# Summary of the Geologic History of St. Croix State Park

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**1997**

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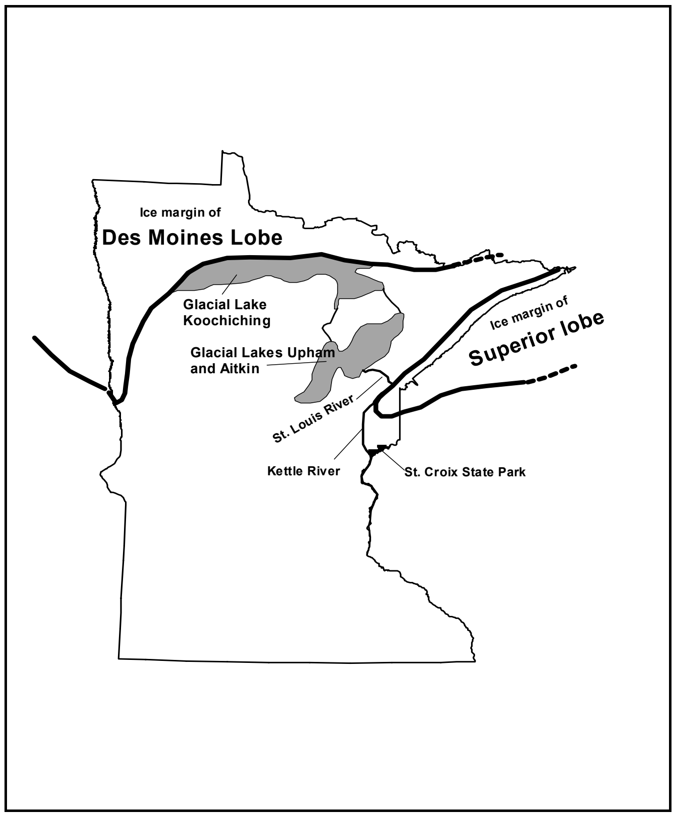
A surficial geology map of St. Croix State Park has been compiled in order to gain a better understanding of the park's geology. The map is based on the study of aerial photos, topographic maps, well logs, published geologic reports and maps, and field work. The geology of St. Croix State Park has experienced a complex evolution throughout its history, enduring periods of volcanism (lava flows), intense weathering, glaciers, glacial lakes, and catastrophic flooding. The following sections describe some of the important geologic events and features that have occurred during the park's geologic history (see Table 1).

## Early Postglacial Flooding *(approximately 12,000 to 8,000 years ago)*

Glaciers played an important role in shaping the landscape of St. Croix State Park, but the power of flowing water probably played the greatest role in forming the current landscape of the park. St. Croix State Park is located at the confluence of two large river valleys, the Kettle River valley and the St. Croix River valley. These valleys formed in early postglacial time (glacial lobes had retreated north of the park), approximately 12,000 to 8,000 years ago. The valleys (spillway channels) were carved out by huge, powerful rivers that drained from vast glacial lakes. The erosive power of these rivers is dramatically displayed within the park. Imagine the size and power of the rivers that once scoured over much of the park, carving out large channels that are now left abandoned above the present Kettle and St. Croix Rivers. The modern Kettle and St. Croix Rivers are greatly undersized in comparison to the large valleys they occupy.




### *Kettle River Spillway*

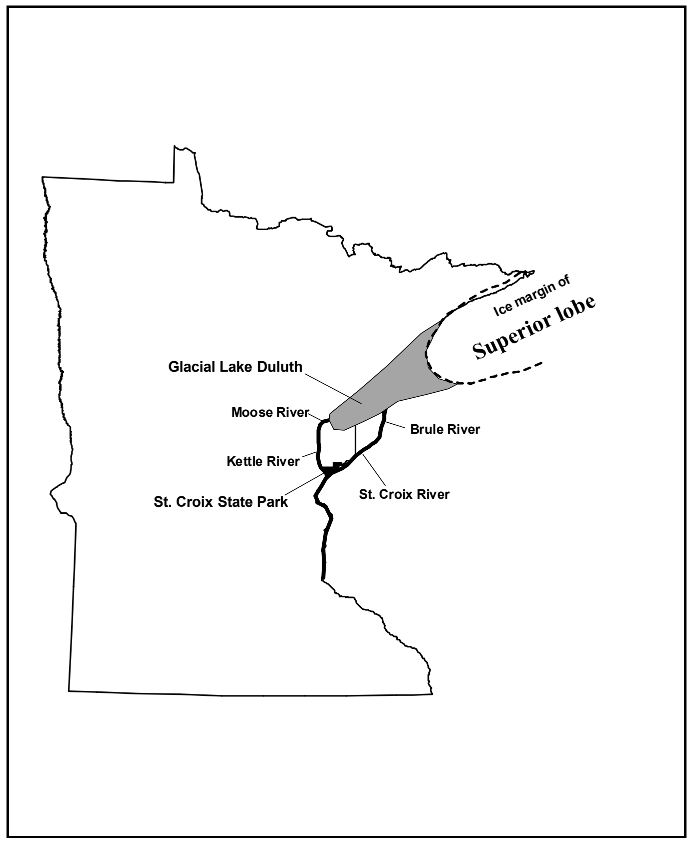
The Kettle River spillway formed earlier than the St. Croix River spillway. The Kettle River valley was carved out by drainage from Glacial Lake Koochiching (the eastern arm of Glacial Lake Agassiz which formed in front of the retreating Des Moines lobe). Catastrophic flooding from Lake Koochiching flowed southeast through glacial Lakes Upham and Aitkin, then south down the St. Louis River, along the margin of the

Superior lobe, entering the Kettle River near Moose Lake, Minnesota (Hobbs, 1983) (see Figure 1). The Kettle River then flows into the St. Croix River which flows into the Mississippi River and eventually into the Gulf of Mexico. The Kettle River spillway was used again by flood waters draining from Glacial Lake Duluth.

The flooding from glacial lakes sent tremendous amounts of water through the Kettle River spillway. Maximum discharge rates for the Kettle River spillway have been estimated to fall between 423,720 to 617,925 cubic feet/second (Carney, 1996). Between 1985 to 1996, the average maximum peak discharge rate for the Kettle River (recorded below Sandstone, MN) was 6178 cubic feet/second (Mitton, Wakeman and Guttormson, 1997).

### *St. Croix River Spillway*

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, an 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 (see Figure 2).




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). Between 1985 to1994, the average maximum peak discharge rate for the St. Croix River (recorded at Danbury, WI, before the Kettle River enters the St. Croix River) was 4478 cubic feet/second (Mitton, Wakeman and Guttormson, 1997).

### *Abandoned Channel Features*

Evidence for the spillway flooding within the park include: abandoned channel escarpments (long, steep-faced slopes) that represent abandoned channel banks eroded into underlying deposits; boulder strewn terraces that are interpreted to be abandoned channel floors; and channel side boulder lag deposits which are accumulations of boulders formed by the eroding action of past currents that carried the finer materials away. These features offer clues for reconstructing glacial stream courses and channel geometry (see Figure 3).

Erosional and depositional processes are still taking place along the rivers and streams within the park, but at a gentle rate in comparison to the past.

## Peat Development

Peat is an organic deposit consisting of dead and partially decomposed plant material. It accumulates where conditions inhibit the decomposition of plant material, such as wetlands. Many of the abandoned channels are now marked with deposits of peat. The channels which exhibit poor drainage are well suited for the development of peat.

## Glacial History

St. Croix State Park's "recent" geologic history has been marked by scouring flood waters, glacial lakes and invading glaciers. Most of the glacial sediments found 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. The Grantsburg sublobe did not quite reach the park, but the glacial lake that formed in front of it did cover the area. The glacial lobe that had the greatest direct impact on the park is the Superior lobe, that advanced out of Canada through the Lake Superior basin. Deposits of till, lake sediment, and outwash can be attributed to this glacial lobe. An exposure of an older glacial till provides the evidence for an earlier (pre-Wisconsinan) period of glaciation, possibly greater than 75,000 years old. The sediments and landforms left behind by the glaciers offer clues for reconstructing their past history.

### *Late Wisconsinan (35,000 to 10,000 years ago)*

### *Superior Lobe Till: (approximately 25,000 to 18,000 years ago)*

During Late Wisconsinan time, glacial ice of the Superior lobe advanced southwestward out of Canada through the Lake Superior basin. As the Superior lobe advanced and then retreated from the area, it left deposits of reddish-brown sandy till. Till is unsorted material directly deposited

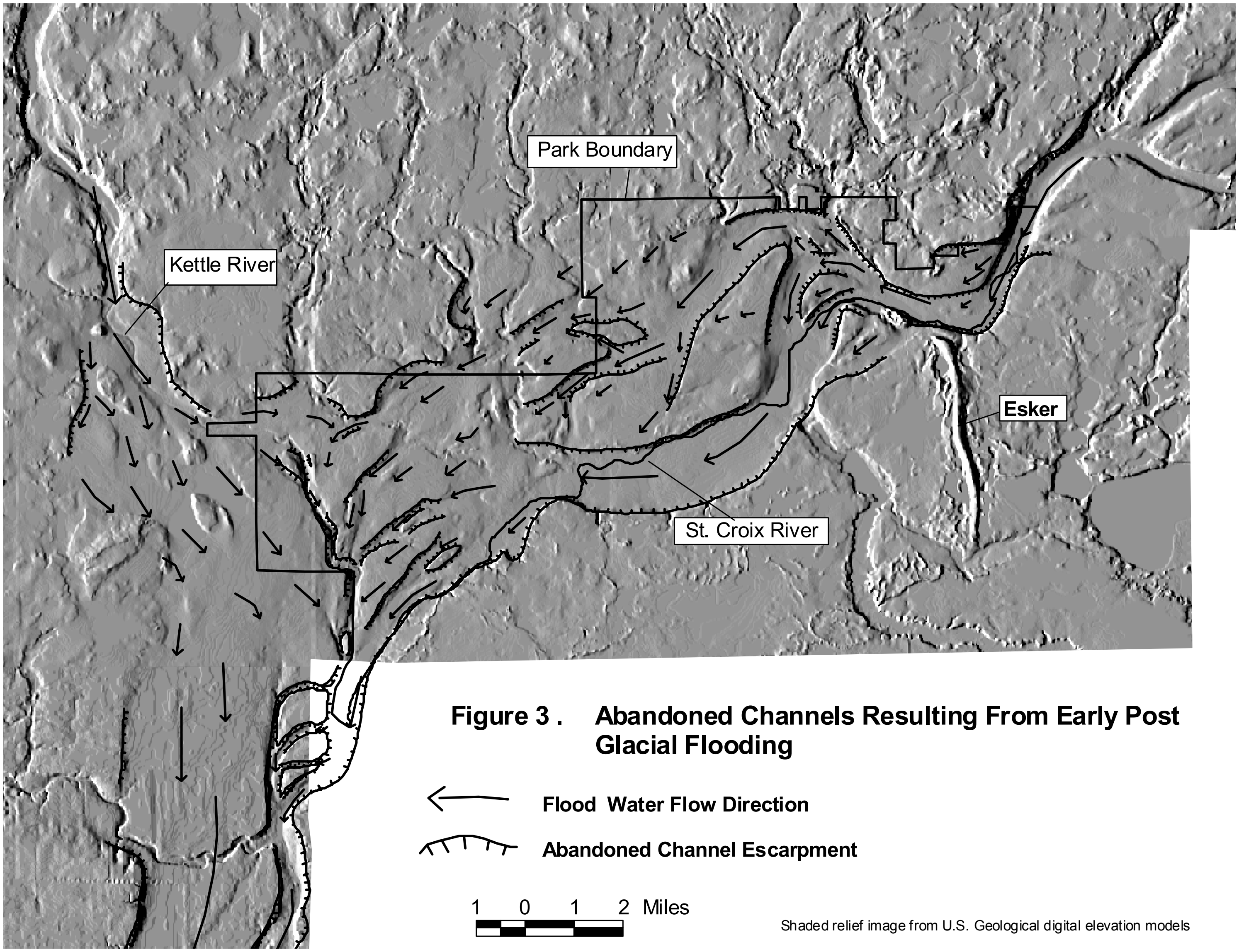



**Figure 3 . Abandoned Channels Resulting From Early Post Glacial Flooding**

Shaded relief image from U.S. Geological digital elevation models by glacial ice. Because the Superior lobe flowed primarily over sandstones and crystalline bedrock, the texture of the till is sandy. Surface exposures of till within the park are limited. Local exposures of till are present within the spillways, but they are generally mantled by a thin veneer of sand to cobbly gravel, or a lag of boulders.

### *Ice Stagnation Features: (approximately 20,000 to 18,000 years ago)*

The ice-contact sand and gravel deposits, esker and kame-like landforms, and ice stagnation moraine suggest that during the retreat of the Superior lobe, the ice margin stabilized in the area long enough to deposit the sediments that form these features.

The ice-contact sand and gravel deposits, found along the northeastern border of the park, appear to be associated with a north-south trending tunnel valley that extends north of the park. The tunnel valley now contains a string of lakes. Tunnel valleys are relatively straight trench-like features that formed as drainage channels at the base of a glacier.

Eskers form where meltwater streams have cut tunnels or channels in a stagnant melting glacier, resulting in ridges of sand and gravel when the ice melts. Kames are conical-shaped hills, composed of sand and gravel deposited by meltwater into holes or depressions on the surface of a stagnant melting glacier. The esker-like ridges within the St. Croix spillway channel may have possibly connected the large north-south tending esker south of the park to the smaller eskers north of the park. It is also possible that the esker and kame-like ridges are not true eskers or kames, but were shaped by flood waters from Glacial Lake Duluth.

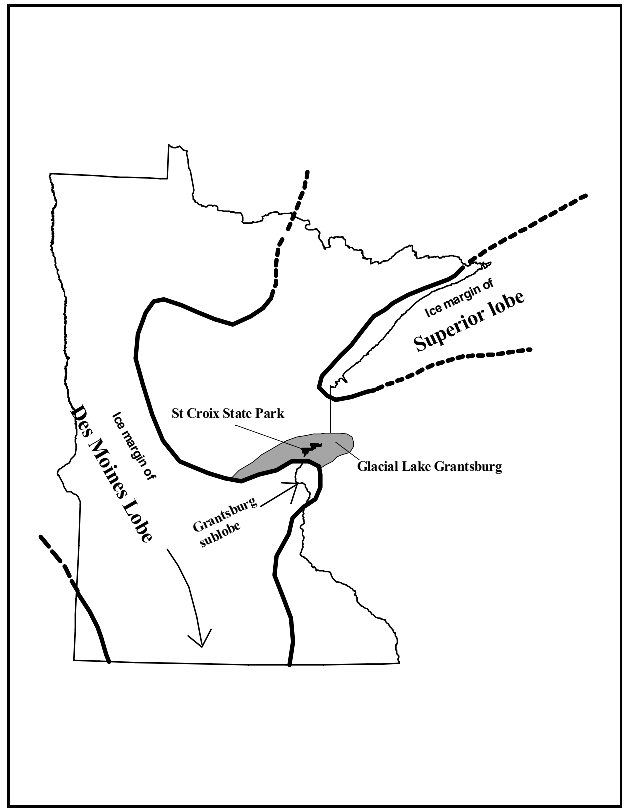
### *Superior Lobe Outwash: (approximately 18,000 to 10,000 years ago)*

As the Superior lobe melted back from the area, sediment rich meltwater streams flowed out from the margins of the retreating glacier and into the ice-abandoned St. Croix River lowland. The meltwater streams transported and deposited sands and gravels into the area, creating broad gently sloping outwash plains. The St. Croix and Kettle Rivers have entrenched themselves below the general level of the outwash plains.

Pitted and collapsed outwash deposits provide evidence that detached blocks of Superior lobe ice persisted in the area after the glacial lobe had retreated to the northeast. Outwash deposits become pitted or collapsed when buried blocks of ice melt allowing the overlying sediments to collapse into the areas the ice once occupied.

### *Glacial Lake Grantsburg: (approximately 16,000 to 14,000 years ago)*

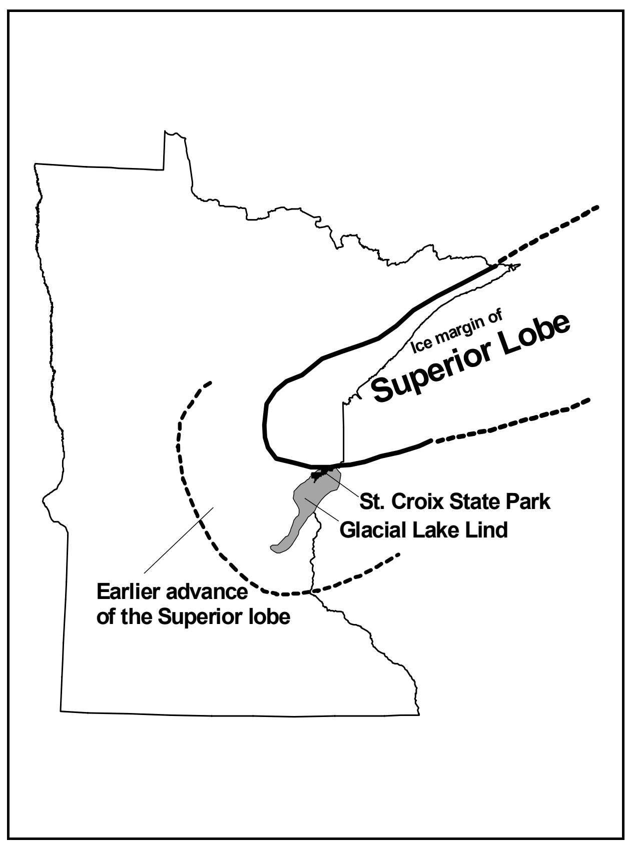
Following the retreat of the Superior lobe from the area, the Grantsburg sublobe advanced in a northeasterly direction to just south of the park (see Figure 4). Glacial Lake Grantsburg formed because the advancing Grantsburg sublobe dammed the southward flow of drainage into the St. Croix and Mississippi River drainage system. The lake was short lived lasting only about 100 years, somewhere between 16,000 to 14,000 years ago. A thin patchy distribution of its sediments is found in east-central Minnesota.




Gray varved silt and clay deposits associated with Glacial Lake Grantsburg have been identified near the park (Johnson and Hemstad, 1996). Glacial lake varves represent seasonally deposited sediment which normally include a coarser-grained "summer layer" and a finer-grained "winter layer". Few sediments within the park can confidently be assigned to the lake. A six inch layer of gray clay buried by a couple feet of sand was observed along the northern border of the park. This clay layer may very well have been deposited in Glacial Lake Grantsburg. The silt mantle overlying the Superior lobe outwash, along the northern border of the park, may also be a deposit from Glacial Lake Grantsburg. The silt layer is similar to sediments that were interpreted as Lake Grantsburg sediments by Cooper in 1935. However, the exact origin of these silts is difficult to determine. They could have also been deposited as wind blown sediments (loess) or as silts from overbank flooding when Glacial Lake Duluth drained.

### *Glacial Lake Lind: (approximately 18,000 to 15,000 years ago)*

Glacial Lake Lind formed as meltwaters became ponded up in front of the retreating Superior lobe (Johnson and Hemstad, 1996) (see Figure 5). The lake is estimated to have existed for approximately 1000 to 1500 years, sometime between 18,000 to 15,000 years ago. The lake's existence can be recognized by red varved lake sediments. Glacial Lake Lind sediments consist of alternating layers of red clay (winter layer) and brown silty clay (summer layer), presumably deposited in seasonal pairs (varves). The exposures within the park are overlain by a deposit of sand. Springs discharging



at the base of the sand expose the underlying lake clays. Water easily percolates through the sand but when it reaches the less permeable clay it moves laterally and forms springs. The clay deposits are located a few feet above the river level of the St. Croix. The lake basin of Glacial Lake Lind was eventually filled in with outwash sands from the Superior lobe.

### Older Till *(Pre-Wisconsinan - possibly greater than 75,000 years old)*

An exposure of an older glacial till (pre-Wisconsinan) provides the evidence for an earlier period of glaciation, possibly greater than 75,000 years old. The old till is observed near the north end of "High Banks" on the east side of the Kettle River. It is rare for older tills of this age to be exposed at the surface in this part of the state. There is not a lot known about the history of pre-Wisconsinan age glacial deposits, because they have been either eroded or buried by younger glaciers. The till is very different in color and texture than the younger red, sandy tills deposited in the region during Late Wisconsinan time. Its dark gray color and fine loamy texture appear to be similar to older glacial tills identified in Wisconsin (J. Attig, L. Clayton, and Mickelson (editors), 1988).

The pre-Wisconsinan age glaciers were probably responsible for removing much of the intensely weathered bedrock (clay-rich saprolite) that had formed in the area prior to glaciation. The fine texture of this till is probably the result of saprolite (clay-rich, thoroughly weathered bedrock) being incorporated into the sediment lode of the glacier that deposited it.

### Intense Weathering

An exposure, at the north side of "High Banks" along the east side of the Kettle River, displays basalt weathering directly into a yellow brown "tooth paste" consistency clay (saprolite). The basalt must have been exposed to a long period of weathering in order for it to be transformed into this soft clayey material. For some reason this soft, easily erodible clay has survived the erosional forces of past glaciers.

### Bedrock: Middle Proterozoic Basalt and Sedimentary Rocks *(1.1 billion years ago)*

Down-cutting from the Kettle and St. Croix Rivers has exposed bedrock in a few places within the park. The bedrock consists of basalt, conglomerates and sandstones.

#### *Volcanic Rocks (basalt)*

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. It extends from the eastern end of Lake Superior to around 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. The lava flows found in the St. Croix Valley are referred to as the Chengwatana Volcanic Group. A total thickness of 20,000 feet has been estimated for the numerous flows that make up the Chengwatana Volcanic Group (Hall, 1901). Individual basalt flows are characterized by a massive central zone and an upper (flow top) zone containing numerous gas cavities that have been filled with secondary minerals.

### *Interflow Sediments (conglomerates and sandstones)*

Sedimentary rocks consisting of conglomerates with minor amounts of sandstones are also found in the park. A conglomerate is a coarse-grained sedimentary rock, composed of rounded to subangular pebbles, cobbles, and boulders set in a fine-grained matrix of sand and/or silt. Pauses between lava flows allowed streams to erode, transport, and deposit pebbles, cobbles and boulders on the volcanic surface. When the volcanic activity resumed, the sediments were then buried by the next lava flow.

Stream erosion has cut through the overlying glacial sediments to expose these ancient basalt, conglomerates and sandstones. Outcrop exposures are found along the Kettle River and, to a lesser extent, the St. Croix River.

## Acknowledgements

Thanks to the following individuals for providing helpful comments during the field review of this project: Mark Johnson (Gustavus Adolphus College), Charley Matsch (U of MN-Duluth) and J.D. Lehr (MN DNR)

G.B Morey (MN Geological Survey) for providing helpful comments about the interflow sediments of the Chengwatana Volcanic Group.

**Table 1.** Summary of the geologic events impacting St. Croix State Park.

| AGE (approximate) | EVENT | DEPOSIT | LANDFORM or EXPOSURE (found in or near park) |
|---|---|---|---|
| **Holocene** (recent) 10,000 years ago to present | "Modern" rivers | Alluvium (silt to gravel) | Channel and point bars |
| | Change in climate to end ice age (establishment of plant communities) | Peat | Wetlands in abandoned channels |
| **Pleistocene ( Ice Age) Late Wisconsinan** | | | |
| Sometime between 12,000 to 8,000 years ago | Flooding from Glacial Lakes Duluth, Koochiching, Aitkin and Upham | Sand and gravel, boulder lag | Abandoned spillway channels, boulder strewn terraces, streamlined hills |
| Sometime between 14,000 to 10,000 years ago | ?? Windstorms (loess), or Glacial Lake Grantsburg, or overbank flooding from Glacial Lake Duluth ?? | Silt mantle | Silt mantle 6 inches to 3 feet thick (along northern border of park) |
| 16,000 to 14,000 years ago | Glacial Lake Grantsburg (advance of Grantsburg sublobe to just south of the park) | Silts and gray clays | Silt mantle?, gray clay (buried by a few feet of sand along northern border of park) |
| 15,000 to 10,000 years ago | Continued Retreat of Superior lobe | Sands and gravel | Outwash plains, outwash channels |
| Sometime between 18,000 to 15,000 years ago | Glacial Lake Lind (Superior lobe has retreated north of the park) | Red/brown varved lake sediments | Lake sediments exposed by flowing springs along the St. Croix River |
| Sometime between 20,000 to 18,000 years ago | Progressive retreat of Superior lobe | Sand and gravel, red sandy till | Ice-stagnation moraines, eskers, kames, tunnel valleys |
| Around 20,000 years ago | Superior lobe advanced into central MN | Red sandy till | Small exposure along bank of Kettle River, local exposures mantled by fluvial sediments |
| **Pleistocene ( Ice Age) Pre-Wisconsinan** greater than 75,000 years | Glacial advance (little is known about this older glacial advance) | Dark-gray, fine textured till | Small exposure along bank of Kettle River |
| Sometime between 1.1 billion to 2.5 million years ago | Intense weathering of bedrock | Saprolite (clay-rich thoroughly weathered bedrock ) | Small exposure along bank of Kettle River |
| **Middle Proterozoic** 1.1 billion years ago | Continental rifting (lava flows) | Basalt (lava) | Small outcrop exposures along Kettle and St. Croix Rivers |
| | Stream erosion and deposition (between lava flows) | Conglomerates and sandstones | " " |

## Bibliography


Attig, J.W., Clayton, Lee, and Mickelson, D.M., 1988, Pleistocene stratigraphic units of Wisconsin 1984-87: Wisconsin Geological and Natural History Survey Information Circular 62.

Carney, S.J., 1996, Paleohydrology of the Western Outlets of Glacial Lake Duluth [M.S. thesis]: University of Minnesota-Duluth.

Cavaleri, M.C., Mossler, J.H., and Webers, G.F., The Geology of the St. Croix River Valley: in Balaban, N.H., ed., Field Trip Guide for the Upper Mississippi Valley: Minnesota Geological Survey Guidebook Series No. 15. p. 23-43.

Chamberlin, R.T., 1905, The glacial features of the St. Croix Dalles region: Journal of Geology, v. 13, p. 238-256.

Clayton Lee., 1983, Chronology of Lake Agassiz Drainage into Lake Superior: in Teller, T.J. , and Clayton, L., eds., Glacial Lake Agassiz: Geological Association of Canada Special Paper 26, p.291-307.

Clayton Lee., 1984, Pleistocene Geology of the Superior Region, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 46, 19 p.

Cooper, W.S., 1935, The History of the upper Mississippi River in late Wisconsin and postglacial time: Minnesota Geological Survey Bulletin 26, 116 p.

Fedkenheuer, A.W., 1975, Past and present forest communities of St. Croix State Park, Minnnesota and their use in determining ecomanagement direction [Ph.D. thesis]: University of Minnesota.

Harris, M.J., 1952, Geology of St. Croix State Park: The Conservation Volunteer, July-August (vol. XV Number 88) p. 41-46.

Hobbs, H.C., 1983, Drainage relationships of Glacial Lakes Aitkin and Upham and early Lake Agassiz in northeastern Minnesota: in Teller, T.J. , and Clayton, L., eds., Glacial lake Agassiz: Geological Association of Canada Special Paper 26, p. 245 - 259.

Hobbs, H.C., and Goebel, J.E., 1982, Geologic map of Minnesota, Quaternary geology: Minnesota Geological Survey State Map Series S-1, scale 1:500,000.

Johnson, M.D., and Hemstad, Chris, in press, New observations about Glacial Lake Grantsburg, submitted to Minnesota Geological Survey, February 26, 1996.

Kehew, A.E., and Lord, M.L., 1986 Origin and large scale erosional features of glacial-lake spillways in the northern Great Plains: Geological Society of America Bulletin:, v. 97, p. 162-177.

Lord, M.L., and Kehew, A.E., 1987, Sedimentology and paleohyrology of glacial-lake outburst deposits in southeastern Saskatchewan and northwestern North Dakota: Geological Society of America Bulletin volume. 99, p. 663-673

Mitton,G.B., Wakeman, E.S., and Guttormson, K.G., 1997, Water Data Report MN-96-1: United States Geological Survey,

Mooers, H.D., Sharkey, John, Madigan, T.M., and Partch, G.M., 1996, Geomorphology of Northern Minnesota, Digital coverage: Minnesotat Department of Natural Resource - Division of Forestry.

O'Connor, J.E., 1993, Hydrology, hydraulics, and geomorphology of the Bonneville flood: Geological Society of America, Special Paper 274, 83 p.

Teller, J.T., and Thorleifson, L.H., 1983, The Lake Agassiz-Lake Superior connection, in Teller, T.J. , and Clayton, L., eds., Glacial lake Agassiz: Geological Association of Canada Special Paper 26, p.262-290.

Teller, J.T., 1987, Proglacial lakes and the southern margin of the Laurentide Ice Sheet, in Ruddiman, W.F., and Wright, H.E., JR., eds., North America and adjacent oceans during the last deglaciation: Geological Society of America, The Geology of North America, v. K-3, p.39-69.

U.S. Geological Survey, Water Resource Division, Monitoring well log data.

Wirth, K.R., Vervoort, J.D., and Naiman, Z.J., 1997, The Chengwatana Volcanics, Wisconsin and Minnesota: petrogenesis of the southernmost volcanic rocks exposed in the Midcontinent rift: Canadian Journal of Earth Science v 34, p. 536-548.

Wright, H.E., 1990, Geologic History of Minnesota Rivers: Minnesota Geological Survey, Educational Series 7, 20 pp.

Wright, H.E., 1972, Quaternary History of Minnesota, in Sims, P.K., and Morey, G.B., eds. Geology of Minnesota: A Centennial volume. Minnesota Geological Survey, p. 515-547.