediment is built up from bottom to top as it accumulates on the floor of ancient seas and lakes. So the relative ages of rock layers are easy to figure out. But how do geologists determine the actual age of sedimentary rocks? The age of a sedimentary rock layer can be deduced from the type of fossils it contains. Index fossils are those which are peculiar to a certain geologic age, but widespread enough to be useful in determining the age of rocks in other regions of the planet. The age of index fossils is known, either because of direct radiometric dating or because the age of the rock layer that contains them has been determined by another method. The presence of index fossils within a rock layer will, therefore, give up the age of the layer. Although igneous rocks, like granite, and metamorphic rock, like gneiss, can be determined directly through radiometric dating techniques, these methods would not work on sedimentary rock. Trying to date a sedimentary rock layer using a radiometric method would give only the age of the sediments within it, not when those loose sediments became rock.

Some regions of south-central Indiana, from near the Ohio River to Mitchell, have enormous deposits of limestone near the surface. The thick layers of limestone have been attacked by the weakly-acidic drainage water that percolates through the soil. Limestone is dissolved by acidic solutions. This area of the state, therefore, is riddled with caves, sinkholes, and underground rivers. The landscape of a region that consists of these features is called karst topography. At Spring Mill State Park near Mitchell, tour guides take tourists on a trip through Twin Caves in a flat-bottomed boat. The cave's floor is completely covered by water because the stream that carved the cave still flows through it. Larger caves occur farther south, near Corydon. These can be explored on foot.

Indiana's Lost River flows through this area; then it disappears, leaving an empty stream bed. Farther downstream, the Lost River reappears from an outcropping of rock. The limestone river bed has been partially dissolved, allowing the river to flow through the porous rock during periods of dry weather. After a period of heavy rain, the water of the Lost River flows entirely on the surface.

## Ages of Ice

The Ice Age began about two million years ago and ended about 10,000 years ago. Or did it? Could it be that, despite global warming, the ice age isn't over yet?

During the two million years since the Ice Age began, there have been four major advances of the ice sheets from the north. But in between those advances the climate was much warmer and the ice sheets retreated into Canada or disappeared entirely. These warmer periods, known as interglacials, lasted for a few thousand years each. It has been 10,000 years since the ice sheets retreated last. Could it be that we are currently living within a interglacial period? Some scientists believe that the ice sheets will be back, but when is anyone's guess. Some interglacials last 12,000 years while others can last 50,000 years or more. Some scientists predict our current interglacial will end in about 25,000 years based on orbital cycles of the earth.

The last ice age, or our current one if we are in an interglacial period, is not the only ice age the world has had. There have been at least four major ice ages. The most severe ice age of the last billion years started about 850 million years ago and lasted for 200 million years. It was so severe that the entire planet was covered with ice, miles thick in places. This resulted in what has been termed a Snowball Earth. It ended when plate tectonics caused massive volcanic eruptions, which poured out carbon dioxide into the atmosphere. This resulted in a period of natural global warming which melted the planetary ice packs.

The most recent ice age had four glacial advances, each named for the present-day state in which their presence is most evident. The first of these advances began more than a million years ago and is called the Nebraskan glacial. Little evidence still remains of this stage because it happened so long ago and much of the evidence was buried by more recent glacial advances.

Following the Nebraskan glacial was a relatively warm interglacial period. This, in turn, was followed by the Kansan glacial, beginning about 700,000 years ago. There are some Kansan deposits at the surface in scattered sites in parts of northern Brown County, Indiana. For the most part, though, the glacial drift left by the Kansan ice sheet was covered by the next advance, the Illinoian glacial, which began roughly 300,000 years ago. The Illinoian glacier extended farther south than any of the other three glacial advances. In Indiana, it reached to the Ohio River in the southeastern part of the state and to Brown County in the south-central region.

About 70,000 years ago, the Wisconsin glacial began. The Wisconsin ice sheet did not extend as far south as did the previous stages. It extended to the central part of Indiana, just south of Indianapolis, along a line from Terra Haute to Edinburgh, to Richmond. This last glacial advance began retreating about 20,000 years ago. By 10,000 years ago, the present interglacial period had begun.

There were several ice lobes associated with the Wisconsin glacial. The Michigan lobe entered Indiana from the northwest. The Huron and Erie lobes entered the state from the northeast. The prints of these lobes can be clearly seen from the arrangement of end moraines, ridges of unsorted glacial sediment. Moraines are just one example of landforms that can be created by glaciers. By studying post-glacial topography, scientists can gain a complete understanding of how the ice sheets advanced and retreated.

Some evidence suggests that minor glaciation began about 2.5 million years ago, but pre-Nebraskan glacials, if they existed, cannot be as easily studied since most of the evidence would have been covered by later periods of glaciation.

### *Landscapes Formed by Ice*

The ice sheets associated with the last ice age were, in places, three miles thick. This extremely heavy layer of ice carved out valleys and scraped the bedrock in Canada, eroding the gouged-out debris to the south as the ice sheet advanced. As the glaciers approached the limits of their southward progression the debris was scattered over the surface of the bedrock in the Midwest, including Indiana. The term applied to any sediment or debris deposited by a glacier is glacial drift. Glacial drift comes in two major varieties. Stratified drift is composed of sediment that is sorted according to the size of its particles. This occurs if the drift was deposited by the melt water of the glacier rather than directly by the ice. Glacial till is unsorted sediment that was deposited by the ice itself as it melted.

The ability of water to carry sediment depends upon its flow velocity. The faster the flow, the more sediment it can carry. Larger, heavier particles are the first to settle to the bottom of a flowing stream as the stream velocity decreases. Melt water flowing over, through, and away from the glacier deposited its sediment in layers according to particle size. The larger and heavier particles such as cobbles and pebbles were deposited first, and became the bottom layer of sediment. Sand settled out above the pebbles, followed by layers of silt and then clay, the sediment composed of the smallest particles. Landforms created by glaciers that consist of stratified layers of sediment, therefore, were laid down by flowing melt water.

Melt water flowing southward away from the leading edge of the ice sheets covering northern Indiana deposited stratified drift in a broad, level plain called an outwash plain. The Kankakee Outwash Plain is the fertile farmland that stretches for miles in an area of Northwest Indiana south of Valparaiso. The Kankakee River, a slow-flowing stream with a very wide flood plain, is the remnant of the torrents that formed the plain about 12,000 years ago.

As a glacier melts, large chunks of ice often break loose and fall from the receding edge. This process is known as calving. In the sea, these chunks of ice form icebergs. On land, the ice chunks sink deep into the outwash plain and form depressions called kettles. The kettles normally fill with water from the melting ice to form a kettle lake. Many kettle lakes dot the countryside of northern Indiana. Some examples include Cedar Lake in northwestern Indiana as well as Hamilton Lake and Lake Wawasee in northeastern Indiana.

Glaciers are often riddled with ice tunnels, holes, and cracks. Melt water that flows down a vertical hole to the ground below often deposits its load of sediment as stratified drift, eventually forming a mound or hill. When the glacier retreats, these hills that are left behind are called kames. One of these kames is School Hill in Edinburgh in Johnson County. Melt water flowing through tunnels in the ice, or channels on top of it, leave stratified drift in long, sinuous ridges known as eskers.

But a glacier can also deposit its load of sediment directly from the ice. This type of debris, ranging is size from large boulders to sand and clay, is unsorted and not stratified. It is called glacial till. The central third of Indiana is a gently-rolling till plain averaging 40 feet thick. The thickness of the till layer across the northern two-thirds of the state varies in thickness from only a few inches to 265 feet near Michigan City on the southern shore of Lake Michigan. The thickest till deposit in the Midwest is 1,189 feet near Cadillac, Michigan. The extreme southeast corner of Indiana, which was covered by the Illinoian glacial but untouched by the later Wisconsin ice is covered by a think, nearly insignificant layer of till that is more than 100,000 years old.

If an ice sheet remains stationary for a prolonged period of time, a ridge of till called an end moraine accumulates at the glacier's edge. The largest of the many moraines in Indiana is the Valparaiso Moraine, arching around the southern end of Lake Michigan through Lake, Porter, and LaPorte counties in

Northwest Indiana. The elevation of the Valparaiso Moraine varies from about 750 feet to 900 feet. The steepness of the grade traveling from the Kankakee Outwash Plain northward across the moraine is so gradual as to be unnoticeable. Parts of the moraine, however, have been dissected by streams that drain it so that it is rather hilly. Other examples of large moraines include the Packerton and Wabash moraines of northeastern Indiana and the Shelbyville Moraine in the east-central part of the state. There are several other smaller moraines scattered across northern Indiana.

Moraines form because, although the ice sheet itself remains stationary, the ice within the glacier continues to advance southward. The melting at the leading edge of the glacier is in equilibrium with the advance of new ice, so the ice sheet neither advances nor retreats. But the ice making up the glacier, and all its cargo scraped loose from the bedrock to the north, continues inching southward toward the melting edge. When the ice reaches the front edge, it drops all its debris, forming an end moraine.

Indiana's bedrock is all sedimentary rock. There are no outcrops of granite or other igneous rock anywhere in the state. However, a stroll along a hiking path in Potato Creek State Park in northern Indiana will reveal a large granite boulder measuring about four feet in diameter. Although landscapers will often truck in granite boulders as decorative stones to be placed in lawns or around commercial buildings, this large boulder was obviously not trucked in. So where did it come from?

Boulders are sometimes embedded within glaciers and are then dropped by the ice when the glacier melts. The ice sheets encroaching from the north during the Ice Age also contained many such boulders, which they scattered across the northern United States. These boulders do not resemble the bedrock of the area where they occur, so the obvious conclusion is that they were scoured loose from the Precambrian bedrock of the Canadian Shield and carried southward. In many places in Canada and on some outcrops in Indiana, the bedrock has been scratched by the rocks embedded within the ice. The scratch marks, called striae, run parallel to the direction of the ice flow and can be used to deduce the direction from which the glacial lobe advanced.

### *How Can Solid Ice Move?*

When summers are cool enough so that not all the snow and ice from the previous winter melts, a glacier can start to form. The coolness of the summers, more so than the severity of the winters, is the prime determiner of a glacial climate. Unless snow and ice can remain on the ground all summer, there is no chance that a glacier can begin, no matter how cold the winters are. This idea was first proposed by Wladimir Koppen in 1914.

Snow is formed of hexagonal crystals. Over time the hexagonal nature of the snowflakes break down. The crystals become granular and the snowfield is more dense and compact. If the snow survives the melting season, the granular snowcover is termed firn. As the firn layer gets thicker as years go by, its density gets greater and eventually it becomes glacial ice. When the glacial ice has accumulated to several thousand feet, the ice near the bottom is compressed into a plastic-like material. It is able to flow very slowly and is squeezed out in front of the glacier. This accumulation of amorphous ice at the front edge of a glacier over time is how a glacier moves forward. Snow and ice begin accumulating on the leading edge of the glacier and, because white reflects most of the sunlight, the cooling effect is enhanced. It is self-perpetuating.

Rocks, soil, and other debris are carved from the surface of the land and become embedded in the ice. This debris is carried with the glacier as it moves and is deposited at the margins, where the ice melts during warmer periods.

The vast weight of the ice sheet depresses the crust of the earth into the mantle. For every 300 feet of ice thickness the crust subsides by about 100 feet.

When glaciers retreat, they do not flow backward. When the forward edge of the glacier reaches an area where the average annual temperature is 0 degrees Celsius, the freezing point of water, melting occurs at the same rate as ice formation. Thus the glacier does not advance further. The ice within the glacier, however, continues to move in the same direction as always. As the forward-moving ice reaches the glacier's melting edge, any rock and debris that is carried by the ice in conveyor-belt fashion, is dumped, forming an end moraine. Glacial lobes may advance and retreat throughout a limited area for hundreds of years. Each time the glacier halts for awhile, debris piles up into a new moraine. A study of the positions of the end moraines in northern Indiana show that the state was invaded by three lobes of ice during the Wisconsin glacial period.

As the climate warms further, melting increases and finally exceeds the rate at which the ice moves forward. The glacier then retreats, due to melting away of its front edge. The forward flow of ice within the glacier continues, however, and the glacial drift is deposited in a broad, flat plain.

## Landscape Regions of Indiana

The landscape of the northern-two thirds of the state is almost 100 percent due to the action of the ice sheets, particularly during the Wisconsin advance. The part of the state shaped by the ice can be broken down into four physiographic regions

The Calumet Lacustrine Plain is the small area that extends from the south shore of Lake Michigan to the Valparaiso Moraine. The term, lacustrine, refers to lake deposits. This region contains deposits that were left by glacial Lake Chicago when it existed at its former shoreline along the Valparaiso Moraine. Most of this region is sandy, but there are significant clay deposits near Hobart.

The area south of the Valpaaraiso Moraine, extending to near Rensselear and then swinging northeastward, paralleling the Kankakee River, is called the Kankakee Outwash Plain. It is a flat area of sorted sediments carried by the melt water flowing over the moraines from the glacier.

The northeast quarter of the state is a moraine region. Numerous moraines deposited by the Erie and Huron lobes of the Wisconsin ice sheet exist in this area. The most prominent of these is the Packerton Moraine, extending from the northeast to the southwest near South Bend.

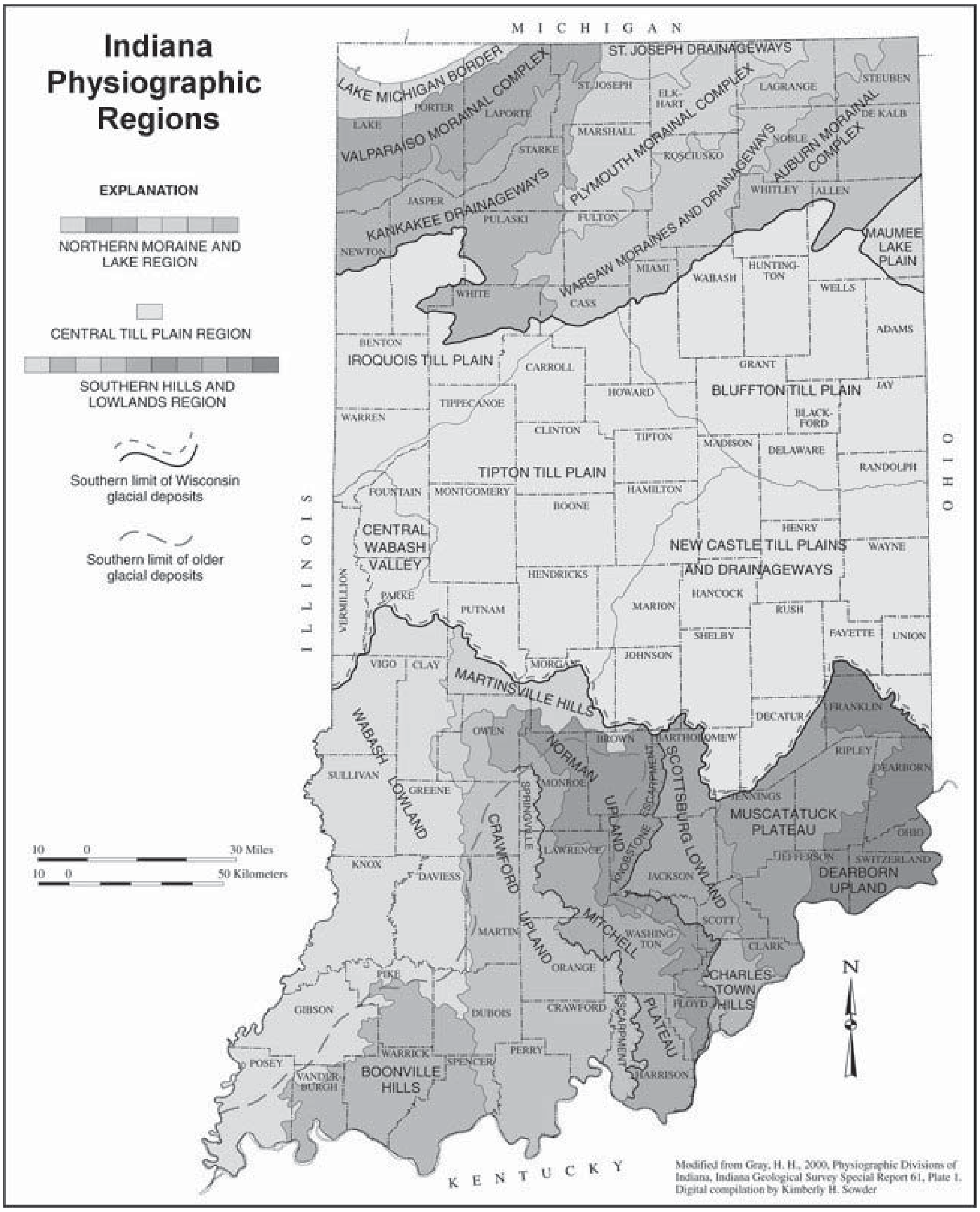
South of a line from Forte Wayne to Rensselear and extending to the southernmost boundary of the Wisconsin glacier is the Tipton Till Plain. It is a broad, flat or gently-rolling region of unsorted drift deposited by the ice as the Wisconsin glacier retreated northward. Valley train sediments occur near rivers.

Indiana is one of the states in the so-called Breadbasket of the United States. It helps feed the world with its sprawling farms. It owes this legacy to the Great Ice Age, whose vast ice sheets deposited the soils, and then leveled them, making the northern two-thirds of the state an ideal farmland.

The southern third of Indiana, south of a line from near Vincennes to Richmond, is broken down into seven physiographic regions. All these regions exist as a result of the bedrock and are not due to the action of glaciers.

Since the layers of bedrock in Indiana are arched, erosion has exposed the edge of several layers in succession from oldest to youngest, going from east to west across southern Indiana. Some of these layers are soft shales, and thus tend to erode easily. Some are pure limestone, and form karst topography. These areas of the state tend to erode to a flat, low plain.

Other bedrock layers that have been exposed at the surface consist of resistant limestone or sandstone. These resistant layers form the more rugged highland regions with their numerous hills and valleys.




Each of these regions runs north and south from the Ohio River to the Wisconsin glacier's southern limit. Their direction is a result of the strike of the Cincinnati Arch.

The Dearborn Upland, the easternmost region, is an area of resistant limestone intermingled with shale. The region, which includes the city of Madison, is quite hilly. To the west is the Muscatatuck Slope. It is a rolling area that is generally lower in elevation. It blends into the next region, the Scottsburg Lowland. This is a rather low, flat region consisting mainly of shale.

To the west of the Scottsburg Lowland is a rather obvious escarpment which begins the Norman Upland. It consists of sandstone and limestone layers. West of here is the Mitchell Plain, an area of karst topography formed from layers of pure limestone.

The Crawford Upland is west of the Mitchell Plain. Finally, the Wabash Lowland extends to the Wabash River. Each of these regions extends well into northern Indiana before the ice sheets covered them with drift.

## The Great Lakes: Legacy of Ice

Indiana has a shoreline on one of the Great Lakes, Lake Michigan. It is the shortest lakeshore line of any of the Great Lakes states, but it is still long enough to have Indiana Dunes National Lakeshore, part of the national parks system. There are several municipal beaches and the Indiana Dunes State Park on the shoreline as well. Lake Michigan and the other four Great Lakes were created by the glaciers of the Ice Age.

As the Wisconsin ice sheet retreated, its melt water formed the ancestors of the modern Great Lakes system. Before the advance of the glaciers, the area now occupied by the Great Lakes was a plain with very broad river valleys. The region covered the southern part of what is now known as the Canadian Shield, and area of bedrock of Precambrian age consisting of granite and a metamorphic rock called gneiss. This area was laid bare by the scouring action of the glaciers.

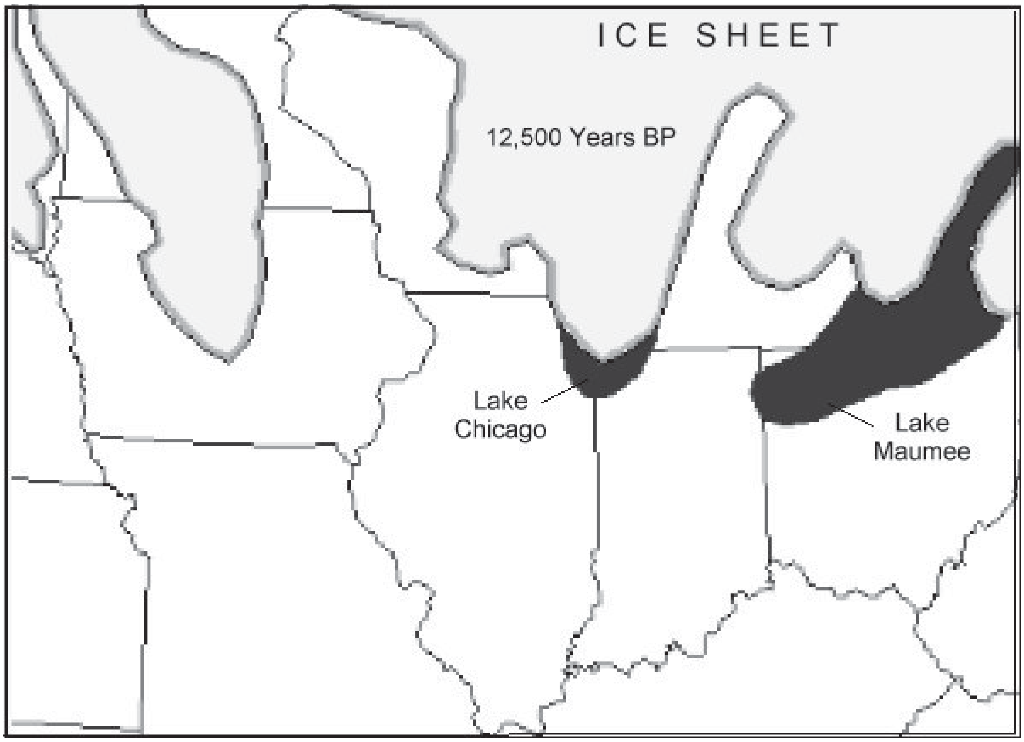
Before the Ice Age, however, the areas which are now the Great Lakes consisted of a wide basin that was filled with thick deposits of sedimentary rock that were laid down by the repeated encroachment of ancient inland seas. Studies of the sedimentary rock layers within this basin show that it is bowl-shaped, with the layers up-turned slightly around the edge. The ice sheets carved sections of this basin into the present basins of the Great Lakes.

Dolomite is a sedimentary rock that is similar to limestone but tends to resist weathering. A resistant layer of dolomite, known as the Niagaran Formation, was laid down in the basin and helped to shape the Great Lakes. The Niagaran dolomite is exposed as a rim of resistant rock starting in New York, east of Niagara Falls, cutting through the falls, then turning northward where it borders the northern and eastern shores of Lake Huron, separating the main lake from Georgian Bay. It then turns westward, bordering the northern boundary of Lake Michigan. The rim follows the western shore of Lake Michigan to the south where it turns east at the southern tip of Lake Michigan. It then traverses northern Indiana and Ohio where it forms the southern boundary of Lake Erie. The younger rocks on the inside of this rim are less resistant are have been carved by the glaciers into Lakes Michigan, Erie, and Huron, west of Georgian Bay. The rock layers lying outside the Niagaran Formation are older, but still less resistant and have been carved into Lake Ontario and Georgian Bay. Lake Superior, the largest of the Great Lakes, has a more complicated history that will be addressed a little later.

Of the five Great Lakes, the one that is most familiar to Indiana residents is

Lake Michigan. But this lake has not always been as stable as it is today. Its current shoreline arcs between the Indiana and Illinois border near Chicago to the Michigan border just northeast of Michigan City. But Lake Michigan has had three other shorelines that lie farther south. These old shorelines can be deduced from the location of ancient sand dunes, as well as the current elevation differences of the landscape.

The earliest precursor to Lake Michigan, which existed during the time the ice sheets were retreating into Canada, was glacial Lake Chicago. It changed its size, and its shoreline location, several times. The earliest stage of glacial Lake Chicago produced no beach as can be found surrounding the present-day Lake Michigan. It was a relatively short-lived lake occurring completely within the borders of present-day Indiana. At this stage, glacial Lake Chicago was a crescent-shaped lake bounded by the ice sheet to the north and the Valparaiso Moraine on its southern shoreline. It drained over a low area in the Valparaiso Moraine west of present-day Chicago where the Des Plaines River is today. The melt water of the glacier, which formed Lake Chicago, drained into the Mississippi River.




*Ancient Shorelines of Glacial Lake Chicago*

The earliest shoreline of glacial Lake Chicago occurred when its waters were held in place by the Valparaiso Moraine. This was at a time when the southern margin of the Wisconsin ice sheet was just exiting what is now Indiana. As the ice sheet retreated, Lake Chicago's shoreline receded to a new location, near Merrillville, Indiana. The ancient Glenwood Shoreline occurs today along U.S. Highway 30 that runs through Northwest Indiana. The lake water level was at 640 feet when this shoreline formed between 14,500 and 12,500 years ago. It is named for the city of Glenwood, Illinois where the former beach is clearly evident. A small, elongated island was present in glacial Lake Chicago during this stage. It is called Hobart Island and lies just west of Hobart, Indiana. Today, Hobart Island is a raised area of glacial till surrounded by beach deposits of sand.

In Gary, Indiana, there is a street called Ridge Road for reasons that are obvious to those traveling along it. On the south side of the street, houses are built atop a high ridge made of ancient sand that formed dunes when glacial Lake Chicago was located at the Calumet shoreline. This ancient shoreline parallels Ridge Road in Gary to Munster, Indiana and runs through the east end of Lake Station. The lake level was at 620 feet when the shoreline and accompanying dunes were formed about 11,000 years ago. The outlet at Chicago that allowed the lake to spill southward was eroding, with a resulting decrease in the lake water level. But a layer of resistant rocks in the Valparaiso Moraine halted the erosion for awhile at the 620-foot level.

Over the next thousand years, the lake water lowered further, by another 15 feet. The Tolleston shoreline formed when glacial Lake Chicago was at 605 feet and parallels 15$^{th}$ Ave. in Gary and U.S. Route 12 in Miller. The Tolleston stage marks the end of glacial Lake Chicago's influence, about 10,000 years ago. But the relatively small Lake Chicago was replaced by an enormous body of water known as glacial Lake Algonquin, which occupied the same shoreline. The outlet over the Valparaiso Moraine near Chicago was further eroded down to the bedrock of the Niagaran formation, causing the water of glacial Lake Chicago, and later, Lake Algonquin, to stabilize at 605 feet. Glacial Lake Algonquin occupied all the area that is now Lake Michigan, Lake Huron, and much of northern Michigan. It was formed as the Wisconsin ice sheets retreated farther to the north about 9,000 years ago.

Prior to 5,000 years ago, the southern shoreline of glacial Lake Algonquin retreated northward in a period of low water level. The lake level at the time was 230 feet. The southern shoreline was situated at about the same latitude as Milwaukee and no longer drained southward into the Gulf of Mexico. But as the Wisconsin ice sheet retreated even farther, a new outlet to the east opened up, emptying the melt water eastward into the present day Hudson River through the two precursors of Lakes Ontario and Erie.

Just as a mattress springs upward when a weight is lifted from it, the land springs upward, although much more slowly, when a huge weight is removed from the surface. Mile thick glaciers are immensely heavy, and so compress the earth's crust downward into its mantle. With the ice sheets melting and retreating northward, the land south of the remaining ice began to bounce back up. This process of equilibrium is known as isostacy. But when the land began to rise, the waters of glacial Lake Algonquin started to spill southward again to its former Tolleston shoreline. This occurred about 4,000 years ago.

About this same time, glacial Lake Duluth, which was a relatively small lake lying west of the main ice sheet, grew larger due to melt water and united with glacial Lake Algonquin to the east. This resulted in the formation of glacial Lake Nipissing, which covered all the area of the present Lakes Superior, Huron, and Michigan. And, once again, the waters drained southward along the present-day Des Plains River over the Valparaiso Moraine. The eastward drainage into the Hudson River was also still active.

A striking artifact of the isostatic rebound of the earth's crust near the end of the Ice Age occurs on Mackinac Island in Michigan. The island sits in the Straits of Mackinac that separate Lakes Michigan from Huron. On one of the highest points on the island sits Arch Rock. It is a limestone rock formation in the form of an archway, carved by the waves of glacial Lake Algonquin. But Lake Algonquin's water level was at 605 feet, the elevation of the Tolleston shoreline. And the present lake level is 580 feet. Arch Rock stands hundreds of feet above the current lake level. The only explanation for this is that the crust of the earth was uplifted.

From about 1,500 years ago Lakes Michigan and Huron have been at elevation 580 feet on the average. Lake Michigan drains directly into Lake Huron, which drains via the Detroit River into Lake Erie. Lake Superior drains into Lake Huron via the St. Mary's River. Finally, Lake Erie drains into Lake Ontario over Niagara Falls in the Niagara River.

The age of the Great Lakes and the resulting shorelines can be determined by a number of different methods. The years gone by since any particular period of glaciation can normally be obtained by a study of the magnetism contained within ocean core samples. The earth's magnetic field has flipped a number of times during the past million years. A record of these reversals is locked in the sediment deposited in the ocean. Other ways of determining the length of ice ages and interglacials is by counting the relative number of warm-water plankton fossils in certain zones of the ocean core samples. A reduction or absence of these fossils indicates an ice age. Radiocarbon dating of organic substances contained within the glacial drift can give a very good estimate of the age of the drift. This method can only be used for drift with an age of less than 40,000 years, however. Before modern techniques based on radioactivity or magnetism, geologists had to use much less reliable methods for estimating the time table of glacial advance. Measuring the rate of accumulation of sediment or the erosion rate of Niagara Falls were methods employed at one time.

During the time of glacial Lake Nipissing, two other glacial lakes were also present to the east. Glacial Lake Maumee was the precursor of Lake Erie, which became isolated in its present form first. Glacial Lake Iroquois was the forerunner of Lake Ontario. When the waters of glacial Lake Nipissing lowered to present-day levels, Lake Superior to the northwest was left isolated at a higher elevation. It is the largest of the five Great Lakes, and the deepest. It lies along a failed rift, where the continent almost tore itself apart near the end of the Precambrian Era, half a billion years ago. It is the only lake whose shape and history has not been influenced by the dolomite of the Niagaran Formation.

*Lake Michigan's Effects on the Landscape of Northwest Indiana*

Lake, Porter, and LaPorte Counties are the three Northwest Indiana counties that border on the southern tip of Lake Michigan. The current lake and its predecessor, glacial Lake Chicago, have had a striking effect on the landscape of the region. Most of the rivers in Northwest Indiana tend to run east and west. This is because there are valleys formed between the ancient sand dune areas formed when glacial Lake Chicago existed at the Calumet shoreline or the Glenwood shoreline. These dune ridges paralleled the ancient shorelines, which ran east and west. Drainage in northern Lake County is poor because of the extremely small slope of the land and because of the parallel ridges of sand.

Going from eat to west along Ridge Road from Hobart into Gary one can see an ancient sand dune ridge on the south side of the street. The houses are built on this dune. Looking northward along any cross street, a gradual dip in the elevation is apparent. This is where the Calumet shoreline existed, sloping downward under the old lake level. It runs eastward, curing up through Lake Station and on to Michigan City. The hilly region on the east side of Lake Station is the remains of old sand dunes.

Driving eastward along U.S. 20 in Miller, one can see another series of dunes. These look more recent in origin because they are clearly recognizable as being made of sand. They were formed when the lake was occupying the Tolleston shoreline. Sand dunes in a current stage of formation can be seen just south of the present shoreline of Lake Michigan in the Indiana Dunes National Lakeshore at West Beach.

During times of flooding, the low-lying areas between the ancient dune regions are affected most. Cemeteries in the Calumet area are all constructed on a former shoreline, which is at a higher elevation and less flood-prone. The clay pits in Hobart represent sediment laid down when Lake Chicago was occupying the Calumet shoreline. Hobart lies in a low area between the Glenwood and Calumet shorelines. During wet weather when Lake Chicago existed at the Calumet shoreline, water accumulated and deposited clay and sand in sorted layers called varves in the area near Hobart.

Dune formation is a story in itself. Currents caused by waves hitting the shore at an angle, called longshore currents, flow southward along the western shore of Lake Michigan. These currents and the waves erode the bedrock and soil from areas of Wisconsin and Illinois and deposit them along the shoreline in Indiana and southern Michigan. Most of the minerals that make up this earth debris are unstable at the earth's surface and tend to weather away rapidly. The quartz, which is a major component of many rocks, is the most stable mineral at the surface and tends to resist weathering. Consequently, the quartz particles remain after the other minerals have eroded away. The sand of the Indiana Dunes is composed of these quartz particles, which have been rounded by the winds and the waves. They pile up on the southern shore of Lake Michigan to form sandy beaches. They are blown by the wind and pile up in ridges and mounds called sand dunes.

Mount Baldy in Michigan City is the tallest living sand dune in Indiana. Living sand dunes are those that are currently migrating due to the prevailing winds. As dunes migrate inland, grasses, such as Marram Grass and Little Blue Stem begin to take root in the sand and stabilize its movement. The dunes are very fragile, however. If the scanty vegetation is killed in a small area on the windward side of a dune, a blow-out is the result. This is a large area devoid of vegetation, causing the dune to become hollowed out at that location. Many features of sand dune succession can be seen at West Beach, part of the Indiana Dunes National Lakeshore, and at Indiana Dunes State Park near Chesterton.

## The Rivers of Indiana

The Ice Age totally changed the drainage pattern of Indiana. In fact, the drainage pattern of the entire nation was radically altered. The ancestral Missouri River drained to the northeast into the Arctic Ocean. The ancestral Ohio River was much farther to the north, running through central Ohio and north-central Indiana. It was named the Teays River by W. G. Tight, one of the men who discovered its existence. The Teays River turned southward in Illinois to drain into the ancestral Mississippi river and then into the Gulf of Mexico, which extended like a finger into the central region of the present-day United States.

Since the end of the Ice Age, a drainage pattern has been established in most of Indiana in a direction from the northeast to the southwest. The location of moraines affects the direction of flow of many rivers in northern Indiana. The Wabash River, Indiana's largest, parallels the end moraines flowing toward the northwest as it enters the state from Ohio. It then takes a sharp westward turn in Huntington County, where it cuts through the Mississinewa Moraine. It then flows southwestward, passing the cities of Lafayette and Terra Haute. South of Terra Haute, it forms the western boundary of Indiana untils its confluence with the Ohio River southwest of Evansville.

The White River drainage basin drains most of the central part of Indiana. The West Fork White River has its source in Randolph County, where it follows the Union City Moraine for awhile. It then turns southwest to flow through Indianapolis. The West Fork reaches its confluence with the East Fork White River in Southwest Indiana. The East Fork flows southwestward from is source in Columbus, where the Driftwood River merges with the Flat Rock River. Big Blue River also adds its flow where it merges with Sugar Creek to form the Driftwood River near Edinburgh. The streams of Sugar Creek and Driftwood River are a favorite for canoeists, who enter the river in the Atterbury State Wildlife Area near Edinburgh.

Just s the Rocky Mountains form the Continental Divide, which separates rivers that drain into the Pacific Ocean from those that drain into the gulf of Mexico, there is also a continental divide running through northern Indiana. This divide separates the southwestward drainage into the Mississippi from the Great Lakes drainage system to the north and east. The Valparaiso Moraine marks this divide in Northwest Indiana. The divide runs along the Valparaiso Moraine from Chicago to Michigan City. It then turns eastward, cutting through South Bend, then southeast to Fort Wayne and finally into Ohio. The Maumee River, originating in Fort Wayne just east of the divide, flows eastward to empty into Lake Erie.

Unlike the mountainous Continental Divide of the Rockies, Indiana’s divide runs only atop the end moraines left by the Ice Age. In Chicago, the divide is only 10 feet above the present level of Lake Michigan.

## What Caused the Ice Age?

This chapter does not have anything to do with Indiana's geography per se, but the ice age glaciers certainly did. And it is interesting to explore what caused those landscape-altering ice sheets to encroach upon what is now the Midwest.

It is now known that continents move around on the surface of the earth, carried on large crustal plates that are floating in the part of the mantle called the asthenosphere. When any continental land mass is over or around the poles, warm tropical water from the equatorial regions cannot flow into the Polar regions. This causes the climate near the ples to become colder. The ocean regions in the middle latitudes, however, become warmer, increasing the amount of global precipitation. Therefore, more snow falls in the Arctic areas. So during the times when the land masses surround or cover the poles, an ice age is likely to occur if other factors are also favorable.

The other factors include variations in the earth's tilt and orbit around the sun. There are three cycles of variation of the earth's motion and alignment in space. One cycle involves the tilt of the earth's axis, which is presently about 23.5 degrees from the plane of the ecliptic. The tilt varies a few degrees on either side of this average. The earth changes its tilt on a cyclical basis. When the earth's tilt is great, the seasons have a greater temperature contrast; summers are hotter and winters are colder. At times when the earth's axis is less tilted, summers and winters are milder.

Another cycle concerns the shape of the earth's orbit around the sun. The orbit forms an ellipse, as do the orbits of all the planets. Sometimes, the ellipse is more elongated than at other times. A greater elongation enhances the seasonal effects.

The third cycle concerns the direction in space the earth's axis is pointing. Presently, the North Pole points to the North Star, Polaris. But 11,000 years ago, the North Pole pointed to a star in the Big Dipper. The earth's axis goes through one complete cycle every 26,000 years. In other words, it wobbles. This motion is known as precession of the equinoxes and it causes the vernal equinox to move slightly westward in the sky each year. Spring arrives when the sun is directly above the equator on its apparent northerly motion toward the Tropic of Cancer. This point in the sky is the vernal equinox. It currently happens each year when the sun is in the constellation of Pisces. At the present moment in history, the vernal equinox is entering the constellation of Aquarius. It is truly the dawning of the Age of Aquarius.

The combination of the three cycles makes it more likely that the earth will experience glacial activity at certain intervals of time. The cycles are collectively known as the Milankovitch cycles after Milutin Milankovitch, a Serbian mathematician who devoted much of his life to the study of the effects of these cycles on climate. If the Milankovitch cycles are in a favorable position for cool summers and if there is land on or near at least one of the poles, the stage is set for an ice age to begin. These astronomical cycles occur more quickly than the drifting of the continents. A continent moves so slowly that it effectively remains in place of millions of years. The orbital cycles are in a favorable position for an ice age to begin about every 100,000 years. The Milankovitch cycles, therefore, apparently are responsible for the many glacial advances within a period of a much longer age of ice.

Note that the earth presently has a land mass covering the South Pole and land masses surround the North Pole. Thus, it is believed, we are currently in a warm interglacial period of a much longer ice age. When the Milankovitch cycles return to the appropriate conditions, a new period of glaciation will likely begin.

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