The Geology of Whitewater State Park

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UNIVERSITY OF MINNESOTA

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Acknowledgments

I thank Dave Palmquist, naturalist at Whitewater State Park, for his advice during the preparation of this report. He also provided many of the photographs. Other photographs provided by A.C. Runkel.

Front cover:
View of Coyote Point (photo by D. Palmquist).

Back cover:
This map shows the distribution of Paleozoic bedrock formations that were deposited in oceans and now are exposed or are covered by only a thin mantle of glacial deposits. Hiking trails and roads mentioned in the report are shown. More comprehensive trail and road maps are available at the visitor center.

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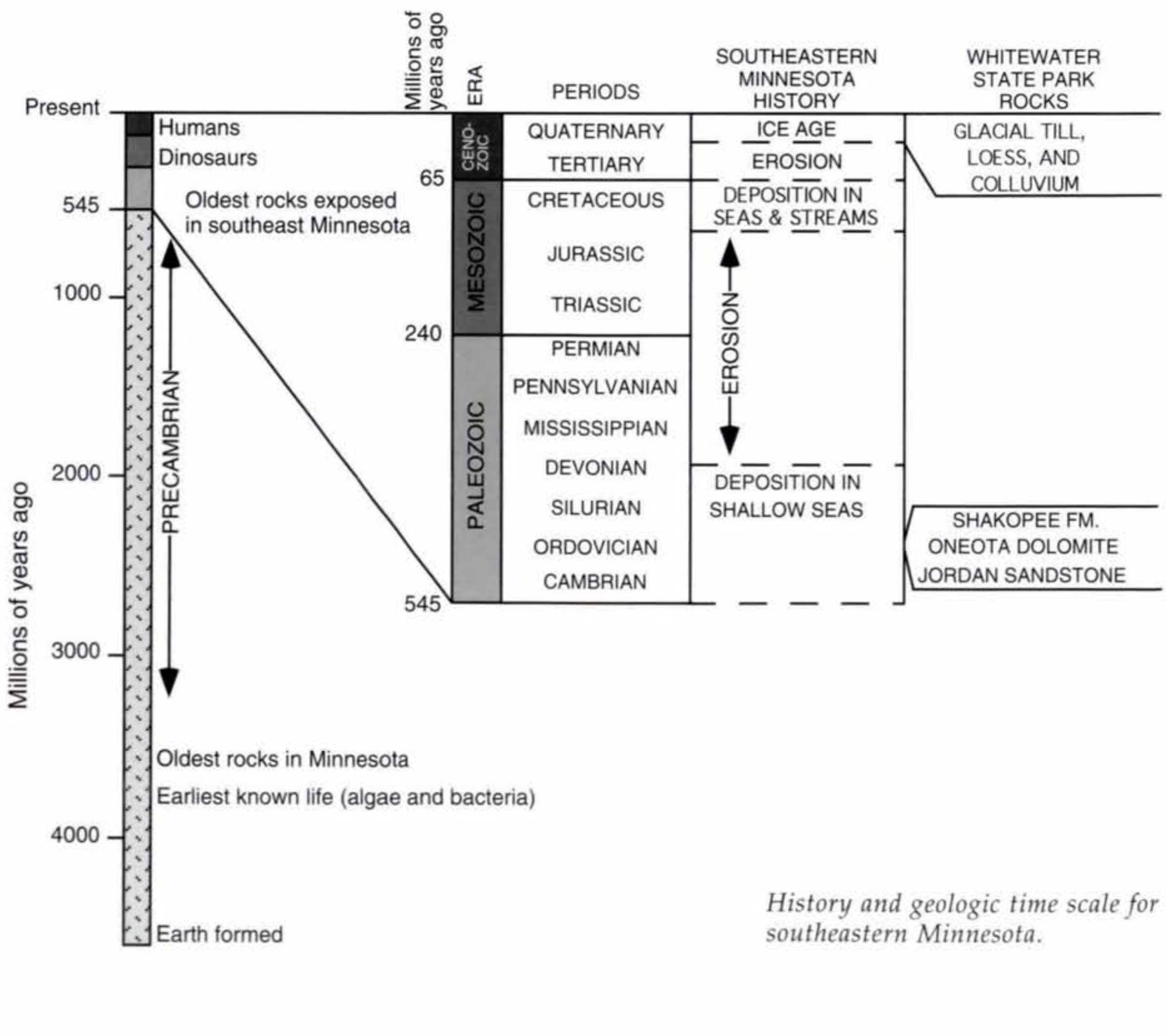
photo by D. Palmquist

Many attractions of Whitewater State Park are related to its geology. The scenic bluffs, caves, and even the cold streams that support a thriving trout population are all related to a geologic history that spans hundreds of millions of years.

You can understand the geology of Whitewater State Park even if you do not have a background in geology. You need only be familiar with the processes of erosion and deposition, and the geologic time scale. Erosion is the natural process whereby water and other agents break down rocks and soil and shape the land. It can be chemical, as when mildly acid water dissolves limestone, or mechanical, as when wind blows away the soil or rainwater washes it away. Deposition is the accumulation of particles into layers, or beds, as small grains are dropped by wind or settle in water to form sandstone, or as elements dissolved in water, such as calcium, magnesium, and iron, precipitate to form limestone or dolomite.

The earth is more than 4.5 billion years old. To have an organized manner in which to discuss the history of the earth, geologists have subdivided this enormous span of time into segments. Nearly all of the rocks you see in southeastern Minnesota were laid down in either the early part of the Paleozoic Era, from about 545 million to 350 million years ago, or in the past 2 million years, during the Quaternary Period. To put these ages into perspective, consider that the oldest bedrock exposed at the surface in Whitewater State Park was laid down more than 200 million years **before** the first dinosaurs, and more than 500 million years **before** human beings. In relation to the entire span of earth history, though, this bedrock is relatively young because it was deposited more than 4,000 million years **after** the earth was formed.

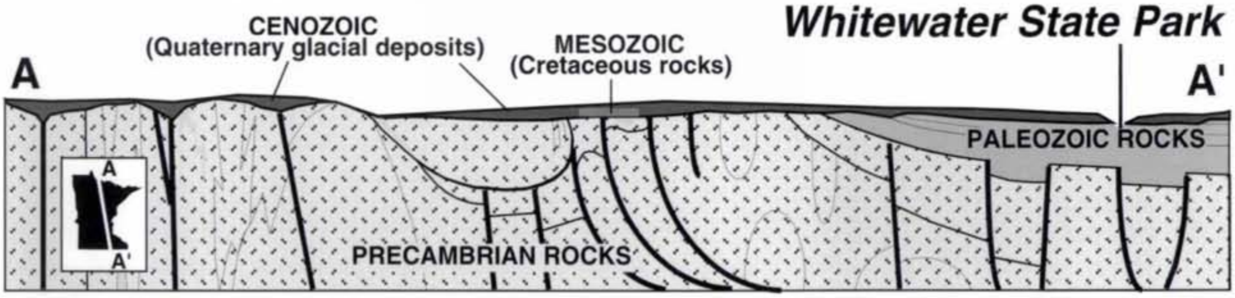


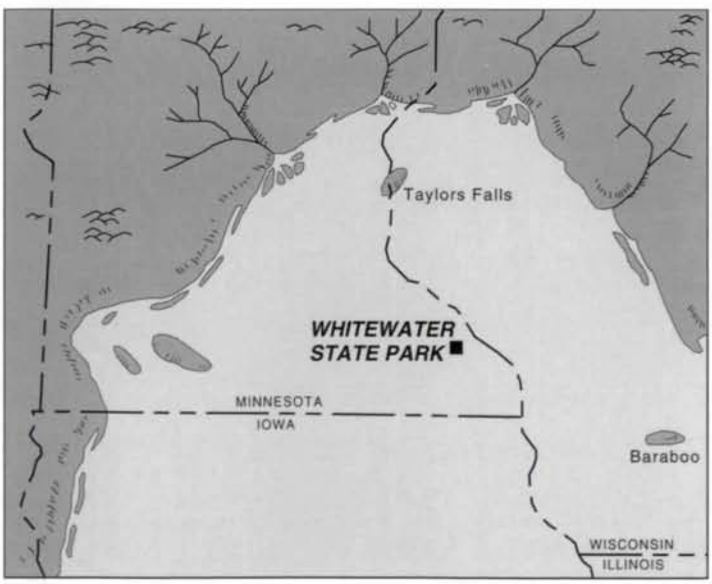
History and geologic time scale for southeastern Minnesota.

Overview of the Geologic History of Southeastern Minnesota

Whitewater State Park lies on the Paleozoic plateau of southeastern Minnesota. This area differs from most of Minnesota in that it has only a very thin layer of glacial materials overlying bedrock of Paleozoic age. The bedrock has been deeply cut by the Mississippi River and its tributaries to form the blufflands.

Cross section from northern to southern Minnesota showing rocks beneath the ground surface.



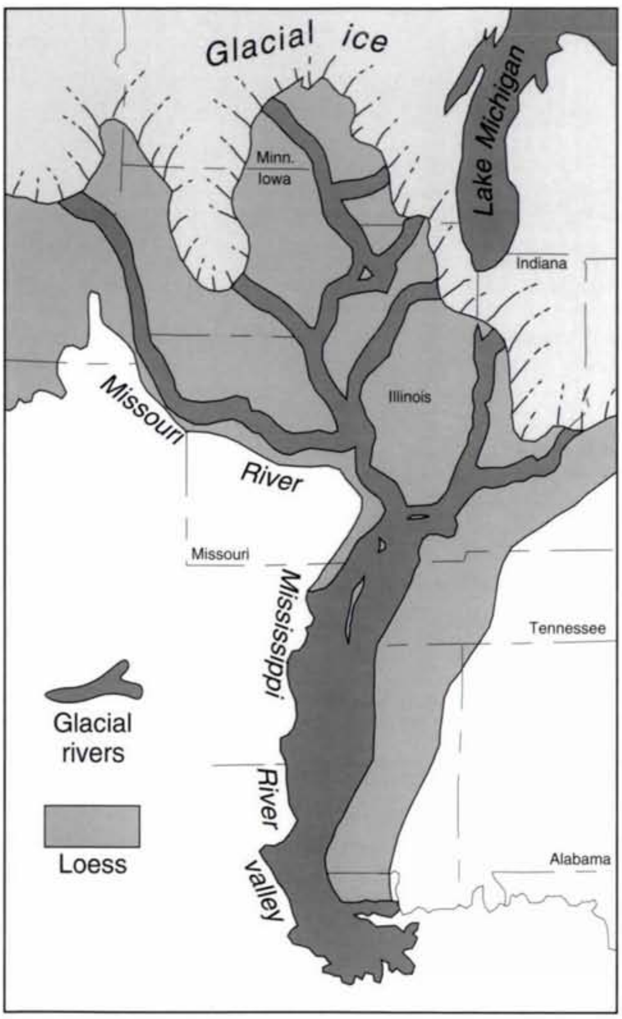


Paleogeographic map of southern Minnesota and adjacent states in Cambrian time when a shallow sea covered much of North America.

In Early and Middle Cambrian time, North America was near the equator, and Minnesota was low-lying and mostly flat. Although the climate was probably tropical, land plants had not yet evolved, so the land surface was barren of vegetation. Beginning about 545 million years ago, an ocean advanced and eventually covered most of North America. Much of southern Minnesota, Wisconsin, and Iowa became a shallow sea with islands at Baraboo, Wisconsin, Taylor's Falls, Minnesota, and in southwestern Minnesota. Over the next 200 million years, sediments accumulated in more or less flat layers in the sea. The sediments were later buried and cemented, eventually forming the layers of rock that form the bluffs in southeastern Minnesota. These Paleozoic rocks are more than 1,500 feet thick in some places; they encompass the three geologic time periods known as Cambrian, Ordovician, and Devonian.

If you examine exposures in quarry walls and road cuts in southeastern Minnesota, you can see that they consist of more than one kind of rock—sandstone, shale, dolomite, and limestone. Different rocks reflect the environmental conditions present at the time the rocks were originally deposited as sediments. For example, the sandstone accumulated at times when streams carried large quantities of sand to the shoreline. When sand was scarce, carbonate minerals, chemically precipitated from seawater, and carbonate shells of marine organisms accumulated to form limestone. Diverse sea life, such as ancient relatives of the clams, snails, and corals, became entombed in these sediments and were preserved as fossils.

There are no rocks in southeastern Minnesota ranging in age from 350 to 100 million years. For most of this time the region was above sea level allowing the land surface to be eroded by wind and water. The sea returned to Minnesota about 100 million years ago during the Cretaceous Period, a time when dinosaurs were widespread. Deposits laid down at this time are commonly found beneath the surface of southwestern Minnesota, but in southeastern Minnesota only thin, patchy remnants of Cretaceous rocks are present.



Generalized distribution of glacial ice, loess deposits, and major river valleys about 20,000 years ago. Modified form Matsch (1976).

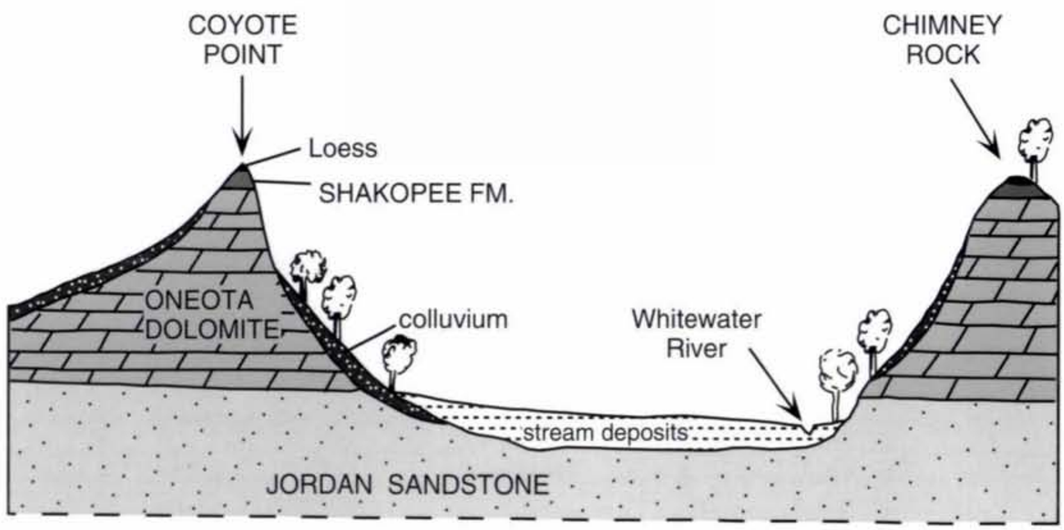
The final chapter recorded in the rocks of southeastern Minnesota—beginning about 2 million years ago—is the Quaternary Period, most of which is called the Pleistocene Epoch or "Ice Age." The Holocene Epoch, or Recent, began only about 10,000 years ago. During cold spells, Pleistocene glaciers flowed southward, at times covering most of Minnesota. The ice retreated during warmer, interglacial episodes. As glaciers advanced they scraped soil and rocks from the landscape, mixed them together, and, when the ice melted, left them as an unsorted mass called till. Meltwater streams deposited outwash deposits of sand and gravel. During cold, dry periods when there was little vegetation, strong winds picked up fine sand and silt from outwash sediment and redeposited it in a thin blanket called loess.

Glacial deposits are not thick in southeastern Minnesota because the area was ice-free during most of the Ice Age. The main effect of the glaciers in southeastern Minnesota was the release of large amounts of meltwater into the ancient Mississippi River, causing it to erode more deeply into its valley. As a result, tributaries, such as the Whitewater River, also began to cut down deeply into their valleys, keeping pace with the downcutting Mississippi, and creating the bluffs we see today.

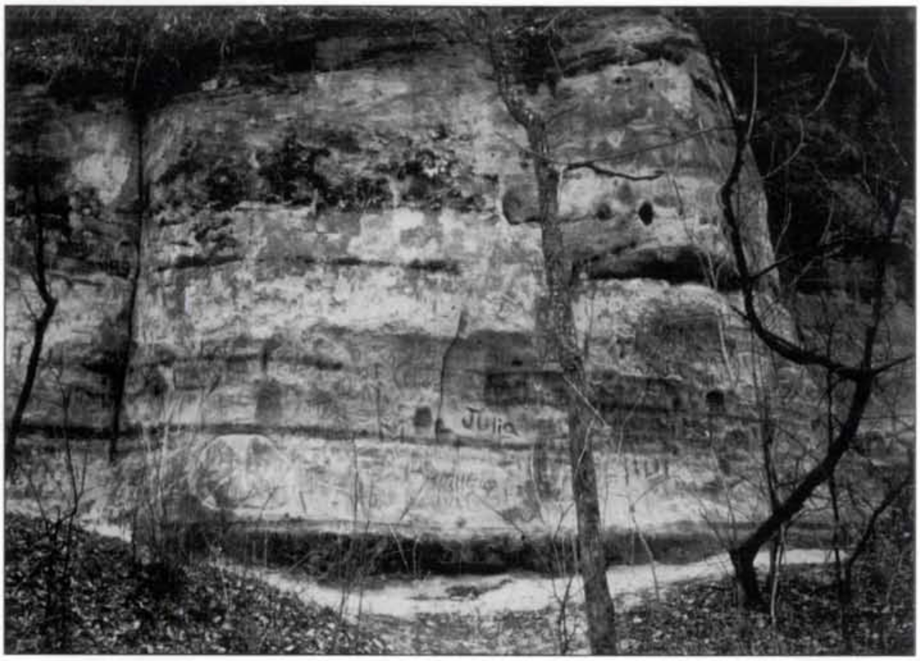
Geology of Whitewater State Park

Only some of the geologic history of the region can be seen in Whitewater State Park. The park's history can be divided into a two-part story. The first part of the story explains how the oldest rocks in the park, the Paleozoic bedrock, were formed. The second part of the story concerns the erosional processes that sculpted these rocks to form the bluffs and valleys.

Three bedrock formations are exposed in the bluffs of the Whitewater River valley—the Jordan Sandstone, Oneota Dolomite, and Shakopee Formation. The underlying St. Lawrence Formation is not exposed in the park but is shown on the map where it is the first bedrock beneath the stream sediments. The rock formations are named after the places where they are or were at one time well exposed. The Jordan Sandstone is named for the city of Jordan, Minnesota; the Shakopee Formation for the city of Shakopee, Minnesota; and the Oneota Dolomite for the Oneota (now Upper Iowa) River in Iowa.



Cross section of the rocks in Whitewater State Park. A cross section shows how rocks would appear on the side of a trench cut vertically into the land surface.



The Jordan Sandstone above the east bank of the Whitewater River along Chimney Rock Trail.

The Jordan Sandstone is about 510 million years old and was deposited toward the end of Cambrian time. The Jordan is well known to geologists as one of several sheet sandstones in this part of the North America that are composed almost entirely of rounded grains of quartz, a mineral rich in silica, similar in composition to window glass. The Jordan is exposed in only a few places in the park, mostly above sharp bends in the Whitewater River. It is yellow, brown, orange, and white in color. The rusty colors are thin coatings of iron oxide—rust—on individual sand grains.

The Jordan Sandstone was laid down on a sandy shoreline that was retreating southward out of Minnesota and into Iowa in Late Cambrian time. Rivers brought sand from what is now the Lake Superior region to the shoreline, where storm waves and shallow ocean currents dispersed it along the coast. A distinctive feature of the Jordan is cross-bedding—seen as distinctive lines that slope down at an angle. The cross-beds were deposited as small underwater sand dunes formed by storms and tidal currents in shallow water just offshore, as is happening in oceans today.

Cross-beds in the Jordan Sandstone.

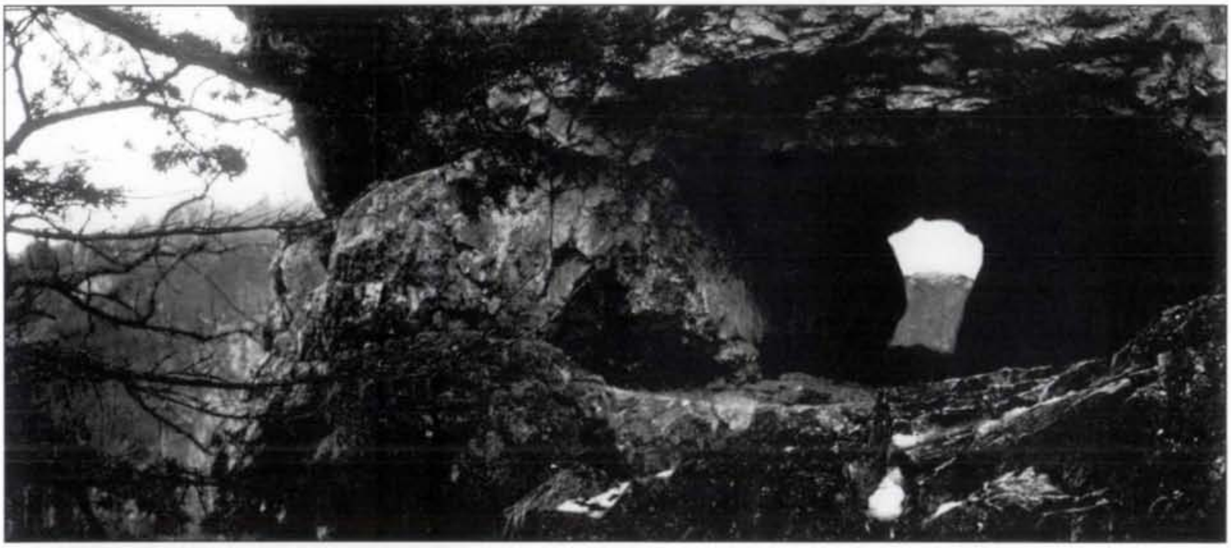
Large angular pieces of light-gray or white sandstone up to two feet long are encased in orange or brown sandstone; they are pieces of cemented beach deposits that were broken up during storms. At the time the Jordan Sandstone was deposited, southeastern Minnesota may have looked like the sandy coast of the Gulf of Mexico, but with a barren, lifeless land surface.

Fragmented pieces of beach deposits in the Jordan Sandstone along Chimney Rock Trail.

Stromatolitic domes in the Oneota Dolomite along Coyote Point Trail.

The Oneota Dolomite, which overlies the Jordan Sandstone, is the tan to gray, hard bedrock layer that forms most of the steep cliff exposures in the park and elsewhere in the blufflands. It was laid down in the sea, which returned to Minnesota about 505 million years ago. The Oneota Dolomite is clearly different from the Jordan Sandstone. Although it contains some sand and shale, it is mostly dolomite, an altered limestone that is made up of calcium, magnesium, and carbon dioxide. This carbonate rock was deposited in shallow water no more than a few feet deep, in an environment called a tidal flat, where water advanced and retreated with high and low tides across a broad, flat shoreline. Distinct beaches were not present and sand was not abundant. Instead, warm, sediment-poor conditions led to the development of communities of animals that precipitate lime. Characteristic of the Oneota are algal features, such as stromatolites. Stromatolites are mounds built up by algae in which mud and carbonate lime were trapped as the tides rose and fell. The algal mounds can be seen as wavy laminations and broad domes. They are the most common fossils in the Oneota, although ancestors of today's clams and snails are found in the Oneota elsewhere in Minnesota.

Another distinctive feature of the Oneota is karst—caves and enlarged fractures dissolved by mildly acid ground water traveling through cracks long after the Oneota was deposited. These can be seen along many of the park trails.



Cavity in Oneota Dolomite formed by dissolution of the carbonate rock (photo by D. Palmquist).

Ripples preserved in the Shakopee Formation.

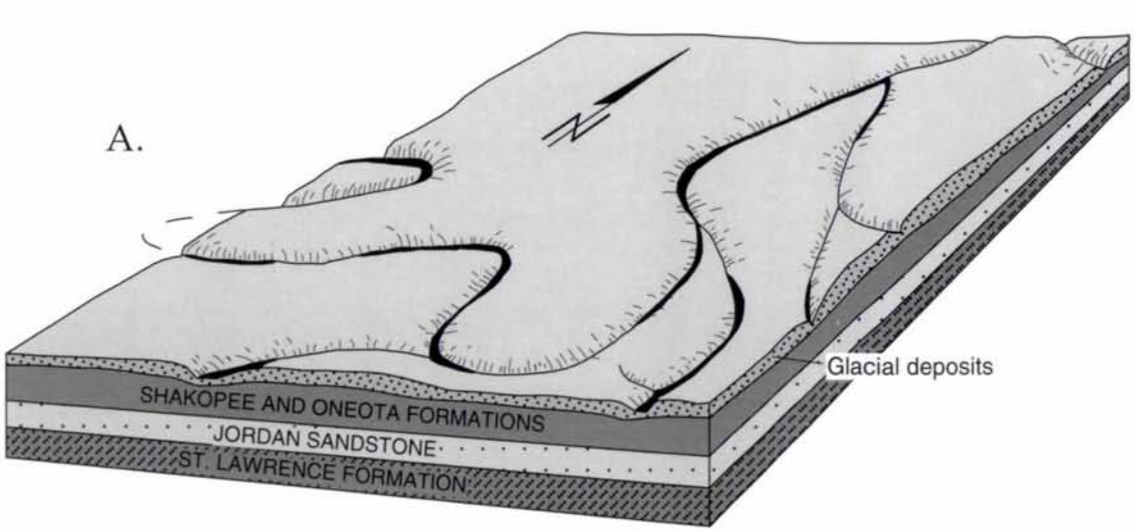
The Shakopee Formation was deposited on top of the Oneota. It is as much as 150 feet thick where it is completely preserved but is present here only as a thin remnant. It is somewhat similar to the Oneota but contains more sand and shale. It was deposited in an environment similar to that of the Oneota, in shallow water subjected to tidal currents, and it also contains algal features such as abundant stromatolites. Also characteristic of the Shakopee are preserved ripples which were formed by waves in shallow water. These can be seen at several outcrops in the park on the top of the bluffs.

The thin remnants of Shakopee Formation that cap the bluffs are the youngest bedrock in Whitewater State Park. Deposition in ancient seas occurred intermittently for another 150 million years in southeastern Minnesota, burying the Shakopee Formation under as much as 500 feet of rock. These younger bedrock layers can be seen in quarries south of the park and along the Mississippi River in Minneapolis. They have been removed from the Whitewater area by erosion.

After a long period of erosion, the oldest glacial deposits in Whitewater State Park were laid down in the early stages of the Ice Age. They are among the oldest glacial deposits in all of Minnesota. The deposits include a thin unit of till—a mixture of clay, sand, and boulders that was carried by a glacier and deposited when the glacier melted. This till, which caps the Shakopee and Oneota in places along the tops of the bluffs, is typically less than 10 feet thick. It is covered by loess.

Although more recent glaciers deposited thick tills across most of the state, southeastern Minnesota remained mostly ice free, and its Paleozoic bedrock eroded. The bluffs in this area were not mountains (as early explorers thought) but were carved by streams over thousands of years. Relatively soft formations like the Jordan Sandstone are fairly easily eroded, and they commonly form the valley floors. Harder, more resistant rocks like the Oneota Dolomite are able to stand as cliffs along the sides of the valleys. The Oneota erodes to form steep cliffs, because it tends to break off in large blocks along vertical fractures rather than slowly weather away. These erosional characteristics control the shape of the valleys in the park. Valleys cut only into the hard carbonate rock of the Oneota Dolomite (along the upper reaches of Trout Run, for example) are typically narrow and steep-sided. Valleys that bottom in the soft Jordan Sandstone, as along the Whitewater River, are wider. Because the valley walls are Oneota Dolomite, these valleys also have steep sides.

During especially cold periods in the Ice Age, repeated freezing and thawing of water in cracks broke angular blocks of Oneota Dolomite away from valley walls. Thick accumulations of this unsorted slope sediment—or colluvium—form the vegetated slopes that extend from the base of the cliffs in the park to the stream sediments on the valley bottoms. The individual boulders that make up the colluvium cannot be seen today because they are covered with soil and vegetation.

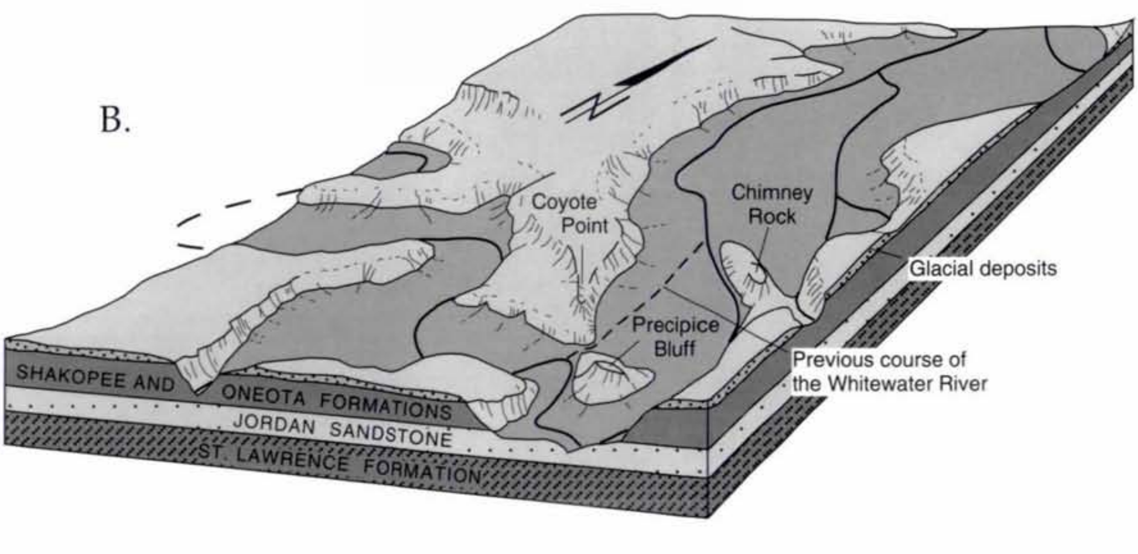


Erosion by streams changed the landscape from what was once mostly flat (A) to the blufflands of today (B). Note that the main channel of the Whitewater River previously flowed on the west side of Precipice Bluff.

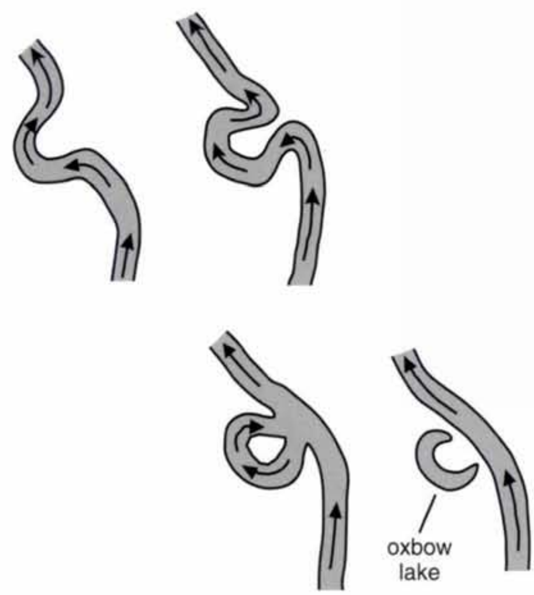
From about 25,000 to 12,000 years ago the climate here was cold, dry, and windy, and vegetation was sparse. Erosion of upland areas occurred at this time as wind picked up fine sand and silt particles. Some of this sediment was redeposited as a thin blanket called loess, which is present in Whitewater State Park beneath the topsoil in upland areas. Large quantities of loess were also carried into streams and deposited on the valley floors, raising the Whitewater River to a level that was higher than it is today. Toward the end of the loess deposition, the climate began to warm and the glacial ice began to melt. The Mississippi River and its tributaries, including the Whitewater River, deepened their valleys as vast amounts of water were discharged from large glacial lakes in the north. Downcutting since then has breached older stream deposits, leaving remnants, called terraces, extending along valley walls. These terraces are level surfaces that are considerably higher than present river levels. Thus they were suitable for farming by the Dakota Indians, and also for the locations of the visitor center and campgrounds in the park today.

The manner in which the ancient Whitewater River and its tributaries eroded the Paleozoic bedrock created several prominent features in the park. Precipice Bluff was formed by stream piracy, whereby one stream diverts the downstream part of a neighboring stream. The main channel of the Whitewater River once passed between Precipice Bluff and Coyote Point, flowing roughly along the present course of Minnesota Highway 74 by the Nature Store. Farther south along this highway, a tributary to Trout Run Creek once flowed along the southwest side of Precipice Bluff, separated from the Whitewater by a ridge of bedrock. This tributary gradually deepened its valley northwestward (headward) until it breached the ridge between the two streams, thereby "capturing" the Whitewater River and causing it to follow the course of the tributary. Thus, Precipice Bluff stands isolated from Coyote Point by a gorge, formerly the path of the Whitewater River.

B.



Because it occupies a wide, flat valley filled with relatively soft stream deposits, the Whitewater River has a series of broad bends called meanders. The popular Beach in the central part of the park was formed by a process common to meandering streams, called neck-cutoff. Through time, meander loops grow more and more pronounced and eventually form a nearly complete circle. The neck of land separating loops is eroded to a point where the river can cut across the neck to form a new, shorter channel. The meander is thus abandoned. If it remains filled with water, it is called an oxbow lake. In the case of the Beach, the process was helped along by a dam built by the Civilian Conservation Corps in the 1930s.



The closing off of a loop in a meandering stream creates oxbow lakes such as the one in Whitewater State Park. Arrows show the direction of flowing water.

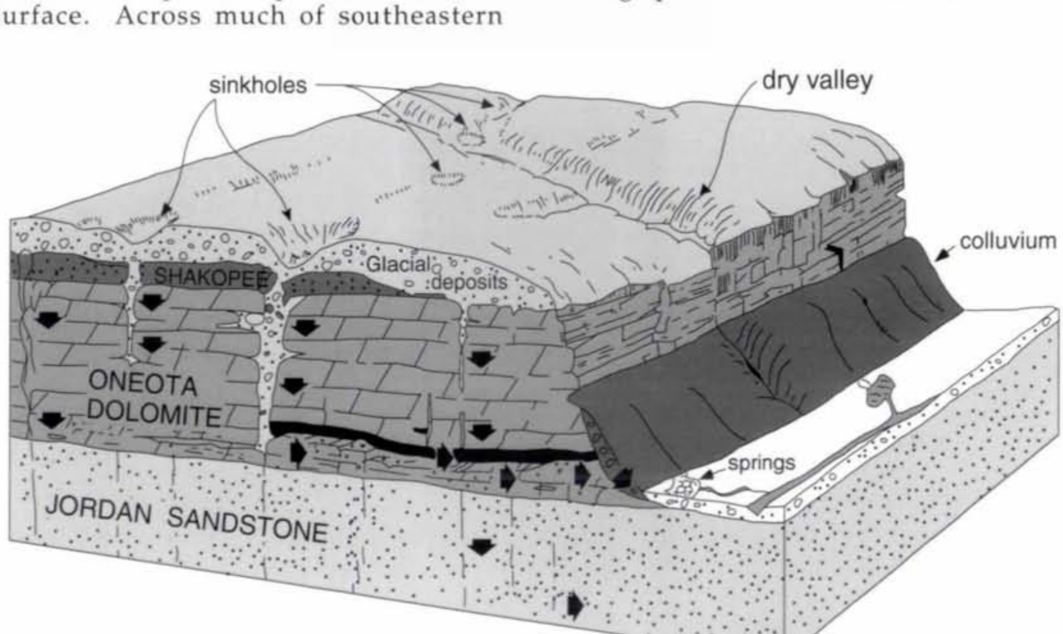
Many of the erosional processes described above are active to some extent today, continually reshaping the landscape. Valleys are slowly widened as blocks of Oneota detach from bluffs, particularly during repeated freezing and thawing in the fall and spring. The meandering Whitewater River and its tributaries, which cut into soft Jordan Sandstone during floods, undercut the overlying Oneota Dolomite, and blocks of the Oneota break and fall.

The effects of human settlement over the past 200 years have drastically altered the drainage of the Whitewater River and its tributaries. Although erosion is a natural river process, certain land-use practices by humans increase the rate of erosion to unnatural levels. Much of the natural vegetation on the plateaus above the valleys was cleared when the land was tilled. This led to increased runoff and soil erosion, which clogged streams with sediment that has accumulated on the valley floors. As much as 14 feet of post-settlement sediment from upland areas accumulated in some valleys, raising the level of streambeds and impeding drainage. Northeast of Whitewater State Park, the towns of Beaver and Whitewater Falls were buried by sediment and today are covered by marshland. The town of Elba, which was originally on high ground, currently has to be protected from flooding by dikes. The introduction of soil conservation practices in the 1940s, including tree planting and contour strip cropping, greatly decreased the rate of erosion. As a result, streams are now cutting into the flood deposits. Land owners are working together in a renewed effort to decrease erosion through the Whitewater Watershed Project, and streams may eventually reestablish their equilibrium more or less at the pre-settlement level.

Environmental Geology

Perhaps the most important resource-related aspect of the bedrock units in the park is the ability of the Shakopee, Oneota, and Jordan Formations to act as an aquifer—a body of rock that can store and transmit economic quantities of water. Together these rock units form the Prairie du Chien–Jordan aquifer, which is the most widely used aquifer in southeastern Minnesota. Ground water in the Oneota and Shakopee Formations travels through large interconnected fractures and solution cavities; in the Jordan Sandstone it travels in the spaces between grains of sand. The time it takes for precipitation to reach the aquifer varies greatly, depending on the thickness and type of overlying bedrock and glacial deposits.

The fractures and solution cavities in the Oneota and Shakopee Formations make the ground water susceptible to pollution from the land surface. Across much of southeastern Minnesota the landscape has developed a karst topography, which is characterized by the presence of sinkholes and caverns. When fractures are enlarged by dissolution of carbonate rocks, the overlying soil can collapse into the void, creating a cone-shaped depression called a sinkhole. Agricultural chemicals dissolve in water and are carried on sediment. Washed into a sinkhole, they move downward through the fractures and solution features, and bypass any natural filtration. Any waste products thrown into sinkholes also contribute chemicals and bacteria that reach the ground-water system relatively quickly. Interconnected cavities within the aquifer allow such contaminated water to disperse rapidly over considerable distances. Therefore, the maintenance of a clean ground-water supply for human consumption depends in large part on how we treat the landscape.



Typical pattern of ground-water movement in the karst topography of Winona County. Modified from Dalgleish and Alexander (1984).

There are no known sinkholes in the park. Steep slopes and deeply incised valleys cause water to run off instead of infiltrating into the bedrock. Sinkholes are abundant about six miles south and can be seen from U.S. Highway 14 between St. Charles and Lewiston.

Sinkhole in Utica Township, south of Whitewater State Park. Trees typically grow in sinkholes and make them easy to identify in cultivated fields.

The many springs in Whitewater State Park are the result of ground water seeping out of bedrock near the contact between the Oneota and Jordan Formations. Ground water moves horizontally within an aquifer at rates of inches to several feet per day. When the ground water reaches the bedrock wall of a river valley, it seeps out of the aquifer and creates a natural spring. The clarity and relatively constant, cool temperature of spring-fed streams in the Whitewater area make them suitable for trout.

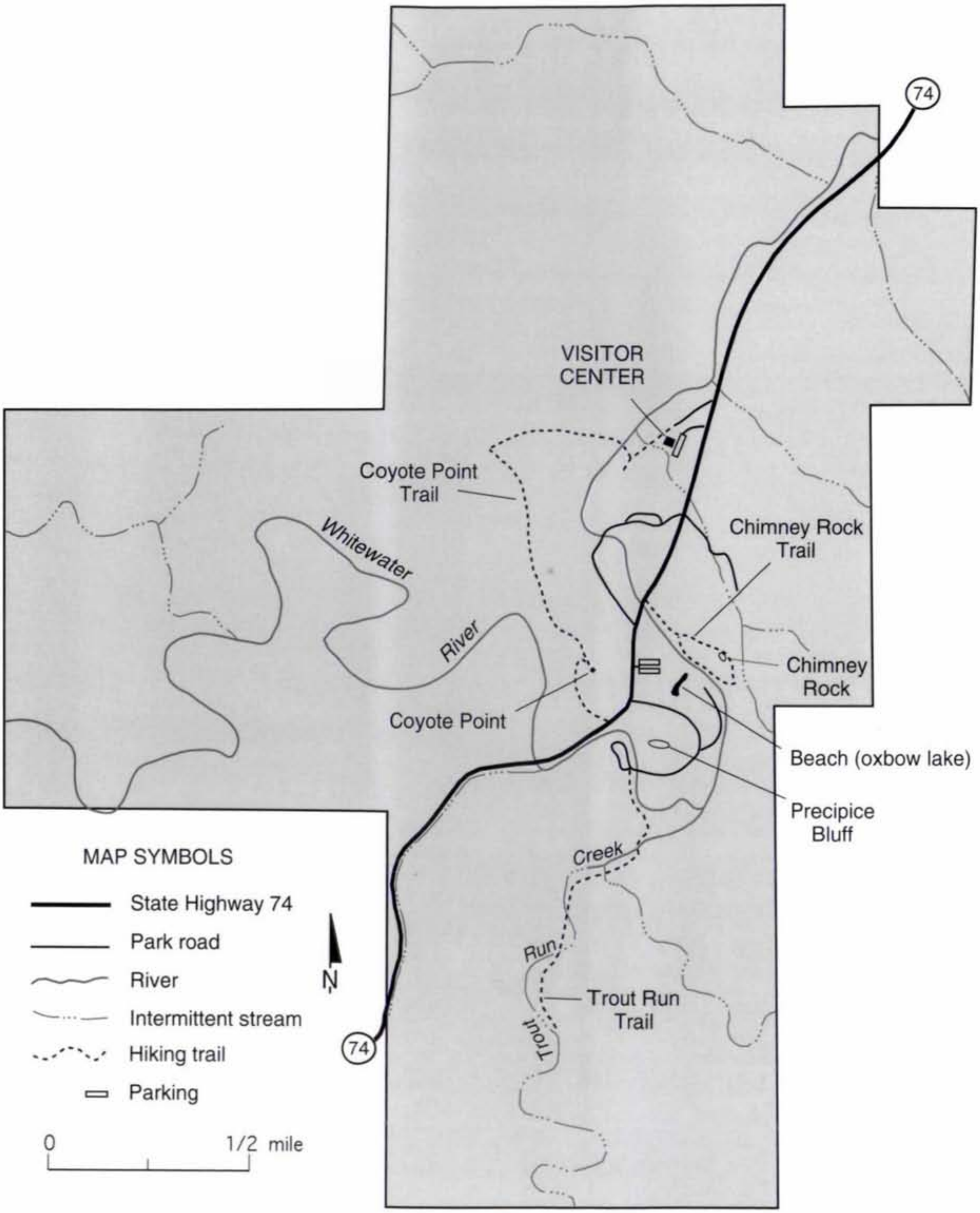
Natural spring along Trout Run Trail.

Where to Go

All of the trails in Whitewater State Park provide a glimpse of its geologic features. There are natural springs along many of the trails, especially along Trout Run Creek Trail. The steep cliffs of Oneota Dolomite can be seen, either up close or at a distance, from practically anywhere in the park. In addition, many of the older buildings in the park, such as those near the Beach, are built of blocks of Oneota Dolomite that were cut from a quarry at the end of Trout Run Trail. Trails on the bluff tops provide a good view of the meandering Whitewater River and an opportunity to visualize how the streams in the park have carved the landscape out of the surrounding bedrock. As you hike the trails, please help preserve the fragile and limited resources by staying on the trails. Collecting rocks and fossils in the park is prohibited.

Two trails in the park—Chimney Rock and Coyote Point—provide an opportunity for hands-on examination of some features.

Coyote Point (photo by D. Palmquist).



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VISITOR CENTER
Coyote Point Trail
Whitewater
River
Chimney Rock Trail
Chimney Rock
Coyote Point
Beach (oxbow lake)
Precipice Bluff
Creek
Run
Trout
Trout Run Trail
MAP SYMBOLS
State Highway 74
Park road
River
Intermittent stream
Hiking trail
Parking
0
1/2 mile
N
74

Chimney Rock Trail

This trail has the most accessible exposures of the 500-million-year-old bedrock in the park. From the Beach, cross the footbridge and go up the steps to your right. The footbridge and steps are made of blocks of Oneota Dolomite. Near the top of the bluff is Chimney Rock. Chimney Rock is an erosional remnant of what was once a much larger bluff of Oneota Dolomite. The dolomite that once surrounded the pinnacle was gradually broken off. The small hole at the base of the pinnacle is an example of the cavities through which ground water travels where the Oneota lies beneath the land surface. This hole is a long-time favorite for children who climb through it.

Past Chimney Rock are two overlook points at the top of the hill. You are standing on exposures of the Shakopee Formation. Close inspection shows that the Shakopee is sandier than the Oneota at Chimney Rock. Note the large ripple features at your feet. These may remind you of wave ripples you have seen in shallow water along the shoreline of sandy lakes in Minnesota. Look across the valley toward the west side of the river and you can see some caverns at the base of the bluffs. Some north-facing caves in the blufflands contain ice year-round because their openings receive no direct sunlight for most of the day, and they are insulated by surrounding rock from the warm outside air in the summer. These unusual conditions create a small fragile environment that supports species of plants and animals, such as land snails, that are not known elsewhere in Minnesota.

As you hike down the hill toward the river you will see angular pieces of the Oneota Dolomite that have broken off from the bluff above you. There is a thick accumulation of similar blocks beneath your feet on the slope—some of the colluvium that accumulated thousands of years ago.

Chimney Rock (photo by D. Palmquist).

The Jordan Sandstone is exposed along the east bank of the Whitewater River near the trail head. The Jordan is the mostly orange or rust-colored bedrock that has been carved into by park visitors years ago. Today, visitors realize that defacing rock outcrops is not appropriate. Remember that 510 million years ago this sand was being deposited as part of a long sandy shoreline that stretched across much of southern Minnesota and Wisconsin. Look for the cross-beds in the Jordan Sandstone. They formed from small, shifting sand dunes in the shallow water of the ocean. Do you see the roughly rectangular blocks of white sandstone about 6 inches to 2 feet across? These are pieces of ancient beach deposits that were broken apart during storms.

Coyote Point Trail

There is a narrow cave in the Oneota about a quarter mile from the trail head, in the steep bluff about halfway up the hill. Fractures and caves such as the ones you see here are also present in the Oneota where it lies beneath the surface in southeastern Minnesota. They are major pathways for moving ground water. As you continue past the cave, look closely at the Oneota, and you should be able to recognize some dome-shaped structures in the rock. These are relicts of ancient algal mounds that accumulated on a tidal flat when shallow seas covered this area about 500 million years ago. At Coyote Point Overlook you are standing on dolomite of the Shakopee Formation. Here and at several other places farther along the trail you can see ancient ripples that formed by wave currents in shallow seawater. Much of the fine sandy soil along the trail at the top of the bluff is developed on the loess deposited 25,000 to 12,000 years ago. This soil, which is crucial to bluff vegetation, is easily eroded, as you can tell by the deep grooves in the trail. The wooden walkways and steps along some trails were constructed to protect the soil and to make hiking safer.

Cave in Oneota Dolomite along Coyote Point Trail.

View from Coyote Point (photo by D. Palmquist).

To learn more about the geology of the Whitewater area, take advantage of the Interpretive Services offered by park staff. Whitewater State Park naturalist programs include lectures on the geologic history of the blufflands, and provide an opportunity to explore caves and collect fossils outside the park. Lists and schedules of activities are available at the park office.

Suggested reading

Dalgleish, J.B., and Alexander, E.C., Jr., 1984, Sinkholes and sinkhole probability, plate 5 *of* Balaban, N.H., and Olsen, B.M., eds., Geologic atlas of Winona County, Minnesota: Minnesota Geological Survey County Atlas Series C-2, scale 1:100,000.

Matsch, C.L., 1976, North America and the Great Ice Age: New York, McGraw-Hill, 131 p.

Ojakangas, R.W., and Matsch, C.L., 1982, Minnesota's geology: University of Minnesota Press, 255 p.

Searle, R.N., 1977, Whitewater: The valley of promise: Minnesota Parks Foundation, Minnesota State Park Heritage Series 2, 38 p.

Bedrock Geologic Map of Whitewater State Park