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AN EVALUATION OF SURFICIAL GEOLOGY AND PEAT RESOURCES

S.W. St. Louis County, Minnesota

By Morris T. Eng

Legend: Surficial Geology

D	Drumlin — An elongated landform pattern constructed of bouldery yellowish-brown to dark reddish-brown till of the Rainy Lobe.
EM-R	End Moraine of red colored sandy till deposited by the Superior Lobe.
GM-R	Ground Moraine of the Superior Lobe composed of reddish-brown sandy till.
MO-G/R	Moraine overlap where the St. Louis Sublobe has overridden and blended its gray till with older red tills. Contains end moraines of variably colored dark to reddish brown calcareous till deposited over sandy red tills of the Superior and Rainy Lobes.
GM-G	Ground Moraine of the St. Louis Sublobe composed of light buff to brownish-red calcareous till.
GM-L	Ground Moraine of the St. Louis Sublobe that is lakewashed.
AM-L	Ablation Moraine — Lakewashed stagnant ice features deposited by the St. Louis Sublobe containing a complex pattern of landforms and channels. Contains variably colored buff to brown calcareous till and alluvial soils.
OS-S	Off Shore Sand — shallow deposits of fine sand deposited by the St. Louis Sublobe into the littoral zone of glacial Lake Upham. Later reworked by wind during a low water phase.
LBS	Lake Bottom Sediments of glacial Lake Upham containing fine grained laminated soils of silt, clay and fine sand.
AL	Undifferentiated alluvial soils deposited by post glacial streams.

SAND AND GRAVEL DEPOSITS

K	Kame - a prominent hill or series of hills of sand and gravel deposited by water flowing into crevasses or holes in the ice near the front of the glacier. Complex deposits are not outlined.
E	Esker - a ridge of sand and gravel deposited in the channel of former glacial streams flowing within or under the ice.
IC	Undifferentiated ice contact gravel deposits, or denotes ice contact slope.
GO	Glacial Outwash - a broad plain of sand and gravel usually deposited by several coexistent meltwater streams which have transported gravel some distance beyond the front of the glacier.
T	Terrace formed by downcutting of existing streams through glacial valley train deposits of sand, gravel or glacial till.
B	Shoreline Beach deposits of glacial Lake Upham. Usually contains shallow deposits of sand and gravel.

PEAT DEPOSITS

Raised bog pattern formed bylines of black spruce radiating outward from a central point. Representative of sphagnum peat deposits and local watershed divides in a bog.

Ribbed fen pattern caused by the selective growth of trees and grasses on a peat bog. Reflects the path of drainage from the bog to local streams. Usually contains reed-sedge peat.

A heavily forested bog usually of black spruce, tamarack, or white cedar. Contains reed-sedge or woody-fibrous peat.

— — — Trace of a wave cut shoreline or an indistinct boundary.

········· Trace of a braided stream channel system.

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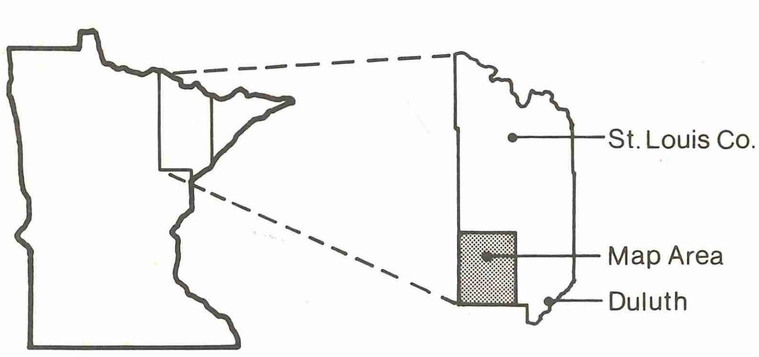

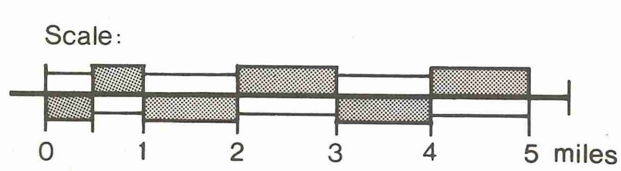

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Minnesota Department of Natural Resources
Bureau of Engineering

Produced by
Minnesota Department of Natural Resources
Division of Minerals,
Box 45
Centennial Office Building
St. Paul, Minnesota 55155

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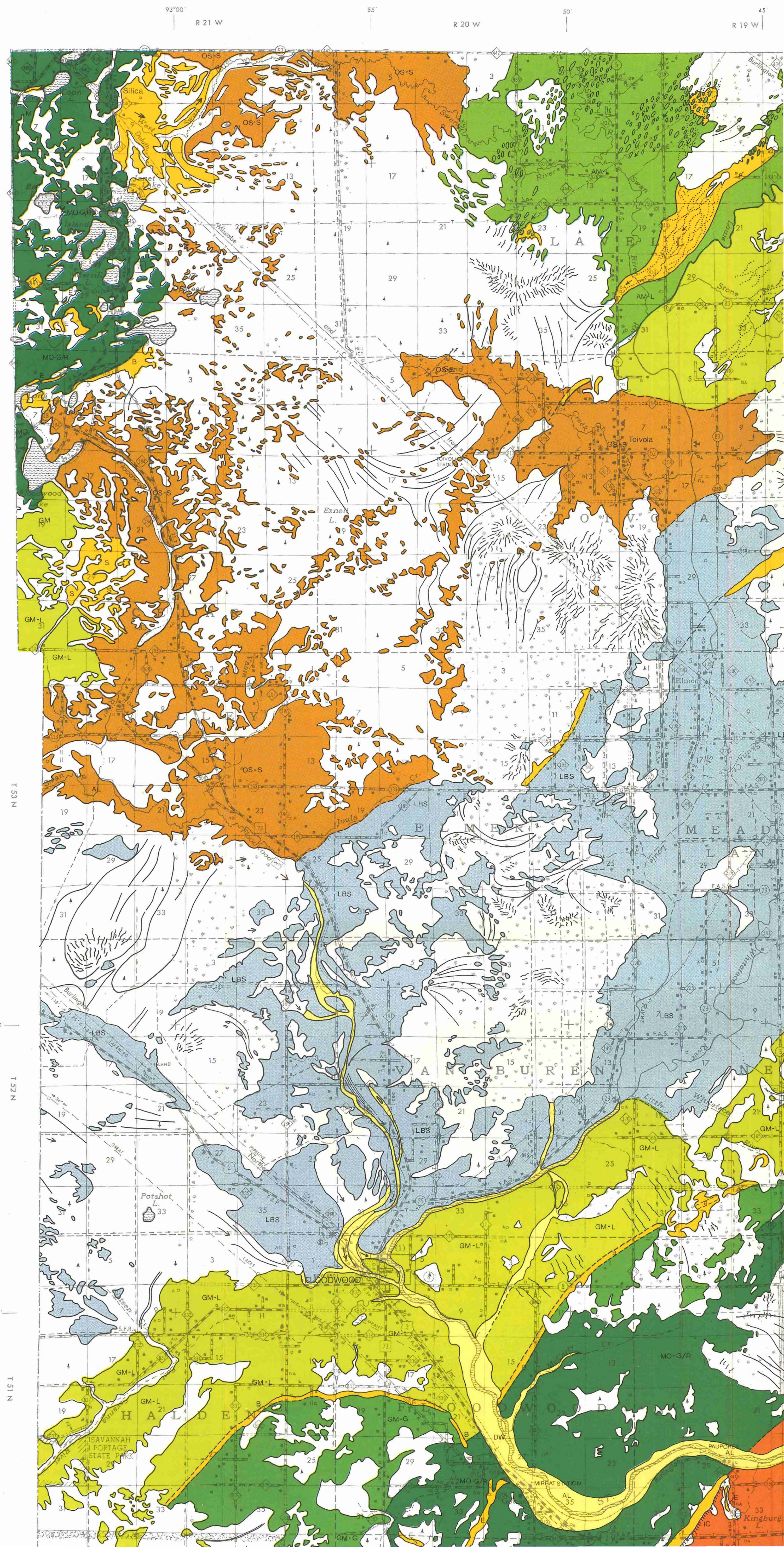

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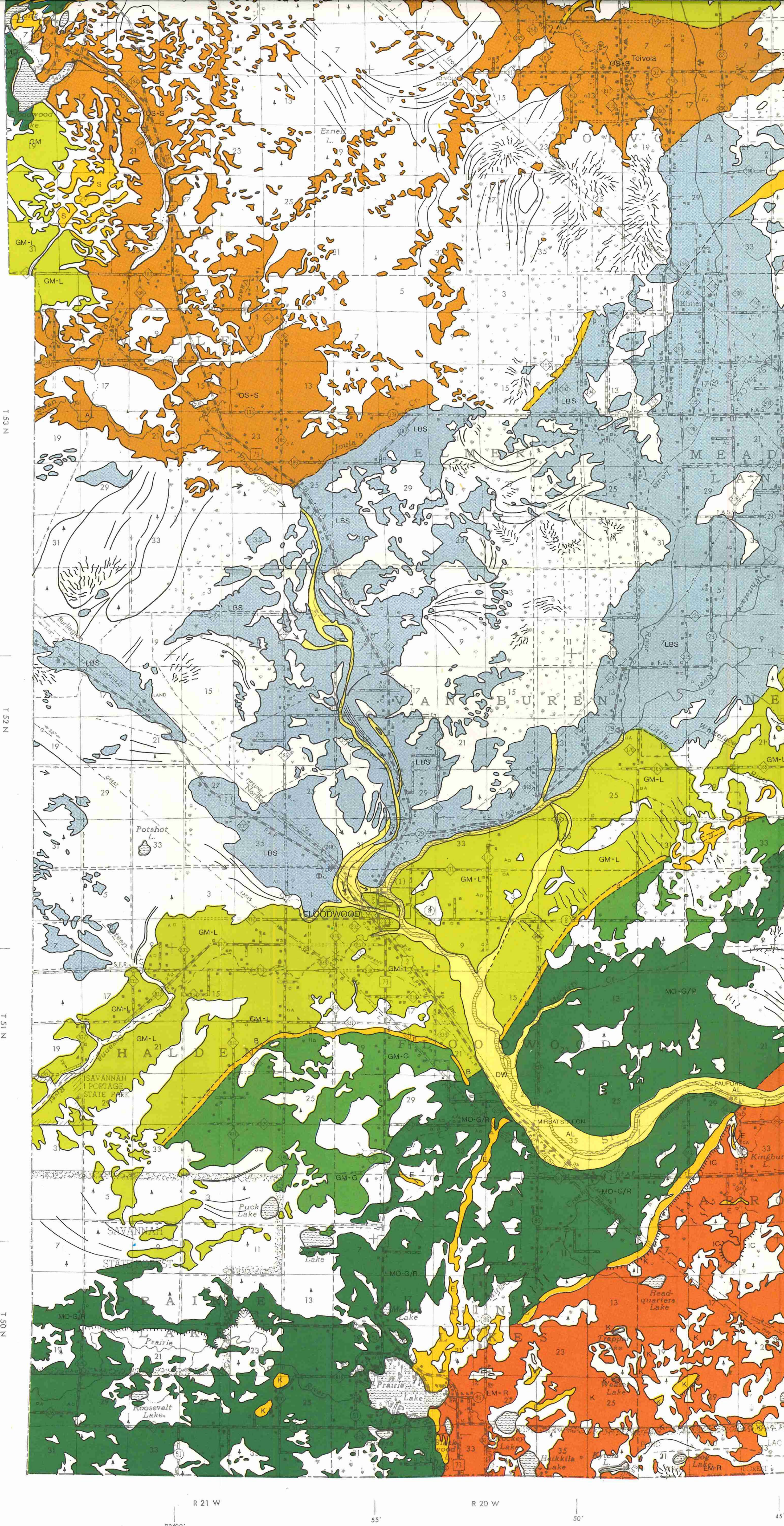

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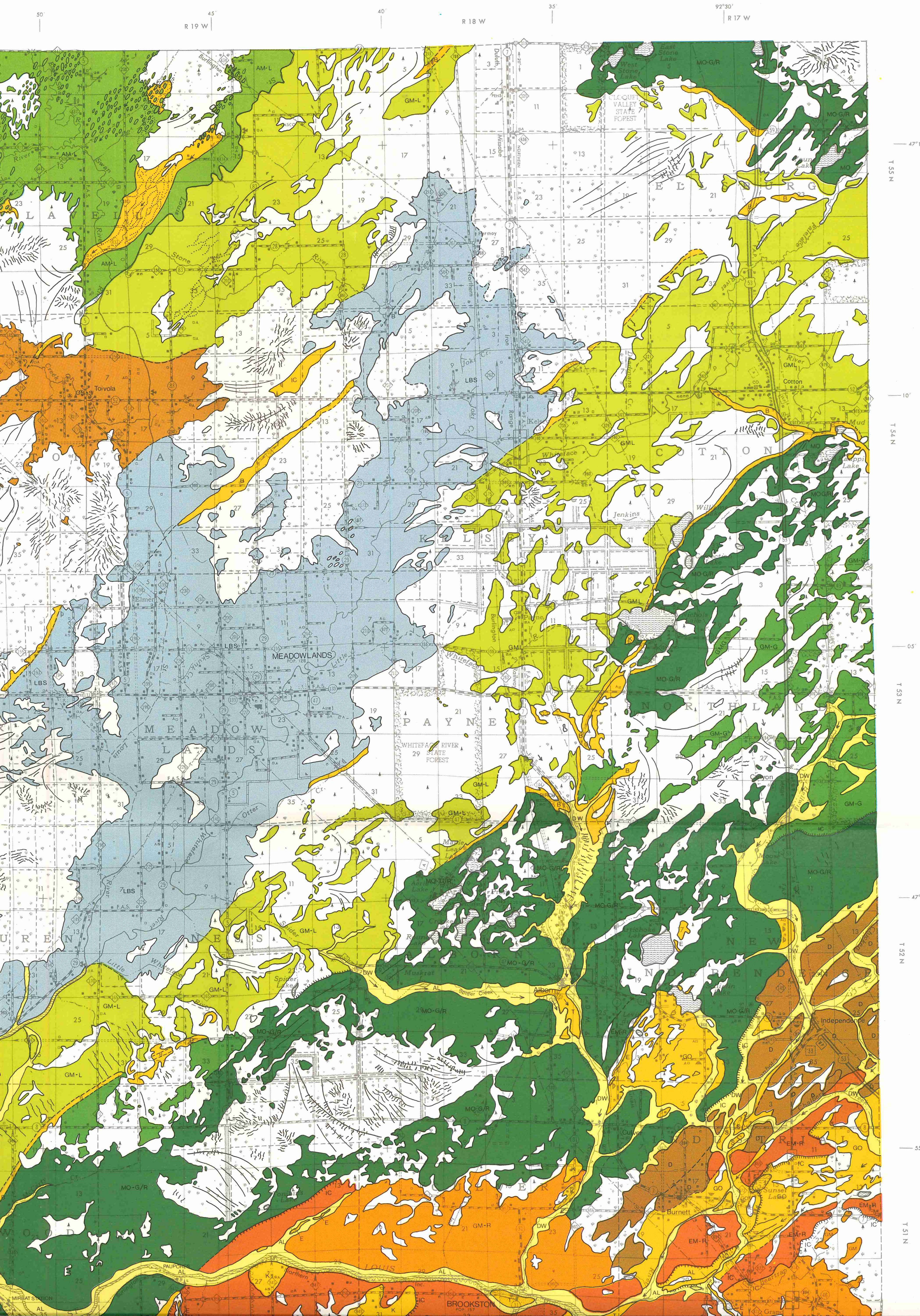

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WHITEFACE RIVER STATE FOREST
East Stone Lake
West Stone Lake
Sunset Lake
Spider Lake
PAYNE
NORTHLAND
COTTON
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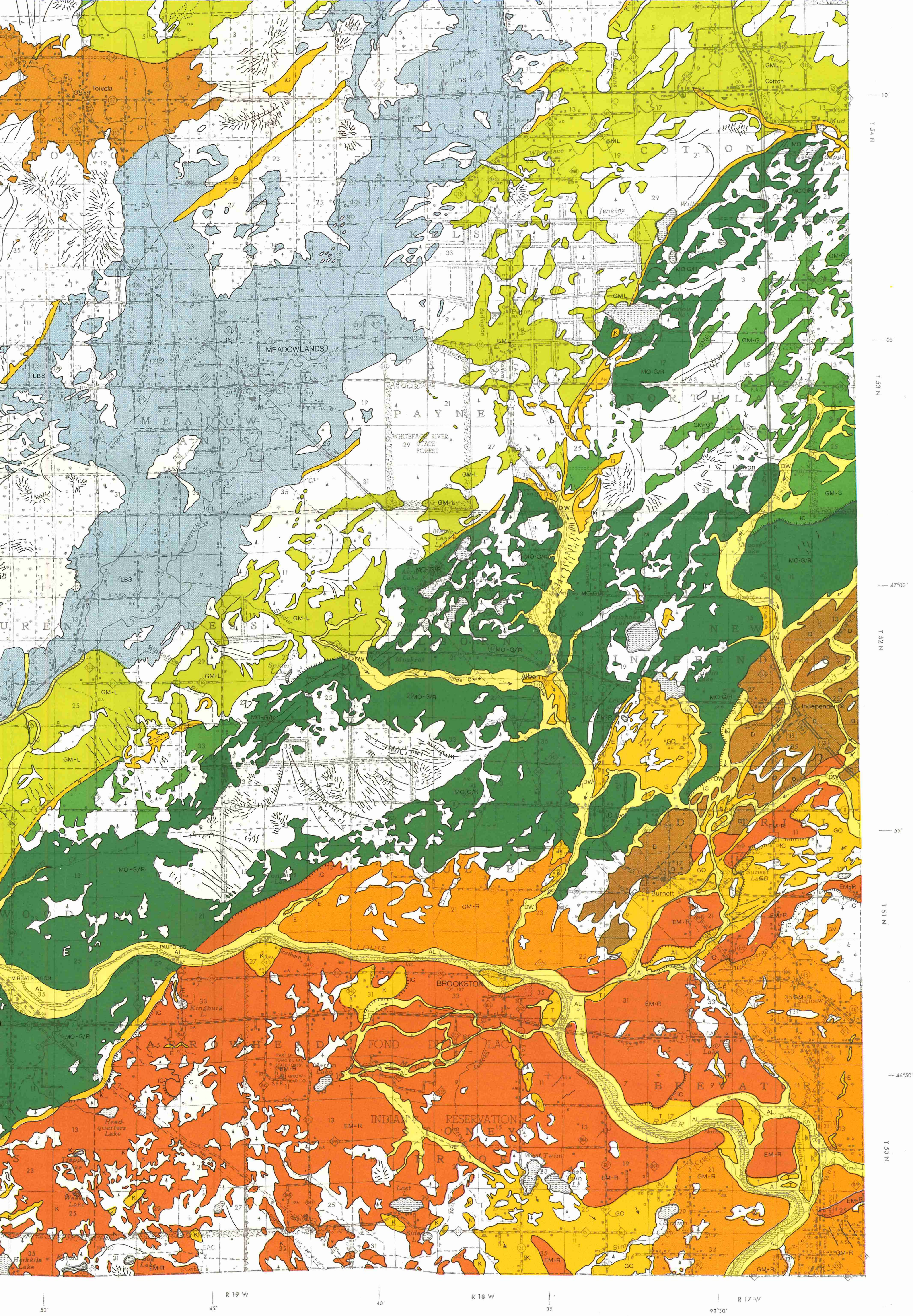

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MEADOWLANDS
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WHITEFACE RIVER STATE FOREST
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NEW INDEPENDENCE
Independence
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Burnett
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Kingsburg
Head-quarters Lake
MIRBAT STATION
Canyon
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Whiteface
Spider Creek
Muskrat
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EXPLANATION OF SURFICIAL GEOLOGY AND PEAT RESOURCES

S.W. St. Louis County, Minnesota

INTRODUCTION

The Department of Natural Resources, Division of Minerals, is responsible for the management of state-owned mineral resources including metallic minerals and non-metallic minerals. In order to develop sound management policies to cope with proposed development, it is essential for the Division to maintain an ongoing evaluation program drawing from a wide range of related disciplines using the best techniques and methods available.

Peat recently has become of significant interest in Minnesota because of the national energy crisis and the emphasis upon finding new sources of energy. Peat has potential as an alternate energy source, for horticulture, and for a number of chemical-industrial uses. Minnesota contains huge deposits of peat estimated to cover over 7 million acres most of which is located on forested state-owned lands. The Minnesota Legislature recognized the growing importance of our peat resources by providing a special appropriation to conduct special studies, develop management policies, and gather other information essential for the proper management of this resource.

The majority of the peatland is associated with the beds of several large glacial lakes: Glacial Lake Agassiz in Beltrami; Lake of the Woods, Itasca and Koochiching counties; Lake Upham in St. Louis county; and Lake Aitkin in Aitkin and Itasca counties (Figure 1).

This study focuses upon Southwest St. Louis county because of several factors:

A. It has significant peat deposits associated with Glacial Lake Upham that are strategically located in relation to transportation, power, and markets. . . .prime prerequisites for development.

B. It is situated between two rapidly developing areas: The Mesabi Iron Range, and the Duluth metropolitan area.

C. The area is of geological significance in that it is adjacent to areas now being mined or evaluated for taconite, copper-nickel and uranium. Detailed mapping of landform patterns could assist others in determining important geological boundaries buried beneath the glacial till.

D. The area contains some of the best agricultural lands in St. Louis county and supports a thriving farming community.

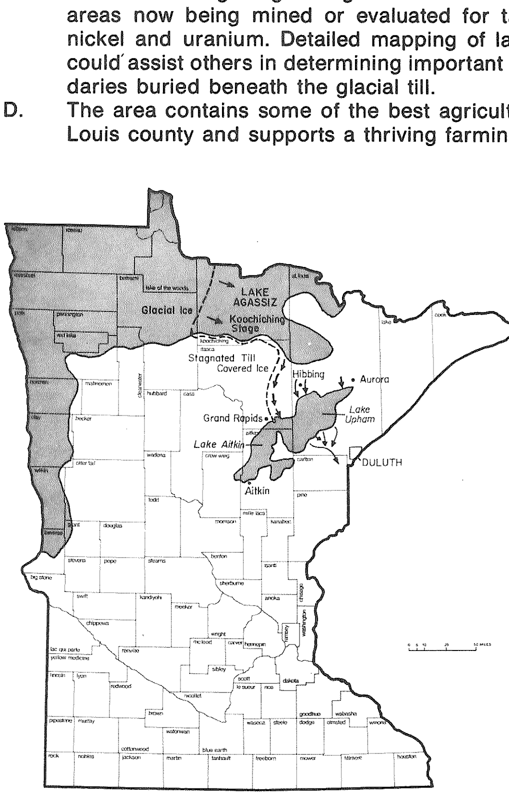


Figure 1 Lakes Upham and Aitkin in relation to the early Koochiching stage of Lake Agassiz.

METHODOLOGY

This study attempts to explain the relationship of glacial events to surficial geology, glacial hydrology and bog development.

The surficial geology, bog patterns, and geomorphic units delineated on this map were interpreted from a combination of high altitude aerial photographs (scale 1:90,000) and lower level photographs (scale 1:20,000). U.S. Geological Survey quadrangle maps were used as references for the general location of landforms. The location of geological boundaries and detailed outlines of geomorphic units were determined primarily through aerial photo interpretations. In this regard the information presented on this map is based primarily upon the opinions of the investigator. Field investigations were made of selected areas after the preliminary aerial mapping was completed.

The map was compiled by entering the aerial photo data upon a General Highway Map, sheet #1, of St. Louis county, having a scale one inch equals one mile and was photographically reduced to one-half inch equals one mile. The mapped area covers 1080 square miles in the southwest corner of the county. The General Highway Map was selected as a base because it is the only map scale having statewide coverage that embodies all current cultural landmarks.

A map of this type is more useful to the general public because it provides familiar points of reference, is of convenient size, and correlates to the State Highway Map.

PHYSIOGRAPHY

Southwest St. Louis county lies within four different physiographic areas (Figure 2).

Glacial Lakes Upham and Aitkin

This area consists of a flat lake plain containing broad expanses of wilderness peat bogs having a regional slope that drains from the old lakeshore towards the St. Louis River and its tributaries. The central part of the basin is entrenched by the St. Louis River. Subsequently this area is better drained and has a level topography containing fine grained lake soils, and lake washed tills. Sand dune and till islands are found scattered throughout the bog areas along the northwest

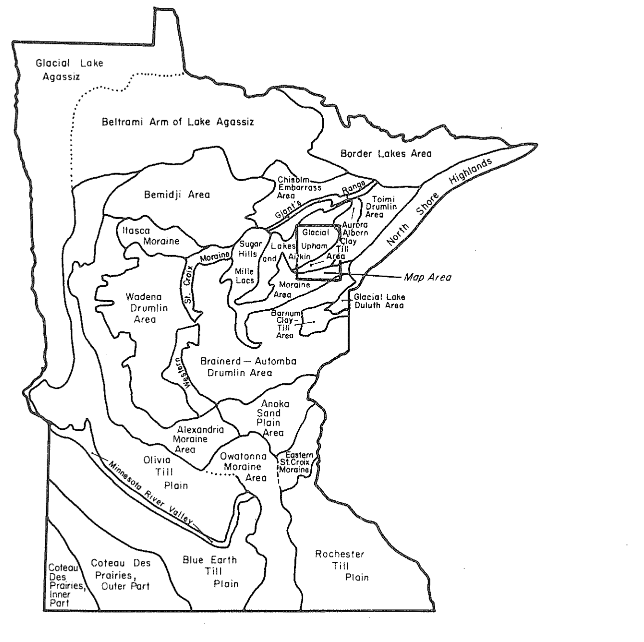


Figure 2 The study area shown in relation to physiographic areas of Minnesota (from H.E. Wright Jr. 1972)

SURFACE DRAINAGE

The surface waters in Minnesota drain into three major river basins: the Mississippi River basin, the Rainy-Red River basins, and the Great Lakes basin (St. Lawrence River). St. Louis county contributes surface water drainage to all three of the major river basins. A continental divide separating the waters draining to the Great Lakes basin and Mississippi River basin passes through the study area in the S.W. corner of St. Louis County.

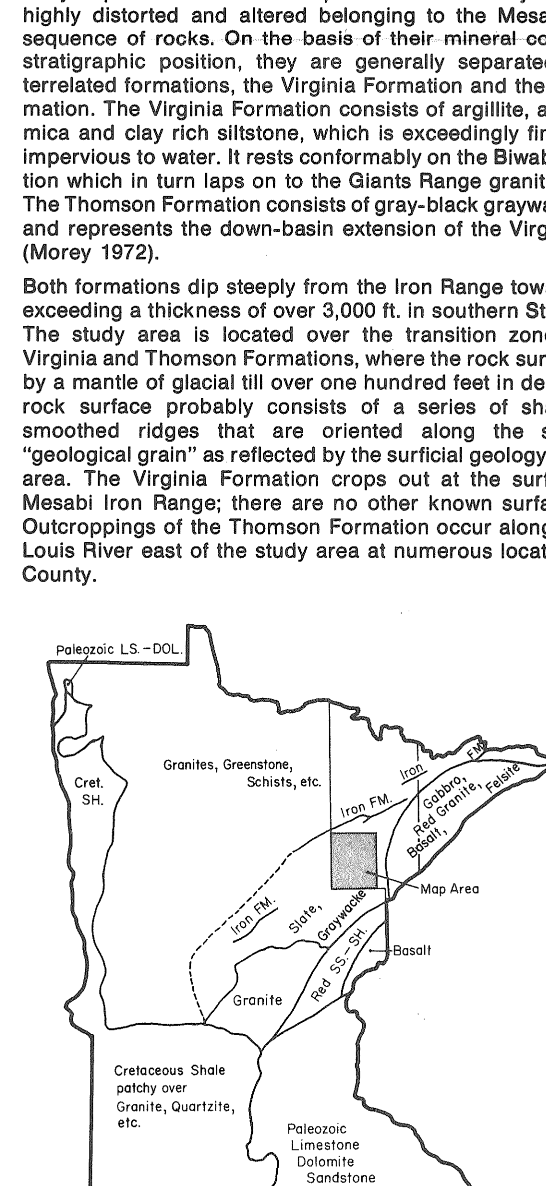
Most of the water in the mapped area drains to the St. Louis River watershed flowing south and east to the Great Lakes basin. The watershed of the St. Louis River is very flat and consists of forests and wetlands, within the old lake plains of Glacial Lake Upham II. Part of the watershed around the old lake plain consists of a high upland topography associated with the Mesabi Iron Range on the north and the rugged glacial moraines on the east and west. Relatively steep gradients are found in the tributary streams in the higher uplands, whereas the main stem of the St. Louis River has a shallow gradient where it crosses the flat lake plain. Downstream from the study area in Carlton County the St. Louis River plunges steeply, dropping several hundred feet to Lake Superior.

The average streamflow of the St. Louis River recorded at Scanlon for a drainage area of 3,430 sq. miles is 2,165 cfs, maximum flow is 37,900 cfs, and minimum flow 80 cfs.

BEDROCK FORMATIONS

The bedrock surface underlying S.W. St. Louis county consists of interbedded slate, graywacke, and argillite deposited during the Middle Precambrian Era (Animikie) about 1.7 billion years ago (Figure 3). They represent old metamorphosed sedimentary rocks that are highly distorted and altered belonging to the Mesabi Iron Range sequence of rocks. On the basis of their mineral composition and stratigraphic position, they are generally separated into two interrelated formations, the Virginia Formation and the Thomson Formation. The Virginia Formation consists of argillite, a gray-greenish mica and clay rich siltstone, which is exceedingly fine grained and impervious to water. It rests conformably on the Biwabik Iron Formation which in turn laps on to the Giants Range granite on the north. The Thomson Formation consists of gray-black graywacke and slates and represents the down-basin extension of the Virginia Formation (Morey 1972).

Both formations dip steeply from the Iron Range towards the south, exceeding a thickness of over 3,000 ft. in southern St. Louis County. The study area is located over the transition zone between the Virginia and Thomson Formations, where the rock surface is covered by a mantle of glacial till over one hundred feet in depth. The actual rock surface probably consists of a series of shallow, glacially smoothed ridges that are oriented along the strong NE-SW "geological grain" as reflected by the surficial geology in the mapped area. The Virginia Formation crops out at the surface along the Mesabi Iron Range; there are no other known surface exposures. Outcroppings of the Thomson Formation occur along the Lower St. Louis River east of the study area at numerous locations in Carlton County.



The glacial events that resulted from the multiple
retreats of major ice lobes during the Wisconsin Ic
divided into phases related to the events of individua
these phases was separated from the next by wa
melting which caused major lobes to diminish and ret
ing the previously glaciated terrain open for more vig
to readvance into the area from other directions. Th
retreat of these glaciers resulted in the deposition of a
tle of sorted glacial materials and unsorted debris (til
can be identified by these remaining deposits acc
structure, composition, color, and other physical ch

Glaciers incorporate rocks from areas over which the
each glacial till contains indicator rocks not found in
area that have been transported some distance by t
dicator rocks are helpful in determining the source
movement of glaciers. For example, the presence of
shale in St. Louis Sublobe till within the study area a
sedimentary rock formations from southern Manitob
can be concluded they were transported into Minnes
passing across that area.

Agate, basalt, sandstone, and felsite are indicators of
in the Lake Superior basin and tills of the Super
deposited by the Rainy Lobe are identified by the pr
bro, iron formation, granite, and the lack of Lake Su

The abundance of certain rocks in a glacial till tend t
characteristics. Generally tills of the Rainy and S
derived from hard, durable igneous and metamor
gravelly and permeable in nature whereas those deri
sedimentary rocks such as in the St. Louis Sublobe
clay and silt content and are more impermeable.

Meltwater from the glacial ice formed large rivers an
Evidence of the old glacial drainages and lakes can
the study area as sand and gravel eskers, kames, te
bars, deltas and shoreline beach ridges. These fea
identified from aerial photographs and topographica

A simplified version of the sequence of Wisconsin g
study area is as follows:

St. Croix Phase

The oldest event recorded by glacial features in this
from glaciation during the St. Croix Phase of the Wisc
about 20,000 years ago. During this time the Rainy L
through the entire region from the north possibly o
sions. It followed a southwest course parallel to the
coastline and flowed side by side with the Superior L
Lake Superior Basin.

Both lobes simultaneously advanced to the southwest
the St. Croix Moraine in the Twin Cities area and ce
(Wright 1972). At the close of the St. Croix Phase t
retreated far to the north, exposing the Toimi Drumlin
about 70 miles long by 25 miles wide. This drumlin fiel
dreds of low elongated hills called drumlins oriented
of ice flow from NE to SW. The southern tip of the fiel
the S.E. part of the study area near Independence. Th
constructed of till that is typically sandy and bouldery
or silt, and contains much iron formation, gabbro, a

The Superior Lobe also withdrew at this time well in
basin. Meltwater from both ice fronts flowed south th
plex system of inter-drumlin channels in the Toimi Dr
around the tongue of the Superior Lobe.

Automba Phase

The Automba Phase occurred some time after bot
earlier Rainy and Superior glaciers had retreated. It is
by a reactivation of the Superior Lobe, which readva
out of the Lake Superior Basin. The ice on the northe
into the study area in a northwest direction, buried pa
Drumlin Field, blocked the drainage channels, and co
with red sandy till.

The Superior Lobe advanced to the rugged Highla
southern St. Louis County, which extends northeast
about 12-15 miles inland from the shoreline of Lake S
far west as the Mille Lacs Moraine at Mille Lacs Lake. D
the Rainy Lobe was inactive and remained farther nor
marked by the Vermilion Moraine near Babbitt. Mel
from the Highland and Vermilion Moraines draining
the Toimi Drumlin Field became ponded and
southwest along the front of the Highland Moraine.
Aitkin I and Upham I may have formed at this time.

Split Rock Phase

The Split Rock Phase represents another resurgence
Lobe somewhat less vigorous than the Automba Phas
the Cloquet Moraine just south of the study area in Ca
counties. Meltwater drained westward to the headwat
River and thence into the St. Croix River (Wright an

Alborn Phase

The final glaciation in the study area occurred dur
Phase, which relates to the advance of the St. Louis S
west in a direction opposite to that of previous invasio
Superior Lobe. This glacier was an offshoot from t
Lobe in western Minnesota, which originated in Ma
Louis Sublobe buried the west edge of the Toimi Dr
deposited end moraines (MO-G/R) that overlap parts
Moraine and then diverge towards the northeast to

The St. Louis Sublobe filled the basins of Glacial Lak
Upham I, incorporating the lake sediments and
calcareous till with the older red Superior lake clay
variably colored till ranging in color from red-brown to
Louis Sublobe retreated, its ice front contributed melt
mation of Glacial Lake Upham II, which inundated a
tending north to the Mesabi Range and northeast to
1). All of the glacial lake shorelines and other lake re
outlined on this map (LBS, OS-S, GM-L, P) were de
various stages of Glacial Lake Upham II and con
derived from the St. Louis Sublobe.

Post Glacial Deposits

Post glacial deposits include alluvium (AL) tra
deposited by streams, sand dunes, and bog depos
dating indicates that peat deposits started to accumul
of Lake Upham about 6,700 years ago (Finney and F
Fine-grained sediments and organic soils also occur i
drainage ways (DW) and in numerous kettle lakes i
Sand dunes developed in the offshore sand unit (O
climate changed to a dry period about 8,000 - 5,
(Grigal, Seversen and Gultz 1976).

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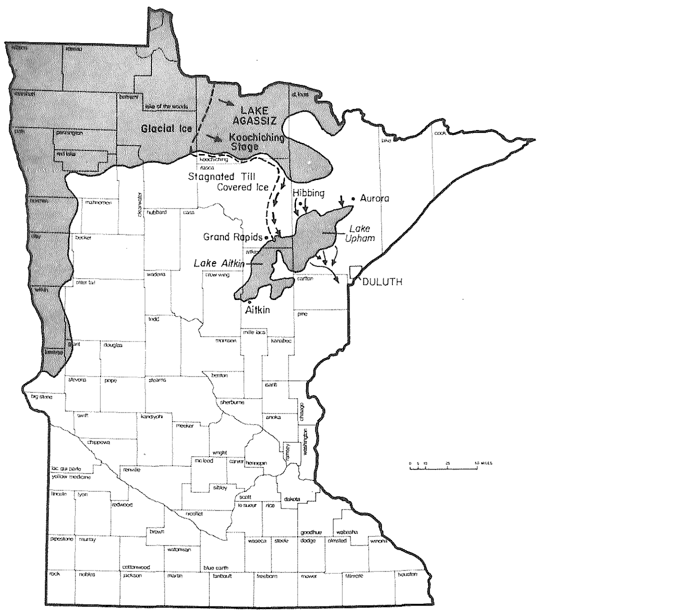

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Aurora Alborn Clay Till Area

This area is representative of the undulating ground moraine topography (GM-G) and the rolling end moraines (MO-G/R) constructed of blended tills of the St. Louis Sublobe incorporated from overridden lake clays of the Superior Lobe.

Sugar Hills, Mille Lacs Moraine Area

This area is locally represented by the rugged rolling end moraine topography (EM-R) constructed of sandy tills deposited by the Superior and Rainy Lobes. Farther west the moraines are overlain in places by till of the St. Louis Sublobe. Steep slopes kettle hole swamps, and ice block lake basins are common to the area.

Toimi Drumlin Area

The southern end of this physiographic area is represented by drumlins (D) extending into the mapped area near Independence. The drumlin field consists of many long ovoid hills that rise to a uniform height of 30-50 feet and lie parallel to one another. Their strong northeast-southwest pattern dominates the local surficial geology even though buried by younger glacial tills.

of Minnesota (from H.E. Wright Jr. 1972)

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BEDROCK FORMATIONS

The bedrock surface underlying S.W. St. Louis county consists of interbedded slate, graywacke, and argillite deposited during the Middle Precambrian Era (Animikie) about 1.7 billion years ago (Figure 3). They represent old metamorphosed sedimentary rocks that are highly distorted and altered belonging to the Mesabi Iron Range sequence of rocks. On the basis of their mineral composition and stratigraphic position, they are generally separated into two interrelated formations, the Virginia Formation and the Thomson Formation. The Virginia Formation consists of argillite, a gray-greenish mica and clay rich siltstone, which is exceedingly fine grained and impervious to water. It rests conformably on the Biwabik Iron Formation which in turn laps on to the Giants Range granite on the north. The Thomson Formation consists of gray-black graywacke and slates and represents the down-basin extension of the Virginia Formation (Morey 1972).

Both formations dip steeply from the Iron Range towards the south, exceeding a thickness of over 3,000 ft. in southern St. Louis County. The study area is located over the transition zone between the Virginia and Thomson Formations, where the rock surface is covered by a mantle of glacial till over one hundred feet in depth. The actual rock surface probably consists of a series of shallow, glacially smoothed ridges that are oriented along the strong NE-SW "geological grain" as reflected by the surficial geology in the mapped area. The Virginia Formation crops out at the surface along the Mesabi Iron Range; there are no other known surface exposures. Outcroppings of the Thomson Formation occur along the Lower St. Louis River east of the study area at numerous locations in Carlton County.

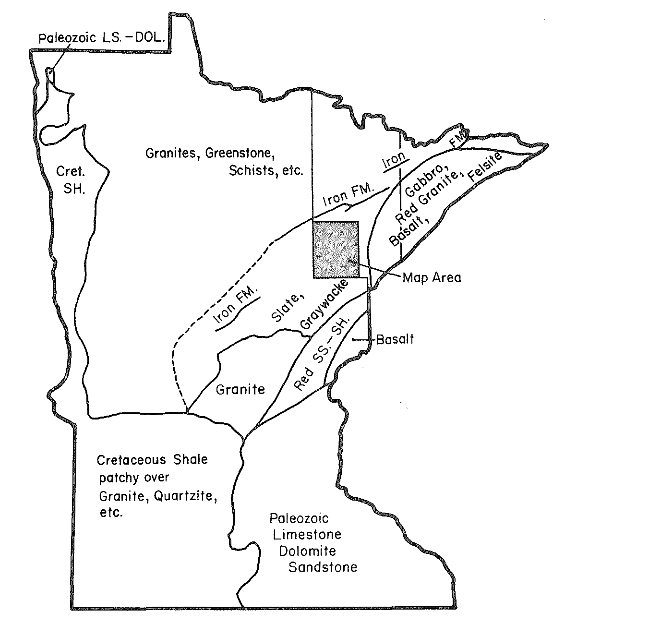

Figure 3 Major distributions of bedrock types

GLACIAL HISTORY AND SOILS

The surface of Minnesota was severely glaciated during the Pleistocene Epoch, better known as the Great Ice Age. During this period of time covering about the last two million years, the state was subjected to multiple periods of continental glaciation commonly referred to as the Nebraskan, Kansan, Illinoian, and Wisconsin Ice Stages. Each Continental Ice Stage was separated by long interglacial (interstadial) periods when the climate moderated and the ice thawed and retreated back into the Arctic regions. A precise picture of early glacial events is not easily constructed because most of the evidence of this glaciation was destroyed or altered by succeeding glaciers. However, most of the surficial glacial features in the state resulted from events that occurred during the Wisconsin Ice Stage spanning a period from 10,000 to 100,000 years ago. Practically all of the discussions and literature published on glaciation in Minnesota is concerned with this period of time.

During the last Wisconsin Ice Stage a succession of glacial lobes originating in Canada entered northeastern Minnesota from several directions (Figure 4).

gravelly and permeable in nature whereas those deriv sedimentary rocks such as in the St. Louis Sublobe clay and silt content and are more impermeable.

Meltwater from the glacial ice formed large rivers and Evidence of the old glacial drainages and lakes can n the study area as sand and gravel eskers, kames, ter bars, deltas and shoreline beach ridges. These fea identified from aerial photographs and topographica

A simplified version of the sequence of Wisconsin g study area is as follows:

St. Croix Phase

The oldest event recorded by glacial features in this from glaciation during the St. Croix Phase of the Wisco about 20,000 years ago. During this time the Rainy L through the entire region from the north possibly on sions. It followed a southwest course parallel to the coastline and flowed side by side with the Superior L Lake Superior Basin.

Both lobes simultaneously advanced to the southwest the St. Croix Moraine in the Twin Cities area and cen (Wright 1972). At the close of the St. Croix Phase t retreated far to the north, exposing the Toimi Drumlin about 70 miles long by 25 miles wide. This drumlin field dreds of low elongated hills called drumlins oriented of ice flow from NE to SW. The southern tip of the field the S.E. part of the study area near Independence. Th constructed of till that is typically sandy and bouldery or silt, and contains much iron formation, gabbro, a

The Superior Lobe also withdrew at this time well int basin. Meltwater from both ice fronts flowed south thr plex system of inter-drumlin channels in the Toimi Dru around the tongue of the Superior Lobe.

Automba Phase

The Automba Phase occurred some time after both earlier Rainy and Superior glaciers had retreated. It is by a reactivation of the Superior Lobe, which readvan out of the Lake Superior Basin. The ice on the norther into the study area in a northwest direction, buried par Drumlin Field, blocked the drainage channels, and co with red sandy till.

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Post Glacial Deposits

Post glacial deposits include alluvium (AL) tra deposited by streams, sand dunes, and bog depos dating indicates that peat deposits started to accumula of Lake Upham about 6,700 years ago (Finney and F Fine-grained sediments and organic soils also occur i drainage ways (DW) and in numerous kettle lakes in Sand dunes developed in the offshore sand unit (O climate changed to a dry period about 8,000 - 5, (Grigal, Seversen and Gultz 1976).

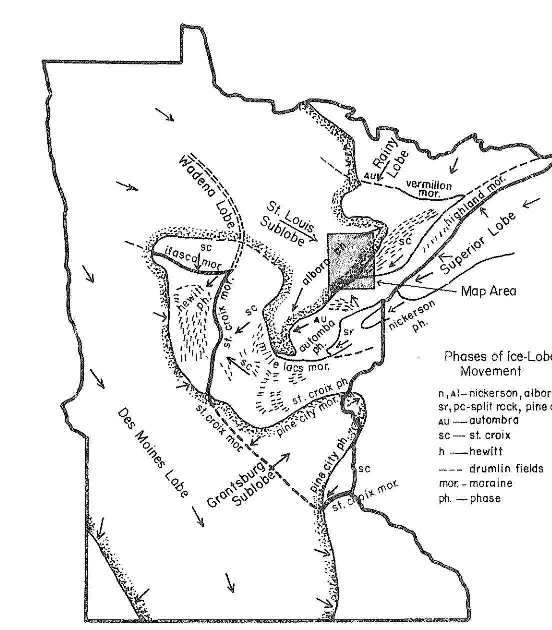

Figure 4 Glaciers in Minnesota during the Wiscon arrows indicate direction of ice flow (Wright 1972)

glacial events that resulted from the multiple advances and ats of major ice lobes during the Wisconsin Ice Stage is sub- ed into phases related to the events of individual lobes. Each of phases was separated from the next by warm periods of ng which caused major lobes to diminish and retreat, often leav- he previously glaciated terrain open for more vigorous ice lobes advance into the area from other directions. The advance and at of these glaciers resulted in the deposition of a complex man- sorted glacial materials and unsorted debris (till). Each glacier be identified by these remaining deposits according to their ture, composition, color, and other physical characteristics.

ers incorporate rocks from areas over which they flow. Usually glacial till contains indicator rocks not found in the immediate that have been transported some distance by the glaciers. In- or rocks are helpful in determining the source, direction and ment of glaciers. For example, the presence of limestone and in St. Louis Sublobe till within the study area are indicators of mentary rock formations from southern Manitoba. Therefore, it be concluded they were transported into Minnesota by glaciers ng across that area.

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GLACIAL HYDROLOGY

Meltwater from the glacial drainage systems had a direct influence upon the deposition of the surficial deposits and the existing hydrology in the study area. Several large glacial lakes formed concurrently at the close of the Wisconsin Ice Stage. Glacial Lake Upham II probably was partly contemporary with Glacial Lake Agassiz which existed between 12,800 and 9,000 years ago in northern Minnesota. At its peak Lake Agassiz covered over 200,000 square miles in the Red River Valley, Canada, and northern Minnesota (Figure 5). Initially, meltwater became ponded ahead of the ice front of two glacial lobes, one in the Red River Valley and another occupying the Beltrami arm of Lake Agassiz that extended east into north-central Minnesota.

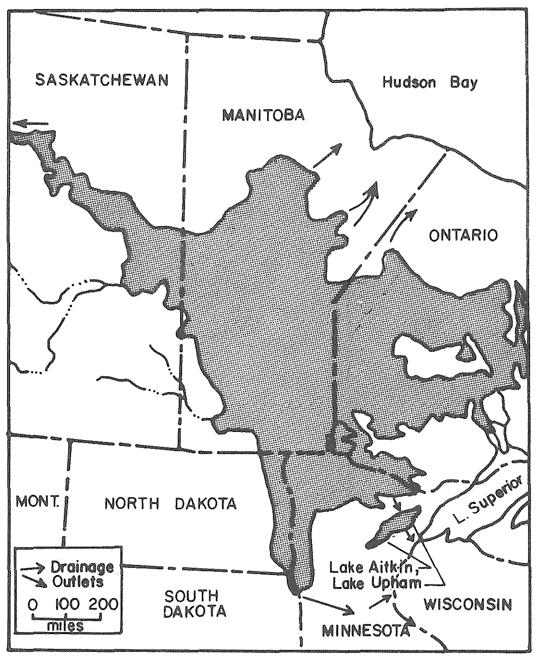
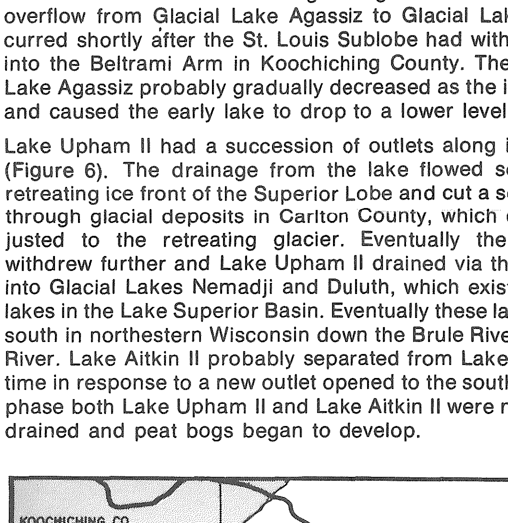


Figure 5 Glacial Lakes Aitkin and Upham compared to maximum area covered by Glacial Lake Agassiz. Arrows show major outlets for the lake (modified from Elson 1967 and Arndt 1977)

During Lake Agassiz's early Koochiching stage, the Beltrami arm contained a pro-glacial lake having a water level standing at approximately 1400 feet above mean sea level, or about 50-60 feet higher than Glacial Lake Upham at elevation 1350 + feet (Nikiforoff 1932). The Mesabi Iron Range formed a drainage divide between Lake Agassiz and Lake Upham. However, mapping of old strandlines on the Iron Range indicates Lake Agassiz spilled over into the northwest side of Lake Upham II at a low point along the Prairie River (Winter 1973).

Another water gap through the divide exists farther east where the Embarrass River cuts through the Mesabi Range and discharged water from Glacial Lake Norwood into the N.E. side of Lake Upham II. Both stream valleys contain outwash sand and gravel deposited by meltwater streams down-cutting through the divide. It is believed the overflow from Glacial Lake Agassiz to Glacial Lake Upham II occurred shortly after the St. Louis Sublobe had withdrawn well back into the Beltrami Arm in Koochiching County. The discharge from Lake Agassiz probably gradually decreased as the ice lobe withdrew and caused the early lake to drop to a lower level.

Lake Upham II had a succession of outlets along its eastern shore (Figure 6). The drainage from the lake flowed south around the retreating ice front of the Superior Lobe and cut a series of channels through glacial deposits in Carlton County, which continually readjusted to the retreating glacier. Eventually the Superior Lobe withdrew further and Lake Upham II drained via the St. Louis River into Glacial Lakes Nemadji and Duluth, which existed as proglacial lakes in the Lake Superior Basin. Eventually these lakes later drained south in northestern Wisconsin down the Brule River to the St. Croix River. Lake Aitkin II probably separated from Lake Upham II at this time in response to a new outlet opened to the southwest. In the final phase both Lake Upham II and Lake Aitkin II were nearly completely drained and peat bogs began to develop.



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8. St. Louis River Outlet
9. Floodwood Outlet

Figure 6 Study area shown in relation to Glacial Lakes Upham and Aitkin at maximum stage. Arrows indicate inlets and outlets of Lake Upham, number relates to their sequence

Glacial Lake Upham II Inlets and Outlets

OUTLETS FOR LAKE UPHAM

Spider Creek Outlet (elevation 1300) - This outlet is located about miles west of Alborn. Formerly Spider Creek drained east to the A tichoke River through a broad, deep valley that is considerably olde than other drainageways in this area. The presence of terraces an deep accumulations of peat and marl in the valley indicates it serve as an early outlet for Lake Upham I (Baker 1964). Depositional pa terns of landforms suggests the valley was subsequently filled wit ice and plugged by a moraine dam on the east end during the Albor phase of the St. Louis Sublobe. As the ice withdrew a proglacial lak formed in the valley behind the moraine dam prior to the formation c Lake Upham II.

Hellwig Creek Outlet - This outlet developed at approximately eleva tion 1340 near Canyon during a early stage of Lake Upham II. At thi time the water level was temporarily supported by glacial ice and th lake attained a high water level standing at approximately elevatio 1350-1360 feet. Discharge was south along existing interdrumli channels to the Cloquet River and then to the St. Louis River.

Birch Outlet - The large drainageway shown on the map leadin south from Birch to the Artichoke River probably was concurrent wit the Hellwig Creek outlet. As the glacier retreated and the lak lowered, Hellwig Creek was abandoned, and the Birch outlet (elev 1310) continued to function when the lake dropped and stabilized a approximately elevation 1300-1310. Beach deposits of sand an gravel developed near the outlet at this time between elevation 131 to 1320. The present drainageway is underlain by alluvium and fille with peat.

Spider Creek Outlet - This outlet shows little evidence of activity dur ing Lake Upham II. However, it probably functioned temporarily, in minor capacity in conjunction with the Birch outlet at the close of th elevation 1300 stage of the lake. Breaching of the moraine dam caused a gravel bar to be deposited at the junction of the Artichok River and the Spider Creek drainageway.

St. Louis River Outlet - In the final phase, Lake Upham II developed new or more effective outlet caused either through headwater ero sion of an existing St. Louis River spillway concurrent with the Birc and Spider Creek outlets; or by a breach of the established elevatio 1300 shoreline caused by subsidence of the ice cored moraine (MO G/R) between Paupores and Mirbat Station. Once the moraine wa breached, the St. Louis River became entrenched and the spillwa advanced through the more erodible soils in the lake basin to as fa as Floodwood. The gravel terraces along the St. Louis River were for med at this time by the river's down cutting through its valley train o sand and gravel. Eventually the lakewashed ground-moraine (GM-L was breached and the last outlet developed at elevation 1230 nea the mouth of the Floodwood River. This outlet effectively drained th lowest stage of the lake, exposing the lake bottom sediments (LBS shown on the map, and those parts subsequently covered by peat

DISCUSSION OF MAP UNITS

D-Drumlins

The drumlins between Independence and Burnette are the oldes glacial deposits in the study area. They are part of the large Toim Drumlin Field, deposited by the Rainy Lobe, that forms a belt o drumlins about 35 miles long by five to fifteen miles wide oriented in NE-SW direction along the Cloquet River Valley (Figure 4). The Toim Drumlin Field contains hundreds of drumlins that are uniforml separated by a complex network of linear drainage channels. In dividual drumlins typically are several miles long and 1/4 - 1/2 mil wide, are of uniform height (30-50 ft.), and have a streamlined profile They are constructed of a yellowish-brown to dark-reddish brow compacted sandy bouldery till containing a high percent of gabbr rock. Farther west the drumlins are overlapped by the drift of the St Louis Sublobe; however, the strong NE-SW pattern of the underlyin drumlins is still reflected through the overlying deposits as displaye by the orientation of the various units of the map.

EM-R End Moraines and GM-R Ground Moraine Constructed of Red Till

Both units contain a reddish-brown sandy till deposited by th Automba Superior Lobe in the rugged end moraine complex (EM-R of the Highland Moraine and in the more level ground moraine (GM R). The glacial drift may range up to 200 feet deep. Ice contac deposits of sand and gravel are abundant in this area.

MO-G/R Moraine Overlap

The advance of the St. Louis Sublobe from the west overrode the out lying rugged morainic topography deposited by earlier phases of th Superior Lobe. It incorporated and blended with the red clays an silts and redeposited them as an end moraine of the St. Louis Sub lobe. The blended tills found within this unit are variably colore ranging from light buff to dark brownish-red depending upon th amount of blending that occurred locally. In certain areas the re color of the Superior till has overpowered the lighter-colored St Louis Sublobe till. Gravel pits and road cuts in this unit show an in crease in limestone and shale indicator rocks towards the inner sid of the moraine. This tends to mark the position of the St. Loui Sublobe.

GM-L Ground Moraine — Lakewashed and GM-G Ground Moraine

GM-L consists of slightly undulating topography of ground morain associated with the St. Louis Sublobe that has been smoothed an modified by Glacial Lake Upham. The surface frequently is covere by large boulders and pebbles washed out of the glacial till by lak currents. Lakewashed ground moraine (GM-L) occupies the are principally located between the LB-S and the shoreline of Lake Up ham II. Conversely, GM-G is a more rolling ground morain topography of the St. Louis Sublobe showing little evidence of bein washed. Both units are constructed of variable buff to brownish- re calcareous till representing a blend of the red Superior till that wa overridden and incorporated by the St. Louis Sublobe.

OS-S Off Shore Sand

This unit represents a uniform fine sand that was deposited b meltwater streams discharging into the early stage of Glacial Lak Upham II about 13,000 years ago by the retreating St. Louis Sublobe Initially a major inflow of water-transported sediment came from th northwest, directly off the ice front marked by the moraine (MO-G/R into the lake. This is reflected by the transition between various soil in the bed of Glacial Lake Upham, changing from sand and gravel i the West Swan River delta near Silica to the offshore fine sand (OS-S and then to deepwater deposits of calcareous silt and clay in the LB unit.

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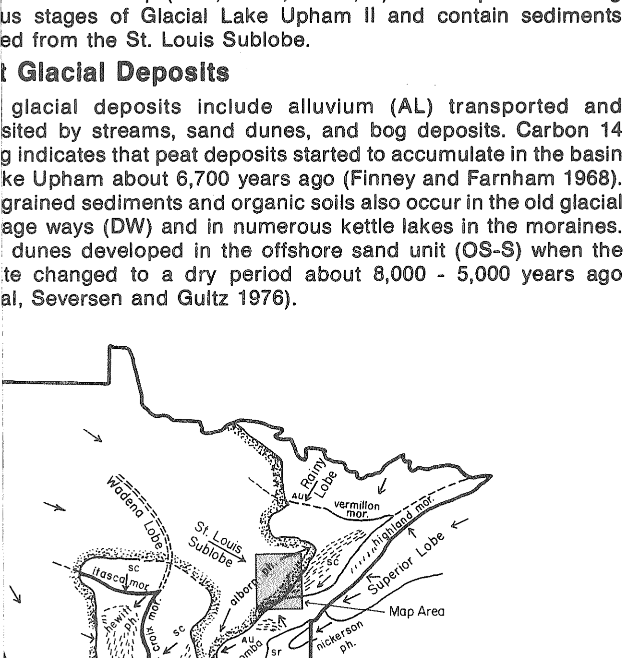
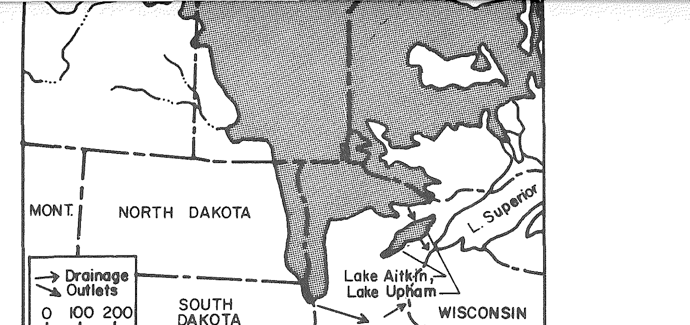


e 4 Glaciers in Minnesota during the Wisconsin Ice Stage arrows indicate direction of ice flow (modified from Wright 1972)



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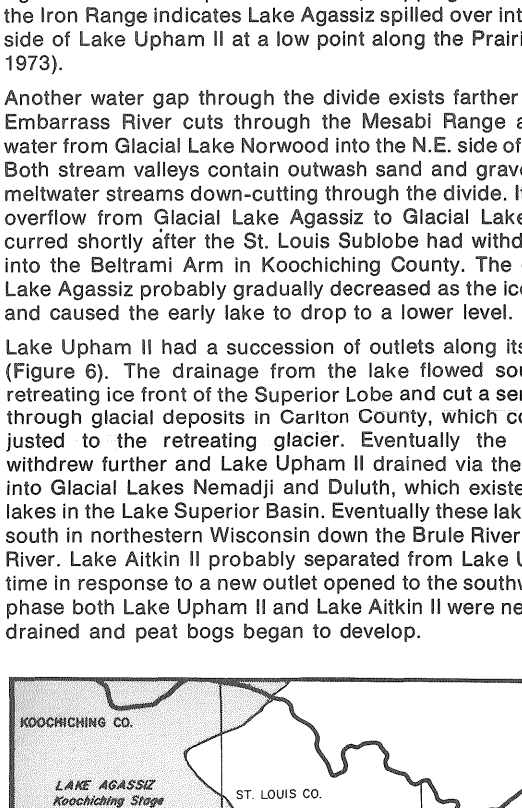

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9. Floodwood Outlet

Figure 6 Study area shown in relation to Glacial Lakes Upham and Aitkin at maximum stage. Arrows indicate inlets and outlets of Lake Upham, number relates to their sequence

Glacial Lake Upham II Inlets and Outlets

Former stages of Glacial Lake Upham II can be generally reconstructed from the various units, especially shorelines (B) and outlets (DW) shown on the map. Only one well defined shoreline is found south of Floodwood at an elevation of 1300 feet. It trends northeast along the inner edge of the St. Louis Sublobe moraine towards Cotton.

Several drainageway (DW) channels that formerly served as outlets for Lake Upham II can be identified along the old shore. The events related to the development of the lakes inlets and outlets probably occurred as follows:

INLETS TO LAKE UPHAM II

Embarrass Inlet - This inlet functioned during an early phase of the lake when water flowed through the Embarrass River water gap into the northeast side of the lake outside of the study area. The Embarrass gap is a deep valley passing through the Mesabi Iron Range upland.

Silica Inlet - This inlet entered the lake along the Swan River near Silica and contributed a major flow into the northwest shore. A delta of sand and gravel was deposited at the point where the stream entered slack water in the lake. Finer grained particles of sand, silt, and clay remained in suspension and was deposited farther out in the lake basin in the offshore sand (OS-S), and lake bottom sediments (LBS) units shown on the map.

Prairie River Inlet - Another major inflow of meltwater to Lake Upham II entered the west side of the lake west of the study area via the Prairie River Valley near Grand Rapids. The inflow probably consisted of a combination of meltwater from stagnant ice and discharge from the early Koochiching phase of Glacial Lake Agassiz located north of the Mesabi Iron Range. It also contributed sand and other fine grained lake sediments of clay and silt derived from the calcareous tills of the St. Louis Sublobe.

ing Lake Upham II. However, it probably functioned temporarily, in minor capacity in conjunction with the Birch outlet at the close of the elevation 1300 stage of the lake. Breaching of the moraine dam caused a gravel bar to be deposited at the junction of the Artichoke River and the Spider Creek drainageway.

St. Louis River Outlet - In the final phase, Lake Upham II developed a new or more effective outlet caused either through headwater erosion of an existing St. Louis River spillway concurrent with the Birch and Spider Creek outlets; or by a breach of the established elevation 1300 shoreline caused by subsidence of the ice cored moraine (MO-G/R) between Paupores and Mirbat Station. Once the moraine was breached, the St. Louis River became entrenched and the spillway advanced through the more erodible soils in the lake basin to as far as Floodwood. The gravel terraces along the St. Louis River were formed at this time by the river's down cutting through its valley train of sand and gravel. Eventually the lakewashed ground-moraine (GM-L) was breached and the last outlet developed at elevation 1230 near the mouth of the Floodwood River. This outlet effectively drained the lowest stage of the lake, exposing the lake bottom sediments (LBS) shown on the map, and those parts subsequently covered by peat

DISCUSSION OF MAP UNITS

D-Drumlins

The drumlins between Independence and Burnette are the oldest glacial deposits in the study area. They are part of the large Toimi Drumlin Field, deposited by the Rainy Lobe, that forms a belt of drumlins about 35 miles long by five to fifteen miles wide oriented in a NE-SW direction along the Cloquet River Valley (Figure 4). The Toimi Drumlin Field contains hundreds of drumlins that are uniformly separated by a complex network of linear drainage channels. Individual drumlins typically are several miles long and 1/4 - 1/2 mile wide, are of uniform height (30-50 ft.), and have a streamlined profile. They are constructed of a yellowish-brown to dark-reddish brown compacted sandy bouldery till containing a high percent of gabbro rock. Farther west the drumlins are overlapped by the drift of the St. Louis Sublobe; however, the strong NE-SW pattern of the underlying drumlins is still reflected through the overlying deposits as displayed by the orientation of the various units of the map.

EM-R End Moraines and GM-R Ground Moraines Constructed of Red Till

Both units contain a reddish-brown sandy till deposited by the Automba Superior Lobe in the rugged end moraine complex (EM-R) of the Highland Moraine and in the more level ground moraine (GM-R). The glacial drift may range up to 200 feet deep. Ice contact deposits of sand and gravel are abundant in this area.

MO-G/R Moraine Overlap

The advance of the St. Louis Sublobe from the west overrode the outlying rugged morainic topography deposited by earlier phases of the Superior Lobe. It incorporated and blended with the red clays and silts and redeposited them as an end moraine of the St. Louis Sublobe. The blended tills found within this unit are variably colored ranging from light buff to dark brownish-red depending upon the amount of blending that occurred locally. In certain areas the red color of the Superior till has overpowered the lighter-colored St. Louis Sublobe till. Gravel pits and road cuts in this unit show an increase in limestone and shale indicator rocks towards the inner side of the moraine. This tends to mark the position of the St. Louis Sublobe.

GM-L Ground Moraine — Lakewashed and GM-G Ground Moraine

GM-L consists of slightly undulating topography of ground moraine associated with the St. Louis Sublobe that has been smoothed and modified by Glacial Lake Upham. The surface frequently is covered by large boulders and pebbles washed out of the glacial till by lake currents. Lakewashed ground moraine (GM-L) occupies the area principally located between the LB-S and the shoreline of Lake Upham II. Conversely, GM-G is a more rolling ground moraine topography of the St. Louis Sublobe showing little evidence of being washed. Both units are constructed of variable buff to brownish-red calcareous till representing a blend of the red Superior till that was overridden and incorporated by the St. Louis Sublobe.

OS-S Off Shore Sand

This unit represents a uniform fine sand that was deposited by meltwater streams discharging into the early stage of Glacial Lake Upham II about 13,000 years ago by the retreating St. Louis Sublobe. Initially a major inflow of water-transported sediment came from the northwest, directly off the ice front marked by the moraine (MO-G/R) into the lake. This is reflected by the transition between various soils in the bed of Glacial Lake Upham, changing from sand and gravel in the West Swan River delta near Silica to the offshore fine sand (OS-S) and then to deepwater deposits of calcareous silt and clay in the LBS unit.

Later, after deposition of the offshore sands (OS-S), a period of sand dune development and vegetative change occurred in north central Minnesota between 8,000 - 5,000 years ago. During this time Lake Upham withdrew, and the offshore (OS-S) was reworked into dunes. Subsequently, the climate again changed, resulting in the accumulation of the peat bogs around numerous dune shaped islands, as evidenced by the Devils Islands in the Toivola Bog near Exnell Lake. One can expect to find offshore sands (OS-S) beneath the peat bog in this area draped over the ground moraine of the St. Louis Sublobe. Peat deposits around the islands are shallow and probably average under five feet in depth.

LBS - Lake Bottom Sediments

This unit is predominantly constructed of fine-grained sediments such as clay, silt, and fine sand that remained suspended in glacial streams for longer periods of time and were eventually deposited in the deep water basin of Glacial Lake Upham II.

Generally the boundaries are transitional, but this unit forms a terrain that is smoother than the surrounding areas, contains less sand and fewer stones and boulders. Road cuts show varved lake deposits consisting of laminations of light gray-buff to brown calcareous clay and silt. The color and calcareous nature of the soils are indicators of St. Louis Sublobe deposition by meltwater streams entering the area from the west and northwest.

A thriving farming community is expanding within this unit. It probably contains some of the best agricultural land in St. Louis County.

AM-L

Represents a lakewashed ablation moraine (elev. 1290) containing stagnant ice features deposited by the waning St. Louis Sublobe. Here, buff to light-brown calcareous till is deposited in a complex pattern of small oval landforms crossed by an intricate braided channel system.

LAKE UPHAM

tlet (elevation 1300) - This outlet is located about 6 orn. Formerly Spider Creek drained east to the Ar- ough a broad, deep valley that is considerably older ageways in this area. The presence of terraces and ons of peat and marl in the valley indicates it served t for Lake Upham I (Baker 1964). Depositional pat- ns suggests the valley was subsequently filled with by a moraine dam on the east end during the Alborn Louis Sublobe. As the ice withdrew a proglacial lake ley behind the moraine dam prior to the formation of

utlet - This outlet developed at approximately eleva- anyon during a early stage of Lake Upham II. At this vel was temporarily supported by glacial ice and the igh water level standing at approximately elevation Discharge was south along existing interdrumlin Cloquet River and then to the St. Louis River. he large drainageway shown on the map leading to the Artichoke River probably was concurrent with ek outlet. As the glacier retreated and the lake Creek was abandoned, and the Birch outlet (elev. to function when the lake dropped and stabilized at levation 1300-1310. Beach deposits of sand and l near the outlet at this time between elevation 1310 sent drainageway is underlain by alluvium and filled

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Sand and Gravel

Kames K, Eskers E, Glacial Outwash GO, Terraces T, Beaches B

The formation and placement of sand and gravel in this area is directly related to glacial hydrology, resulting from hydraulic sorting of the glacial till by glacial lakes and streams. Melting of the glaciers produced a vigorous outflow of meltwater that formed many broad glacial streams, which reworked the till and transported the fine-grained particles downstream. Strong currents tumbled and rolled the larger heavy gravel size particles along the channel bottom, causing them to be rounded off and redeposited as gravel. Many streams were overloaded with sand and gravel, and they continuously shifted their channels, thereby changing the current flow, rate of deposition, and type of material being deposited. Each resurgence of meltwater upgraded the gravel quality. Consequently, the better gravel deposits are those that were reworked many times by strong currents and transported considerable distances beyond the ice front.

Gravel deposits are subdivided into Ice-Contact Deposits or those deposited within or under the ice and Glaciofluvial Deposits (or those deposited by rivers beyond the ice).

ICE-CONTACT DEPOSITS — Examples of ice-contact deposits are kames K, eskers E, and crevasse fillings IC, consisting of sand and gravel deposited in holes and channels within the glacier.

K-Kames — are prominent cone-shaped hills of sand and gravel formed by water plunging into a hole in the ice. Kames frequently are found in clusters and characteristically are sandy near the top, grading to gravel near the bottom. All of the kames in the mapped area are located in the MO and EM-R units associated with the ice front of the St. Louis Sublobe and Superior Lobe.

E-Eskers — are narrow sinuous ridges formed by subglacial streams flowing through tunnels within the glacier. The gravel deposited in eskers represents stream-bottom sediments. Gravel pits opened in eskers usually display a complex slump-bedded pattern of deposition, reflecting the subsidence of supporting ice walls. The quality of gravel in these deposits is very irregular because of the hydraulic effect of ice movement on streamflow. Nearly all of the eskers shown on the map are associated with the Superior Lobe. The large esker trending north-south from Mirbat Station to Prairie Lake contains indicator rocks of both the St. Louis Sublobe and Superior Lobe and appears to mark the location where the two glaciers confronted one another. This esker is a major source of gravel for road construction in the study area.

Crevasse fillings and ice-contact slopes are included together under the ice-contact (IC) designation on the map. The term crevasse filling is generally applied to those ice-contact deposits (IC) that cannot be readily identified with other categories. They present irregular steeply sloping landforms within the MO-G/R and EM-R units, constructed of bouldery sand and gravel often mixed with inclusions of till.

Several gravel pits are opened in the old bed of Lake Upham north and east of Toivola in the GM-L unit that probably represent ice-contact deposits of the Rainy Lobe. All of the deposits are oriented in the northeast-southwest direction of the Toimi Drumlin Field. They contain a bouldery gravel rich in gabbro, granite, and iron formation rocks covered by a thin overburden of St. Louis Sublobe till and lake sediments.

Prominent ice-contact slopes are also designated IC on the map primarily to help in determining the position and relationship of local ice lobes.

FLUVIAL DEPOSITS — Fluvial gravel deposits are deposited by streams beyond the ice front and are represented by Glacial Outwash GO, Terraces T, and the Alluvial AL units on the map. Lake Beaches B are also included in this category.

GO-Glacial Outwash — This unit presents a broad outwash plain of sand and gravel deposited by overloaded glacial streams. These streams often shifted their channels and merged to fill in large expanses with a plain of uniformly deposited sand and gravel. This type of deposit usually contains better-quality gravel because it was subject to more intensive reworking, and transported longer distances by the streams. Outwash deposits are preferred for mining because they are very uniform as to depth and quality and cover large areas. Several large gravel-pit operations are located in the outwash deposits along the Cloquet River near Burnette at Sunset Lake. Other outwash deposits are found south of Schielin Lake and along Simian Creek.

T-Terraces — Significant gravel deposits occur in the terraces along the lower St. Louis River from Brookston downstream to the White Pine River. Several large commercial gravel pits are opened in one of these terraces along Trunk Highway 33. This terrace is situated in a former channel of the St. Louis River now occupied by Johnson Creek and lower White Pine River. It was formed when increased flow from Lake Upham to the St. Louis River caused the river to start downcutting through its valley fill of sand and gravel. Originally the valley fill was deposited by glacial drainage systems (GO) discharging from the Superior end moraine (EM-R) near Burnette and Sunset Lake to the Cloquet River Valley.

B-Lake Beaches — Sections of a weakly developed beach of Glacial Lake Upham are found scattered between Floodwood and Cotton along the inner side of the MO-G/R unit at elevation 1300 feet. Gravel pits opened in the beach near Birch, Maple Lake, and Floodwood range between five to six feet in depth. The gravel pits contain considerable limestone and shale indicator rocks of St. Louis Sublobe material.

AL-Alluvial Deposits — Alluvial soil of recent stream deposition is found along the St. Louis River Valley and its tributaries. Other postglacial alluvial deposits exist in the old glacial drainageways (DW) beneath a shallow cover of peat.

PEAT DEPOSITS

Peat deposits are represented as the uncolored areas on the map. The broad expanse of peatland oriented in a NE-SW direction across the map consists of peatlands deposited within the bed of Glacial Lake Upham II. This portion of St. Louis County contains the second largest peatland in Minnesota. The Conservations Needs Inventory (1959), published by the U.S.D.A. Soil Conservation Service, indicates St. Louis County has 810,644 acres of peatland covering about 26.6 percent of the county's area. Most of the peatland is

Reed-Sedge Peat

Aquatic peat is usually succeeded by reed-sedge peat which forms from vegetative mats of cattails, reeds, and sedges in shallow water areas. Eventually this plant debris may completely fill the basin. As the peat accumulates and thickens it tends to retain water and raise the water table, thereby perpetuating the peat cycle. Reed-sedge is usually found in the wettest portion of the bog where sedges and grasses predominate. A ribbed-fen pattern is indicative of reed-sedge peat and is the natural drainage route for surface runoff to streams. A typical ribbed-fen pattern consists of a sweeping lineation miles in length cutting through the bog. Each is systematically crossed at right angles by a delicate arrangement of wavy transverse patterns formed by narrow ridges separated by open wet areas. Ribbed-fens are not abundant in the study area. Most of the ribbed-fens are found in the Arlberg Bog within the MO-G/R unit in the south-central part of the map.

Forest Peat (Woody-fibrous)

Forest peat deposits resulted from growth of wetland forests that developed around the perimeter of lake basins and other shallow locations where nutrients became available from water discharging from the surrounding upland into the local basins. Extensive forest-peat development began about 5,000-4,000 years ago when the climate moderated. A heavily forested bog usually denotes uniformity in peat type and depth.

Sphagnum Peat

Sphagnum moss peat began to accumulate about 3,000 years ago in certain areas of a bog where thick accumulations of reed-sedge peat or forest peat blocked off all influence from ground water systems (Boelter & Verry 1977). Sphagnum moss tends to isolate itself by growing upward from the regional ground water table and receives most of its nutrients directly from precipitation and dust. Sphagnum moss characteristically is found associated with a black spruce raised bog pattern that grows outward as a number of rays radiating from a central axis, similar to a feather. Eventually the accumulation of sphagnum forms a local dome or "raised bog" within the larger bog. Often they develop into local watershed divides. Aerial photos and field work by others indicate raised bogs are frequently located over local basins within the bog having the thickest peat section.

Significant Peat Bogs

There are many large peat bogs within the study area associated with Glacial Lake Upham. However, discussion of individual peat bogs will be limited to the Toivola Bog, the largest bog in Lake Upham, and the Arlberg Bog, a large glacial moraine bog.

TOIVOLA BOG — The Toivola Bog is the most extensive bog in the study area. It is located in the northwest quadrant of the map principally between the OS-S and LBS units along the west shore of Glacial Lake Upham. A heavy forest covers the west and northern parts, whereas a more open muskeg-type bog prevails along the east and southeastern parts. The surface of the bog slopes from west to east towards the St. Louis River from elevation 1315 near Silica to elevation 1285 at the Sand River. South of the Devils Islands and the Sand River the bog slopes and drains towards the south from elevation 1290 down to elevation 1250.

The west side of the Toivola Bog is broken by a belt of islands three to four miles wide by twelve miles long containing hundreds of small low islands. Many of the islands are not shown on U.S.G.S. quadrangle maps because they rise only a few feet above the general bog level. The presence of numerous islands and heavy forest cover suggests the surrounding peat is shallow and averages less than five feet in depth in this area.

Strong linear patterns shown on the map marks the route of surface drainage through the bog. Four raised-bog patterns are situated over local depressions in the substratum, indicating the bog has greater depths of peat in the eastern one-half.

ARLBERG BOG — This bog differs from other large bogs shown on the map in that it is completely encircled by the MO-G/R unit of the St. Louis Sublobe, that separates it from the Lake Upham basin. Alignment of the high steeply sloping Highland Moraine along the south side of the bog suggests the Arlberg Bog lake basin was created by an ice thrust of the St. Louis Sublobe when it overrode the Superior moraine. Water levels in the resulting lake stood ten to fifteen feet higher than Lake Upham because of ponding behind the barrier moraine. Subsidence of the barrier moraine eventually caused the outlets to become opened. This explanation of the bog's origin tends to be substantiated by previous tests by others, which indicate this bog contains a much deeper section of peat than other large bogs in this area.

Surface drainage is from south to north and west towards several small feeder streams cutting through the barrier moraine to the St. Louis and Little Whiteface Rivers. Another small unnamed creek drains the eastern end of the bog through an outlet at elevation 1315 east to the Artichoke River. Generally the entire bog slopes from elevation 1330 at the foot of the moraine north to the mentioned outlets at elevation 1315.

Arlberg Bog contains well-developed raised bog and ribbed-fen patterns. The ribbed-fen patterns show a close relationship of surface drainage from the moraine to various outlets of the bog. Raised bogs of sphagnum peat mark the location of watershed divides between each ribbed-fen pattern.

The origin for the Arlberg Bog basin serves to explain why it is now a deep bog rather than a lake as other existing ice block lakes located within the Highland Moraine. It is believed the basin became filled with peat earlier than other lakes in this area because of its manner of formation and close proximity to the ice front.

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GO-Glacial Outwash — This unit presents a broad outwash plain of sand and gravel deposited by overloaded glacial streams. These streams often shifted their channels and merged to fill in large expanses with a plain of uniformly deposited sand and gravel. This type of deposit usually contains better-quality gravel because it was subject to more intensive reworking, and transported longer distances by the streams. Outwash deposits are preferred for mining because they are very uniform as to depth and quality and cover large areas. Several large gravel-pit operations are located in the outwash deposits along the Cloquet River near Burnette at Sunset Lake. Other outwash deposits are found south of Schielin Lake and along Simian Creek.

T-Terraces — Significant gravel deposits occur in the terraces along the lower St. Louis River from Brookston downstream to the White Pine River. Several large commercial gravel pits are opened in one of these terraces along Trunk Highway 33. This terrace is situated in a former channel of the St. Louis River now occupied by Johnson Creek and lower White Pine River. It was formed when increased flow from Lake Upham to the St. Louis River caused the river to start downcutting through its valley fill of sand and gravel. Originally the valley fill was deposited by glacial drainage systems (GO) discharging from the Superior end moraine (EM-R) near Burnette and Sunset Lake to the Cloquet River Valley.

B-Lake Beaches — Sections of a weakly developed beach of Glacial Lake Upham are found scattered between Floodwood and Cotton along the inner side of the MO-G/R unit at elevation 1300 feet. Gravel pits opened in the beach near Birch, Maple Lake, and Floodwood range between five to six feet in depth. The gravel pits contain considerable limestone and shale indicator rocks of St. Louis Sublobe material.

AL-Alluvial Deposits — Alluvial soil of recent stream deposition is found along the St. Louis River Valley and its tributaries. Other postglacial alluvial deposits exist in the old glacial drainageways (DW) beneath a shallow cover of peat.

PEAT DEPOSITS

Peat deposits are represented as the uncolored areas on the map. The broad expanse of peatland oriented in a NE-SW direction across the map consists of peatlands deposited within the bed of Glacial Lake Upham II. This portion of St. Louis County contains the second largest peatland in Minnesota. The Conservations Needs Inventory (1959), published by the U.S.D.A. Soil Conservation Service, indicates St. Louis County has 810,644 acres of peatland covering about 26.6 percent of the county's area. Most of the peatland is forested and is located on State or County lands.

Peat represents accumulations of vegetation residue that is deposited in a water saturated environment that prevents decay. The wet environment and high ground water tables of the glacial lake plains, coupled with a cool, wet climate with low evaporation provide ideal conditions for the formation of peat. According to carbon-14 dates, aquatic peats began to form in Minnesota about 11,000 years ago (Boelter & Verry 1977).

In addition to climate, peatlands evolve in relationship to the interaction of a number of factors controlled by local and regional topography, soils, vegetation, and the water environment receiving the plant residue. Generally the deposition of a peat bog follows a prescribed course of evolution, starting with the deposition of aquatic peat and proceeding to reed-sedge, forest peat, and finally sphagnum peat. Peat and other organic sediments have been identified on the basis of plant origin, using descriptive names such as aquatic, reed-sedge, herbaceous, and sphagnum peat. More recently organic soils have been classified according to their degree of decomposition or fiber content into Sapric, Hemic, and Fibric.

Aquatic Peat

Aquatic peats represent the earliest accumulation of peat in the bog filling process and originates from submerged aquatic plants that accumulate in local lakes. Typically this peat is lower in fiber content than other types of peat because of its fine textured organic matter. In a typical bog profile aquatic peat is usually found buried beneath more fibrous peat near the bottom of the bog.

climate moderated. A heavily forested bog usually denotes uniformity in peat type and depth.

Sphagnum Peat

Sphagnum moss peat began to accumulate about 3,000 years ago in certain areas of a bog where thick accumulations of reed-sedge peat or forest peat blocked off all influence from ground water systems (Boelter & Verry 1977). Sphagnum moss tends to isolate itself by growing upward from the regional ground water table and receives most of its nutrients directly from precipitation and dust. Sphagnum moss characteristically is found associated with a black spruce raised bog pattern that grows outward as a number of rays radiating from a central axis, similar to a feather. Eventually the accumulation of sphagnum forms a local dome or "raised bog" within the larger bog. Often they develop into local watershed divides. Aerial photos and field work by others indicate raised bogs are frequently located over local basins within the bog having the thickest peat section.

Significant Peat Bogs

There are many large peat bogs within the study area associated with Glacial Lake Upham. However, discussion of individual peat bogs will be limited to the Toivola Bog, the largest bog in Lake Upham, and the Arlberg Bog, a large glacial moraine bog.

TOIVOLA BOG — The Toivola Bog is the most extensive bog in the study area. It is located in the northwest quadrant of the map principally between the OS-S and LBS units along the west shore of Glacial Lake Upham. A heavy forest covers the west and northern parts, whereas a more open muskeg-type bog prevails along the east and southeastern parts. The surface of the bog slopes from west to east towards the St. Louis River from elevation 1315 near Silica to elevation 1285 at the Sand River. South of the Devils Islands and the Sand River the bog slopes and drains towards the south from elevation 1290 down to elevation 1250.

The west side of the Toivola Bog is broken by a belt of islands three to four miles wide by twelve miles long containing hundreds of small low islands. Many of the islands are not shown on U.S.G.S. quadrangle maps because they rise only a few feet above the general bog level. The presence of numerous islands and heavy forest cover suggests the surrounding peat is shallow and averages less than five feet in depth in this area.

Strong linear patterns shown on the map marks the route of surface drainage through the bog. Four raised-bog patterns are situated over local depressions in the substratum, indicating the bog has greater depths of peat in the eastern one-half.

ARLBERG BOG — This bog differs from other large bogs shown on the map in that it is completely encircled by the MO-G/R unit of the St. Louis Sublobe, that separates it from the Lake Upham basin. Alignment of the high steeply sloping Highland Moraine along the south side of the bog suggests the Arlberg Bog lake basin was created by an ice thrust of the St. Louis Sublobe when it overrode the Superior moraine. Water levels in the resulting lake stood ten to fifteen feet higher than Lake Upham because of ponding behind the barrier moraine. Subsidence of the barrier moraine eventually caused the outlets to become opened. This explanation of the bog's origin tends to be substantiated by previous tests by others, which indicate this bog contains a much deeper section of peat than other large bogs in this area.

Surface drainage is from south to north and west towards several small feeder streams cutting through the barrier moraine to the St. Louis and Little Whiteface Rivers. Another small unnamed creek drains the eastern end of the bog through an outlet at elevation 1315 east to the Artichoke River. Generally the entire bog slopes from elevation 1330 at the foot of the moraine north to the mentioned outlets at elevation 1315.

Arlberg Bog contains well-developed raised bog and ribbed-fen patterns. The ribbed-fen patterns show a close relationship of surface drainage from the moraine to various outlets of the bog. Raised bogs of sphagnum peat mark the location of watershed divides between each ribbed-fen pattern.

The origin for the Arlberg Bog basin serves to explain why it is now a deep bog rather than a lake as other existing ice block lakes located within the Highland Moraine. It is believed the basin became filled with peat earlier than other lakes in this area because of its manner of formation and close proximity to the ice front.

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