Surficial Geology of Interstate State Park

Minnesota Department of Natural Resources
Division of Lands and Minerals
William C. Brice, Director

Project 336-5

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Summary of the
Geologic History of Interstate State Park

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Summary of the
Geologic History of Interstate State Park

Interstate State Park's rugged scenic beauty is to a great extent the result of the areas geologic history. The opportunity to interpret the parks geologic past has been greatly enhanced by down-cutting from the St. Croix River, which has exposed the underlying glacial and bedrock deposits. The park has experienced a complex evolution throughout its geologic history, enduring periods of volcanism (lava flows), advancing seas, glaciers, and catastrophic flooding.
A geology map of the park has been compiled here in order to gain a better understanding of the park's geology. The map is based on the study of aerial photos, topographic maps, published geologic reports and maps, and field work. The following sections describe some of the important geologic events and features that have occurred during the park's geologic history (see Table 1).

Middle Proterozoic Lava Flows
(1.1 billion years ago)

About about 1.1 billion years ago a large fracture, or rift, system developed across the central United States. This large fracture zone is known as the Midcontinent Rift System (see Figure 1). It extends from the end of Lake Erie to Kansas. Extensive volcanic activity occurred along this rift. The volcanism was not in the form of large volcanoes, but occurred primarily as fissure eruptions, where basaltic lava flowed out of long cracks in the earth's surface.

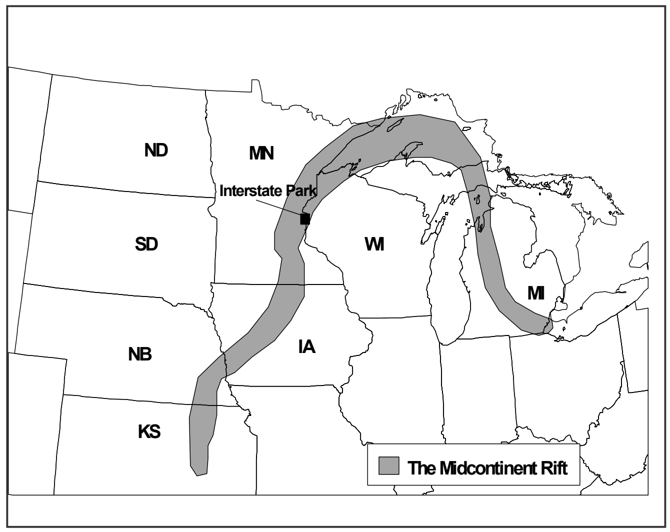

Figure 1. Generalize geologic map showing extent of the Midcontinent Rift System. Modified from Cannon and others, 2001.

Recent geophysical studies have helped scientists better understand the ancient rocks of the Midcontinent Rift. The lava flows in the Taylors Falls area consist almost entirely of basaltic lava. These flows are considered to be part of the Clam Falls Volcanics (Cannon, 2001). A total thickness of 20,000 ft. (6 km) has been estimated for the numerous flows that make up these volcanic rocks (Hall, 1901). According to Cordua (1989) the exposed flows in the Dresser-St. Croix Falls area are at least 6500 ft. (2 km) thick. Berkey (1897) recognized ten individual flows in the Taylors Falls area.

Individual lava flows within the park can be recognized by textural variations. A typical flow exhibits a relatively thin, fine-grained flow base, grading into a coarser interior. The upper-most zone or flow top often contains numerous gas cavities (vesicles) that are commonly filled with secondary minerals.

Description of volcanic map units identified within the park

The volcanic map units identified in this mapping project are based on previous geologic mapping by William Cordua (Bedrock Geology of the Dresser-St. Croix Falls Area, 1989). For mapping purposes the volcanic flows have been subdivided based on their geographic distribution and mineralogic characteristics. Map units may consist of a single flow or a group of flows. The map units were named by Cordua (1989) for exposures located in both Minnesota and Wisconsin.

The basalt flows are well exposed within the park. The flows are generally gray to greenish-gray in color, weathered surfaces vary greatly from tan, gray, green, reddish-brown, to purple. The flows are very resistant to erosion, outcropping as steep cliffs along the St. Croix River or as thinly vegetated round hills in the northern part of the park. The flows generally strike north to northeasterly and dip gently west at approximately 15 degrees. Figure 2 represents the "stair-step" topography the flows create within the St. Croix River Valley. The "stair-step" topography formed by erosion of the westerly dipping lava flows. The lava flows were extruded one on top of the other. The younger flows are found on top of the older flows.

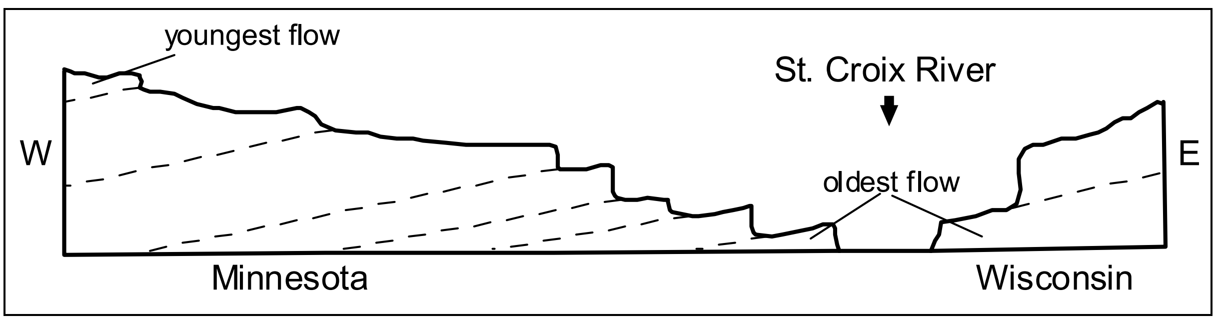

Figure 2. Generalized profile of lava flows in the St. Croix River Valley at Interstate State Parks, MN and WI. Erosion of the westerly dipping lava flows created a "stair-step" topography. The gentle west facing slopes are developed on the flow tops. Modified from Berkey, 1897.

Five distinct flow units (map unit) have been identified at Minnesota's Interstate State Park: (Flow units may consist of a single flow or a group of flows)**.**

1. The oldest flow in the park is the **Pothole trail flow (Kpt)**. This flow contains large reddish-pink to tan plagioclase crystals (phenocrysts) in a gray to greenish-gray, fine grained crystalline matrix. The large plagioclase crystals aid in identifying this unit from the overlying Dresser flows. Outcrops are exposed along the St. Croix River near the Hwy 8 bridge and boat landing. The map unit was named for exposures along the Pothole Trail in Wisconsin's Interstate State Park.

2. The next oldest flow unit is the **Dresser flows (Kd)**, which consists of a series of basaltic lava flows 30 to 40 ft. (10 to12 m) thick (Cordua, 1989). This unit is well exposed within the park and contains most of the potholes. The flow top is typically amygdaloidal (containing gas cavities filled with secondary minerals) and extensively epidotized (contains epidote, a yellowish-green mineral). The Dresser flows lack the large plagioclase crystals found in some of

the other flow units. The Dresser flows dip gently west under the younger Trap Rock Alley Flow. This map unit is named for exposures in quarries of the Dresser Trap Rock Company in Wisconsin.

3. The **Trap Rock Alley Flow (Kt)** is a single lava flow at least 115 ft. (35 m) thick (Cordua, 1989). The weathered surfaces of this flow exhibit a distinct mottled and pitted appearance. The flow is recognized by medium-grained, somewhat circular pyroxene crystals. The pyroxene weathers as lighter patches and/or pits, giving the rock a mottled and pitted appearance. This map unit is named for the exposures along Trap Rock Alley in Minnesota's Interstate State Park.

4. The **Eagle Peak flows (Kep)** overlies the Trap Rock Alley flow. Within the park three thick flows of this unit are evident. The flows contain large, tan to pink plagioclase crystals (phenocrysts) up to 2 inches (5 cm) long in a gray to greenish-gray, fine crystalline matrix. The numerous large plagioclase crystals aid in identifying this unit. This map unit is named for exposures at Eagle Peak in Wisconsin's Interstate State Park.

5. The youngest flow within the park is the **Ski Trail Flow (Ks)**. It is a single flow approximately 30 ft. (10m) thick (Cordua, 1989), exhibiting scattered, light green to pink plagioclase phenocrysts in a gray to greenish-gray, fine crystalline matrix (I did not observe augite phenocryts as mentioned in Cordua, 1989) This map unit is named for exposures in a small abandoned quarry near a major ski trail in Wisconsin's Interstate State Park.

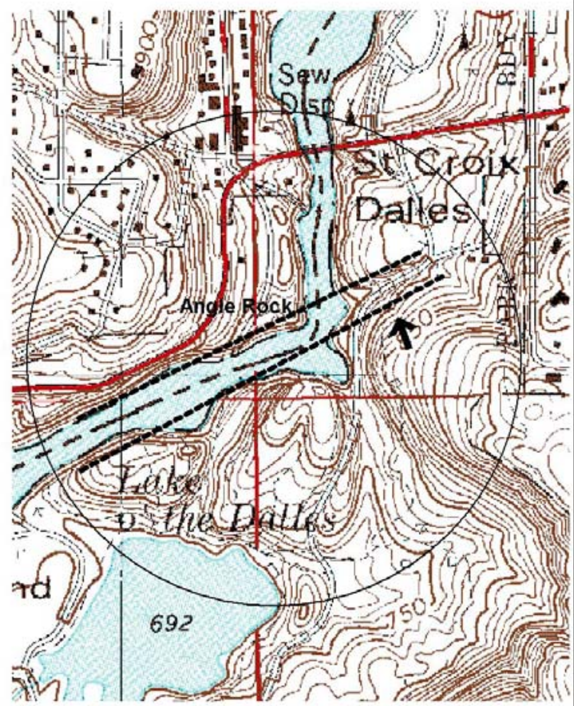

Figure 3. Fractures in the bedrock have influenced the course of the river. Parallel dashed lines represent a crevasse created by intense fracturing of the basalt. The arrow points to where the crevasse can be seen extending out of the river channel.

Joints and Fractures within the Lava Flows

Joints are fracture surfaces in the bedrock, that exhibit no horizontal or vertical displacement. In basalt, joints form as the lava cools. Lava shrinks between 5 to10 percent as it crystallizes, this shrinking causes the joints to form. A system of horizontal and vertical joint planes is well developed in the lava flows at Interstate Park. These fractures have been instrumental in the development of the present topography of the area. The jointing has influenced the course of the river as well as the development of the steep cliff faces along the dalles.

Bend in the River at Angle Rock

An example of how fractures in the bedrock have influenced the course of the St. Croix River can be seen at Angle Rock. The map in Figure 3 shows the sharp right hand turn the south flowing river takes as it flows through the steep basalt gorge. Evidence suggests that the sharp change in direction of the river is a result of fracturing in the rock that created a crevasse or a zone of weakness in the rock where the river could more easily flow. In Figure 3 the parallel dashed lines represent a crevasse created by intense fracturing, the arrow points to were the crevasse can be seen extending out of the river channel.

Steep Cliff Faces

The basalt flows erode to form steep cliffs along the dalles (the term "dalles" refers to a steep rock bound gorge). Figures 4 and 5 are intended to show how joint sets have influenced the development of the dalles steep cliff faces. The dashed lines in Figure 4 delineate a set of vertical joints. As the basalt outcrops erode, they tend to break off in large blocks along these fracture planes rather than slowly weathering away.

Thousands of years of repeated freezing and thawing of water in the fractures aids in separating the joint bound pieces away from the valley walls. Recent rock slides within the park remind us that this process still plays an important role in the forming of the gorge walls.

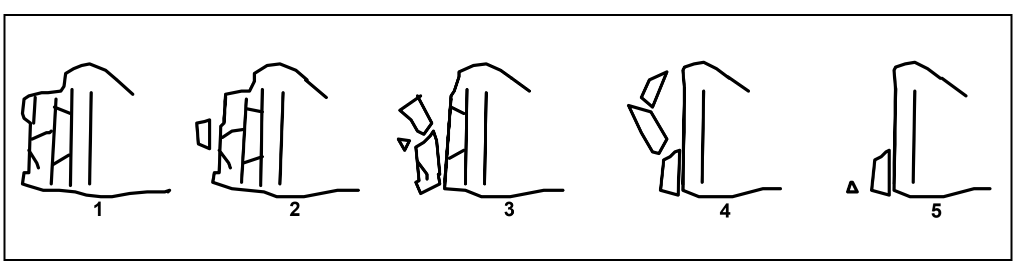

Figure 5. This diagram illustrates how fracture patterns (joints) in a rock cliff can influence the way it will erode. As the basalt erodes, joint bound pieces break off from the cliff face, while still maintaining a nearly vertical cliff face.

Cambrian Sedimentary Rocks - *Advancing Sea 550 million years ago*

During Upper Cambrian time, about 550 million years ago, a sea advanced from the south into Minnesota (figure 6). The lava flows, by this time had endured about 575 million years of weathering and erosion, and stood as irregular cliffs and as islands in the advancing sea. For millions of years, streams carried sands and fine silts into the sea from the surrounding highlands. With continued rise of sea level, the basalt cliffs and islands were gradually covered with marine sediments. Over time, the sands and silts compressed and hardened to form sandstones and shales. The Cambrian age sediments found in the park consist mainly of quartz sandstones with minor shales and local conglomerates.

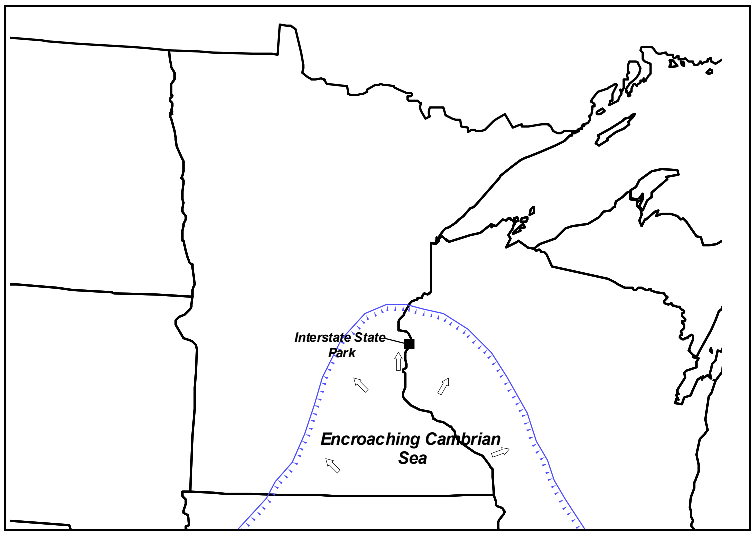

Figure 6. By late Cambrian time, about 550 million years ago, a shallow sea extended into Minnesota. Modified from Webers, 1972.

Sandstones of the Franconia Formation

The sandstones within the park are part of the Franconia Formation (see Figure 7). They outcrop in the western portion of the park as buff colored, steep faced cliffs just above Highway 8, and in the steep ravines along the Sandstone Bluffs Trail. The sandstone deposits mark where ancient beaches had once existed. Over 110 vertical feet of sandstone is exposed along the cliff faces within the park. The exposures consist primarily of fine- to medium-grained sandstone with minor amounts of shale. Local zones containing fossil fragments of trilobites and brachiopods are present. Cross-bedding is observed at many of the sandstone exposures, seen as beds of sandstone that slope down at an angle. The cross-beds were deposited as small underwater sand dunes formed by near-shore tidal currents in the Cambrian sea. The lower portion of the exposures are reported to contain the mineral glauconite. Glauconite forms on sea floors in oxygen-poor waters. The presence of specific fossils and glauconite indicate that sediments were deposited in a marine environment.

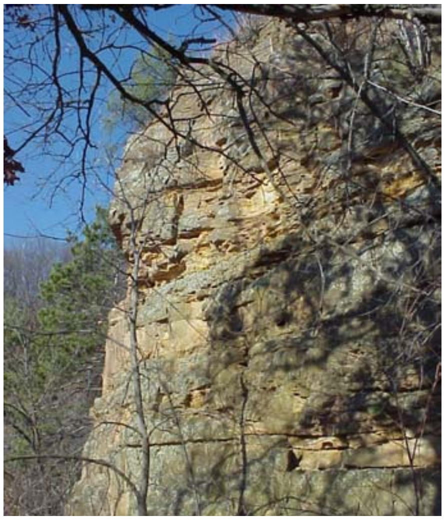

Figure 7. The sandstones of the Franconia Formation mark where ancient beaches had once existed.

Figure 8. The Mill Street Conglomerates formed at the base of wave battered cliffs in an ancient Cambrian sea approximately 550 million years ago.

Mill Street Conglomerate

Storms in the Cambrian sea generated large waves that battered the basalt coastlines. Occasionally the storm waves were of sufficient magnitude to dislodge boulders from the steep basalt cliff faces and transport them downslope into the sea. The boulders were then covered by marine beach sands. Over time the boulders and sand matrix compressed and hardened to form conglomerates.

The Mill Street Conglomerate is a coarse-grained conglomerate, composed of rounded to angular pebbles, cobbles and boulders of basalt, up to three feet in diameter, surrounded by a fine- to medium-grained matrix of quartz sandstone (see Figure 8). Fossils of trilobites, brachiopods, and monoplacophorans have been found in pockets of sandstone between the boulders. A yellowish- brown to reddish-brown, iron-rich cement helps bind the conglomerate together. Exposures of this conglomerate are of interest to geologists because there are only a few exposures in North America where Upper Cambrian conglomerates occur at the base of an Upper Cambrian sandstone, and where Upper Cambrian conglomerates lie unconformably on Precambrian-aged rocks. Within the park outcrop exposures can be seen in the S1/2 of SW1/4 of SE1/4 of section 25, just above and to the east of the old cement building foundations, and a small exposure was also observed north of the Sandstone Bluffs Trail in the large eastern ravine.

Glacial History
Late Wisconsinan (35,000 to 10,000 years ago)

Minnesota's "recent" geologic history has been marked by periodic invasions of glacial ice from Canada. The glacial sediments observed within the park were deposited during the last stage of glaciation, which lasted from 35,000 to 10,000 years ago. This period is called the Late Wisconsinan stage of the Pleistocene (Ice Age) Epoch. During this stage, individual ice lobes advanced into Minnesota from the northeast and northwest. The glacial lobes that had the greatest direct impact on the park are the Superior Lobe and the Grantsburg sublobe of the Des Moines Lobe. Earlier glaciers had covered the area but the deposits left by them have either been eroded or buried by later geologic events.

As the ice lobes advanced out of Canada they picked up rocks and debris along their flow paths and deposited these materials as they melted. Their flow paths crossed different rock types allowing the glaciers to pick up distinctive sediment loads. The glacial drift deposited by each lobe has a distinct color, texture, and stone content. The sediments and landforms left behind by the glaciers offer clues for reconstructing the glacial history of the area.

Within the park, surface exposures of glacial till are very limited. Glacial till is unsorted material deposited directly by glacial ice. During the mapping project, till deposits were primarily observed north of Highway 8. Most of the till deposits observed within the park are mantled by a veneer of sand and/or silt. Mantle thickness ranged from 1 ft. to greater than 6 ft. for sand and 1ft. to 31/2 ft. for silt. The sand mantle was deposited primarily by glacial meltwaters and the silt was deposited as wind blown sediments (loess).

Superior Lobe Glacier: (approximately 20,000 years ago)

During Late Wisconsinan time, glacial ice of the Superior lobe advanced southwestward out of Canada through the Lake Superior basin (Figure 9). As the Superior lobe advanced and then retreated from the area, it left deposits of reddish-brown sandy till. Because the Superior lobe flowed primarily over sandstones and crystalline bedrock, the texture of the till is sandy. Exposures were noted along the Sandstone Bluffs Trail below the observation bench located on the high bluff between the two large ravines (see Plate 1). Buried Superior lobe till was also observed using a soil auger in the sides of some of the ravines.

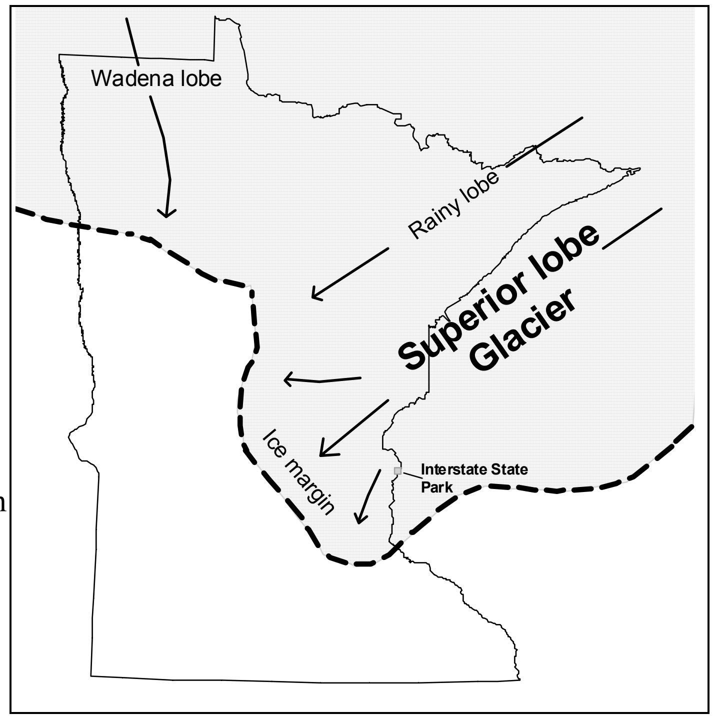

Figure 9. Ice margin of the Superior lobe glacier approximately 20,000 years ago. The Rainy and Wadena lobes are also shown. Modified from Wright, 1972.

Grantsburg Sublobe of the Des Moines Lobe Glacier: (approximately 16,000-14,000 years ago)

Following the retreat of the Superior lobe from the area, the Grantsburg sublobe advanced across the region in a northeasterly direction. The Grantsburg sublobe is an offshoot of the south flowing Des Moines lobe (Figure 10). Deposits from this lobe are typically fine textured and contain a significant volume of Paleozoic carbonates and Cretaceous shale fragments derived from North Dakota and Manitoba, Canada. No surface exposures of Granstburg till were noted during the mapping project. However, a sample of Grantsburg till was collected using a soil auger in the SW1/4 of SW1/4 of section 25 (see Plate 1). The till was mantled by two feet of silt (loess). The sample is a tan - yellowish brown, loamy till with small scattered pebbles. Carbonate and shale pebbles were noted.

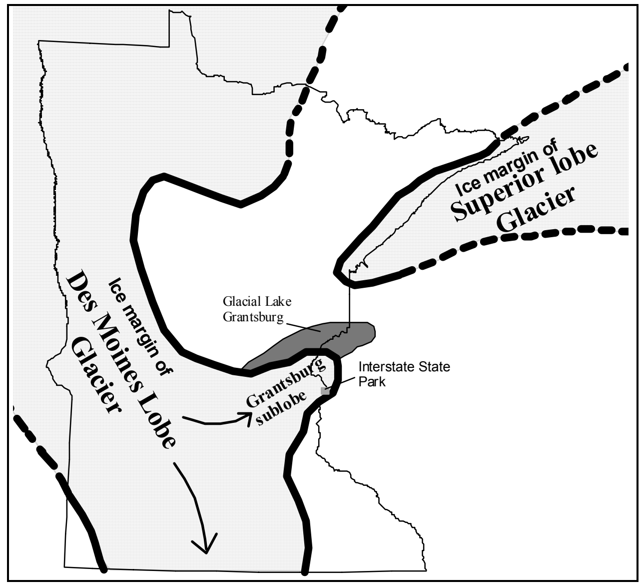

Figure 10. Ice margins of the advancing Des Moines lobe and Grantsburg sublobe and retreating Superior lobe. Glacial Lake Grantsburg formed in front of the advancing sublobe. Modified from Cooper, 1935 and Johnson and Hemstad, 1996.

Glacial Lake Grantsburg

Glacial Lake Grantsburg formed because the advancing Grantsburg sublobe dammed the southward flow of drainage into the St. Croix and Mississippi drainage system (see Figure 10). The lake was short-lived, lasting only about 100 years. Evidence for the location of the lake's drainage outlet has been difficult to find. It may have drained down the St. Croix River Valley.

Early Post Glacial Flooding (approximately 12,000 to 9,000 years ago)

The modern St. Croix River is greatly undersized in comparison to the large valley it occupies. The large river valley formed in early post glacial time (when the glacial lobes had retreated north of the park), approximately 12,000 to 9,000 years ago. The valley (spillway channel) formed when Glacial Lake Duluth overflowed it's basin sending tremendous amounts of water down the St. Croix River (see Figure 11). The erosive power of the ancestral St. Croix River is dramatically displayed within the park.

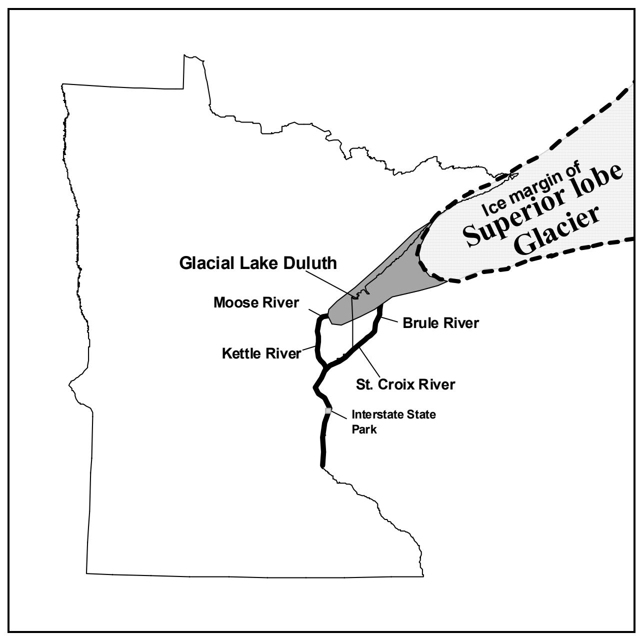

Figure 11. The St. Croix River valley formed when Glacial Lake Duluth overflowed it's basin sending tremendous amounts of water down the St. Croix River.

St. Croix River Valley (Spillway Channel of Glacial Lake Duluth)

As the Superior lobe retreated into the Lake Superior basin, water began to pond up in front of it, progressively growing into a large glacial lake. Glacial Lake Duluth, the ancestor of Lake Superior, stood about 500 feet above the present lake level. As the glacial lake rose, it overtopped its basin and drained through various outlets. The outlet streams quickly became huge, powerfully erosive rivers. In Minnesota, drainage was through the Moose River (or Portage spillway) which flowed into the St. Croix River via the Kettle River. In Wisconsin, outlet discharge occurred through the Brule River (Brule spillway) which then flowed into the St. Croix River. The Brule (or St. Croix) spillway handled the majority of drainage from Glacial Lake Duluth until new outlets to the east were uncovered as the glacier retreated further into the Lake Superior Basin (Figure 11).

Flooding from Glacial Lake Duluth sent tremendous amounts of water through the St. Croix River spillway. Maximum discharge rates for the St. Croix River spillway have been estimated to fall between 494,340 to 971,025 cubic feet/second (Carney, 1996).

Major Erosional Features

The erosive power of the ancestral St. Croix River is dramatically displayed within the park. Imagine the size and power of the river that once scoured over the park, carving out the steep gorge walls and spectacular potholes that are now left abandoned high above the present river.

St. Croix Dalles - Basalt Bound Gorge

The nature of the bedrock influenced the morphology of the St. Croix River valley. In the Taylors Falls area, the powerful flood waters cut through the soft glacial and Cambrian sediments and ultimately into the hard basalt flows. In order for the river to erode a deep gorge into the resistant basalt, it must have encountered a zone of weakness within the basalt. This erodible zone was probably an area of highly fractured bedrock, created by intense jointing or faulting. The surrounding less fractured basalt, being more resistant to erosion, confined the river to a deep, narrow, rock bound gorge. Above and below the Dalles the river valley is wider because the flood waters were not confined by the resistant basalt.

Potholes

The potholes formed when the turbulent, high-velocity flood waters from Glacial Lake Duluth, scoured over the park. Pebbles, cobbles, and boulders became trapped in depressions on the channel floor and were swirled around by the high velocity waters. The abrasive action of the swirling stones cut the potholes into the hard basalt (see Figure 12). The number of potholes within the park has been reported to be over a hundred. The potholes vary in size from a few inches to over twenty-five feet wide, with depths from less than an inch to greater than sixty feet. The potholes are thought to be some of the deepest in the world. The majority of the potholes are formed on the Dresser Basalt flows.

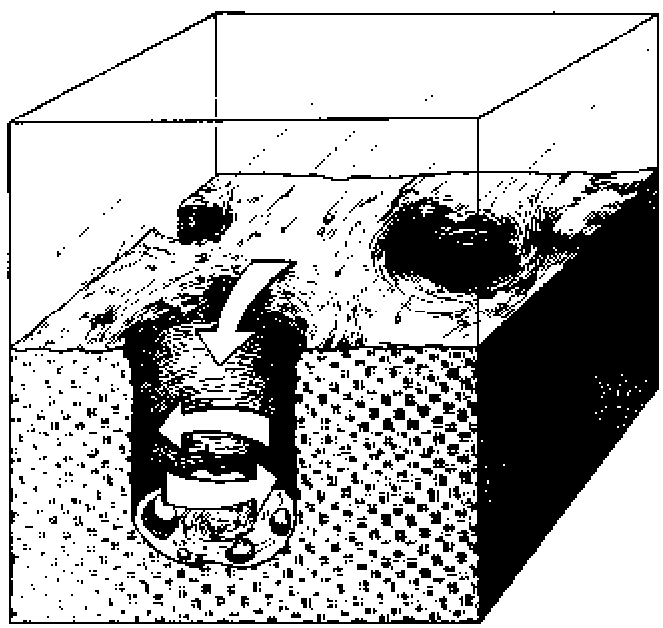

Figure 12. The abrasion action of swirling pebbles and boulders cut the potholes into the hard basalt. Diagram from Ojakangas and Matsch, 1982.

Curtain Falls

In the western portion of the park just north of the highway are a series of narrow, steep-sided ravines confined by impressive sandstone cliffs (Figure 13). The Curtain Falls hiking trail traverses through the two largest ravines. About 110 vertical feet of Fanconia Formation sandstone is exposed along the trail leading to Curtain Falls. Rock fragments which dislodged from the cliff faces (talus) now lay at the base of many of the cliffs. Colluvium deposits, composed of materials that have slumped from the overlying glacial deposits, are commonly found at the base and/or sides of the ravines. Curtain Falls is dry most of the year, flowing mainly after large rainstorms and during the spring melt. Thousands of years of erosion has been required to carve out the steep sandstone walled ravines.

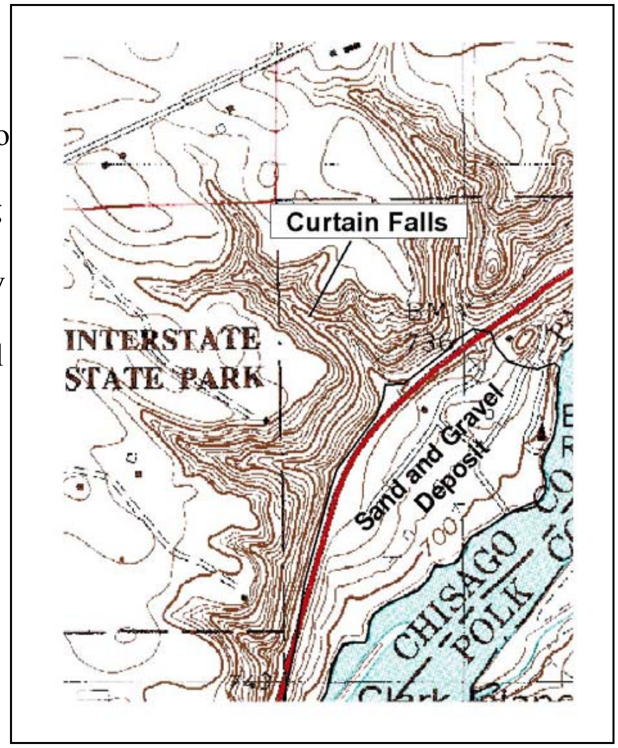

Figure 4. The trail leading to Curtain Falls winds through narrow, steep-sided ravines that are confined by impressive sandstone cliffs. A deposit of sand and gravel is found near the mouths of the ravines.

Sand and Gravel Deposit

A gently southeasterly sloping deposit of sand and gravel is found near the mouths of the above-mentioned ravines. The deposit continues across the highway underlying the park headquarters and campground area (Figure 13). This feature appears to be comprised of coalesced alluvial fans overlying an older stream terrace. The fans were possibly deposited by the streams that formed the ravines. The stream terrace was created during flooding from Glacial Lake Duluth. The terrace represents a former river-bed deposit that has been dissected and left abandoned by further down-cutting from the river. The deposit contains Superior provenance materials with locally derived pebbles, and cobbles of basalt and sandstone.

Erosion and depositional processes continue to take place in the park, but at a much gentler rate in comparison to the past. Streams continue to erode, transport and deposit sediments, and occasionally a block of basalt or sandstone will dislodge from its cliff face and fall to the ground below.

Table 1. Summary of the geologic events impacting Interstate State Park.

AGE (approximate)	EVENT	DEPOSIT or SEDIMENT	LANDFORM or EXPOSURE (found in or near park)
Holocene Epoch of the Quaternary Period 9,000 years ago to present	Wind blown sediments	Loess (silt)	Silt mantle over till
	Flooding of modern rivers	Alluvium (silt to gravel)	Flood plain
	Stream erosion and deposition	Sand and gravel	Alluvial fan
	Stream erosion	Erosional landforms	Narrow, steep-sided ravines confined by sandstone cliffs
Pleistocene Epoch of the Quaternary Period (Ice Age)			
Sometime between 12,000 to 9,000 years ago	Flooding from Glacial Lake Duluth	Erosional landforms and features	Abandoned spillway channels, steep gorge, potholes
"	Flooding from Glacial Lake Duluth	Silt, ,sand and gravel	Stream terraces
Sometime between 16,000 to 14,000 years ago	Advance and retreat of Grantsburg sublobe	Tan to yellowish-brown, loamy till	Till plain (mantled by sand and/ or silt in park)
Sometime between 18,000 to 15,000 years ago	Superior lobe has retreated north of the park		
Around 20,000 years ago	Superior lobe advanced into central MN	Red sandy till	Till plain, generally mantled by sand and/or silt in park
Upper Cambrian Period Approximately 550 million years ago	Waves battering basalt cliffs during major storms in the Cambrian Sea	Conglomerate (Mill Street Conglomerate)	Conglomerate outcrops
	Advancing Cambrian Sea	Sandstone and shale (Franconia Formation)	Sandstone outcrops
Middle Proterozoic 1.1 billion years ago	Continental rifting (lava flows)	Basalt - lava flows (Clam Falls Volcanics)	Basalt outcrops

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