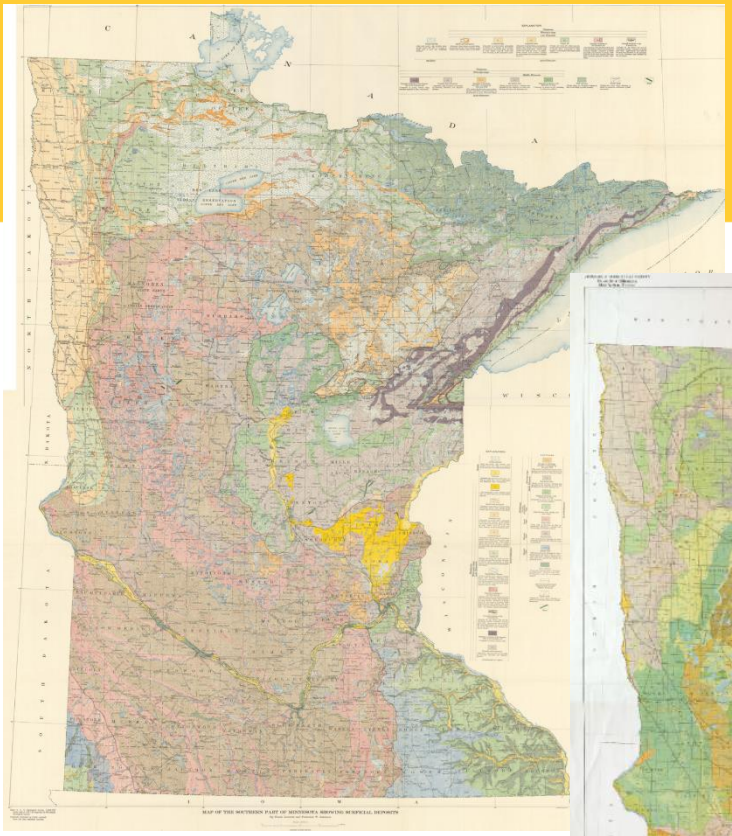
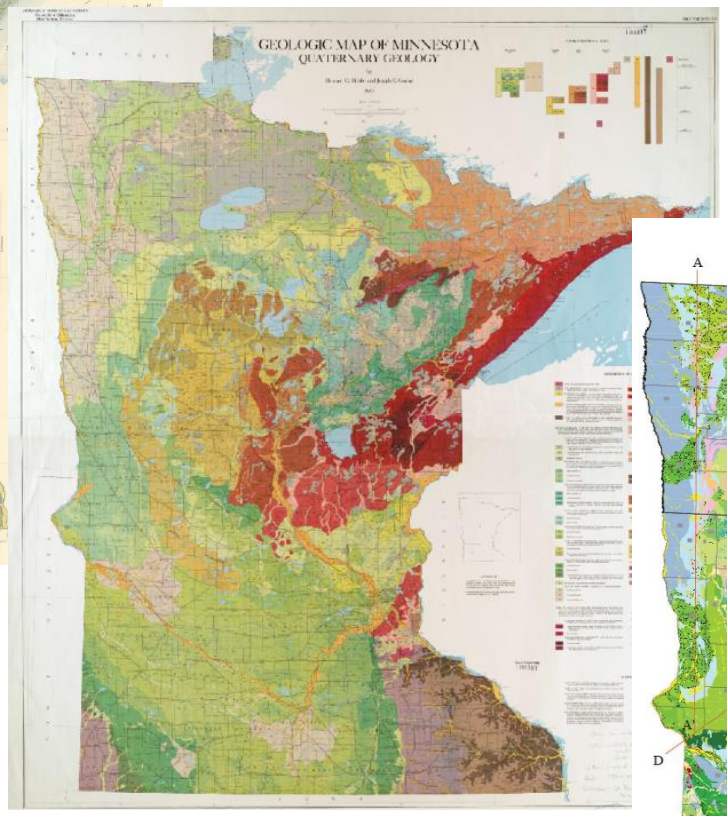
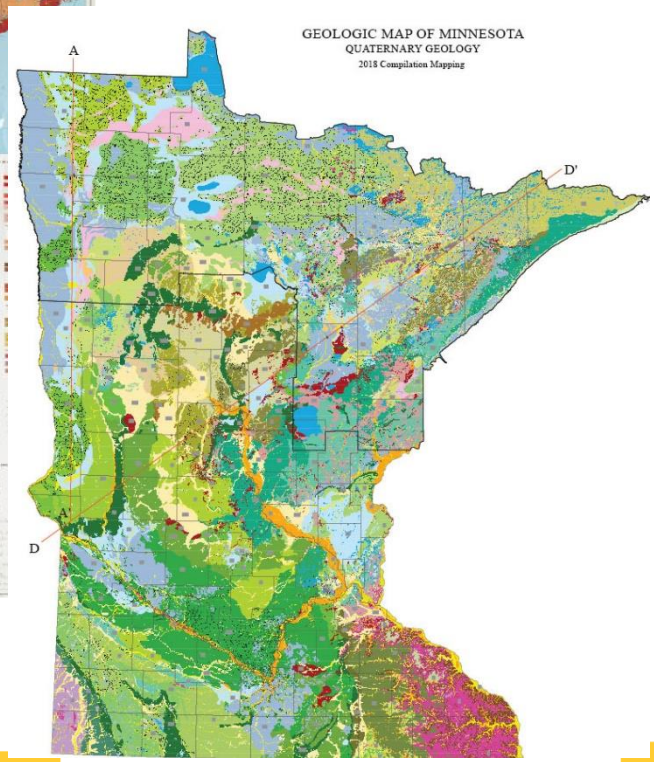
The “Old Gray Till”
It ain’t what it used to be. . . .







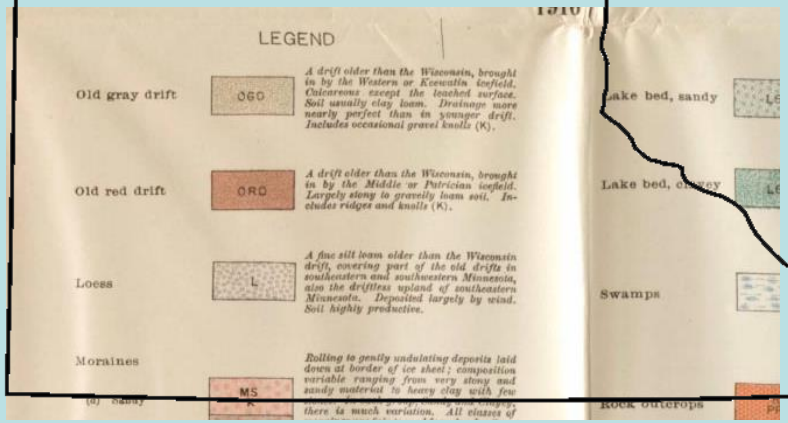
Minnesota Ground Water Association
April 25, 2019
Barbara Lusardi, Minnesota Geological Survey

UNIVERSITY OF MINNESOTA

Northwest

Northeast

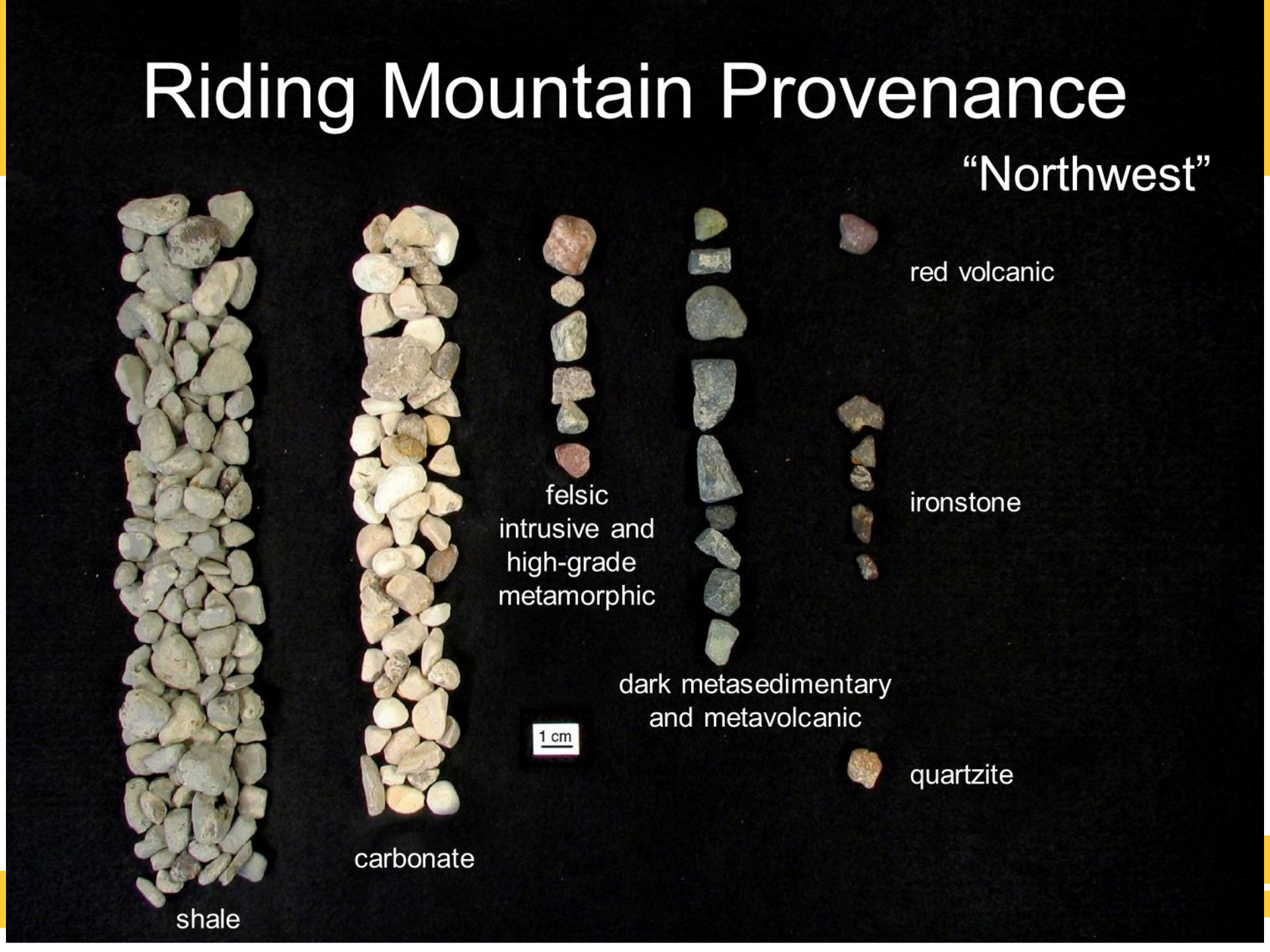
In the early days. . .




felsic intrusive and high-grade metamorphic
dark metasedimentary and metavolcanic
mafic intrusive high-grade meta
red volcanic
quartzite
sandstone
ironstone
1 cm
Superior Provenance
"Northeast"

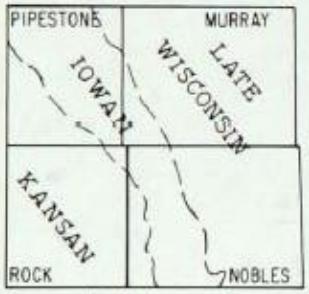
Riding Mountain Provenance

"Northwest"

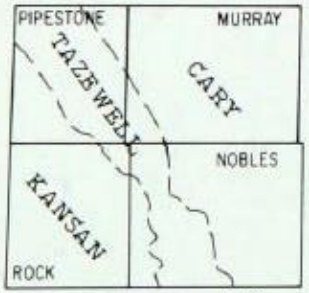


by description

Gray Sandy Till .....
Stratified Keewatin Drift .....
"Patrician" Drift .....
General .....
Red Sandy Till .....
Brown Sandy Till .....
Stratified Patrician Drift ...



by Stage



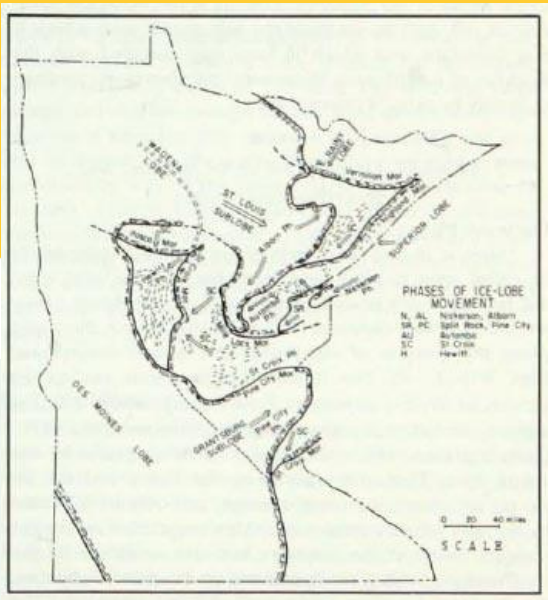


Figure VII-4. Composite map showing main phases of Wisconsin glaciation in Minnesota. Short dashes show drumlin fields.

by Phase

Des Moines lobe
D-nu New Ulm phase
Wadena lobe
W-i Itasca phase
W-h Hewitt phase
W-gf Granite Falls phas
Rainy lobe
R-v Vermilion phase
R-sc St. Croix phase
Superior lobe
LD Lake Duluth
S-n Nickerson phase
S-sr Split Rock phase
S-a Automba phase
S-sc St. Croix phase
S-hc Hawk Creek phase

From then until now. . .

by Geomorphic Expression

Qtc

Qtm

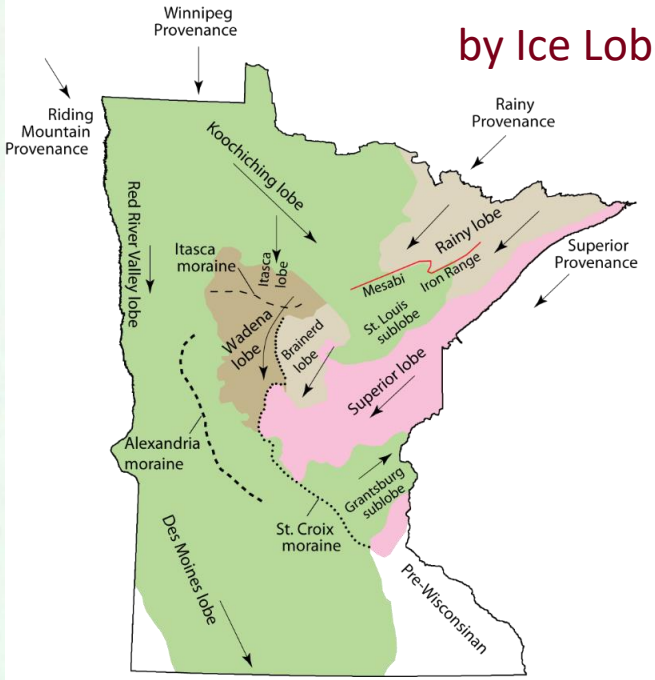
Qtw

Collapsed—Diamicton as above surface collapsed over an ice ca to be subglacial drainageway *sediment, collapsed.*

Aligned hills—Diamicton as abov be a demarcating margin of act ice-marginal processes includi and debris flows. *Moraine.*

Washed—Diamicton as above; vaguely streamlined. Interpre

by Ice Lobe



St. Louis–sublobe till
Des Moines–lobe till
Rainy–lobe till
Superior–lobe till
Winnipeg-lobe till
Old Rainy-lobe till
Granite Falls Till
Hawk Creek Till

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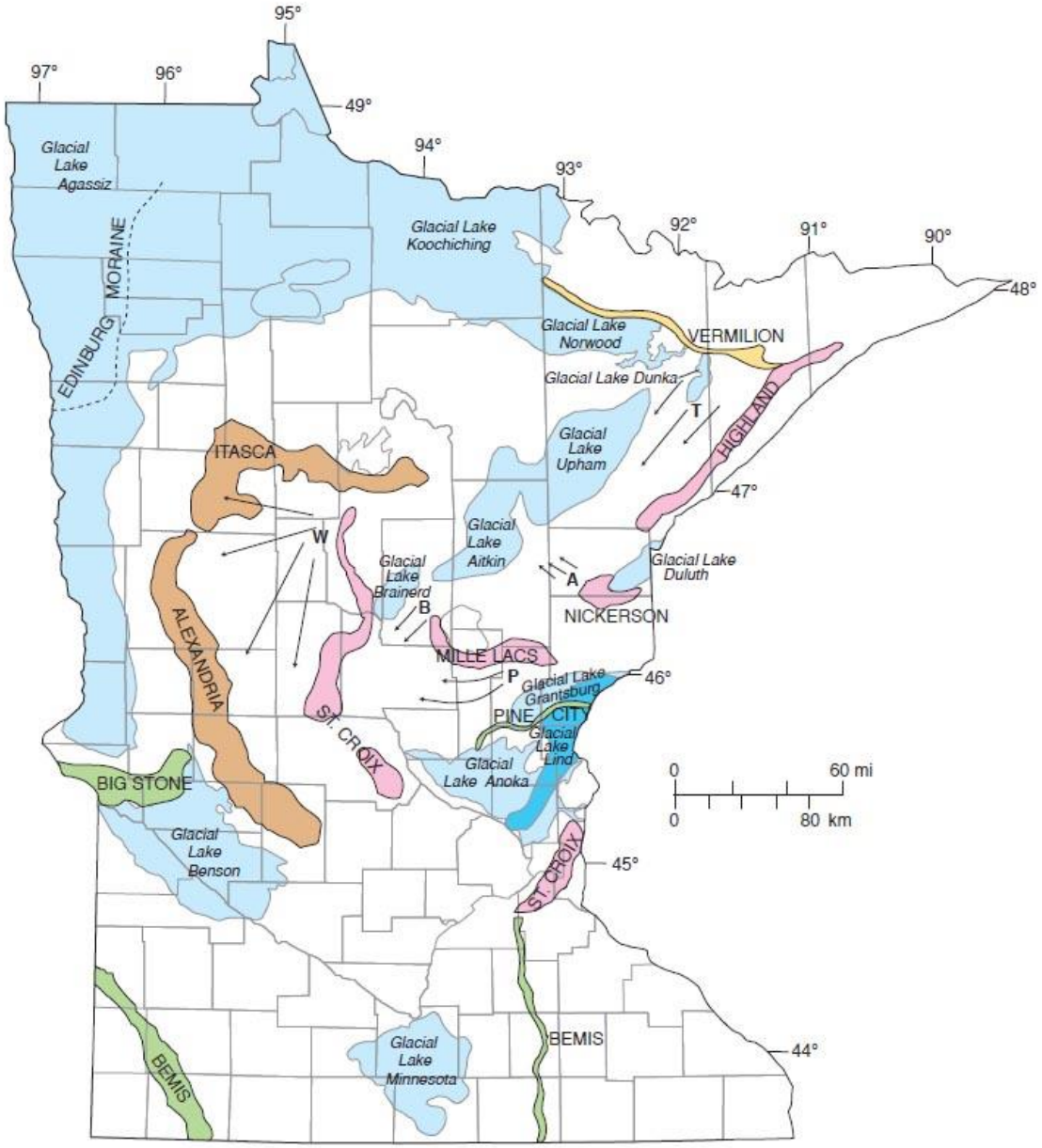


by Ice Lobe and Moraine Association

DEPOSITS ASSOCIATED WITH THE RAINY LOBE
WISCONSINAN)—*brown to gray noncalcareous dr*
igneous and metamorphic rocks of the Canadian Shield

VERMILION MORAINE ASSOCIATION—*c*
Mille Lacs-Highland moraine association; t
stony, containing only trace amounts of clay

rvg — *Ground moraine; in most of this area, the till*
hilly terrain of scoured bedrock.

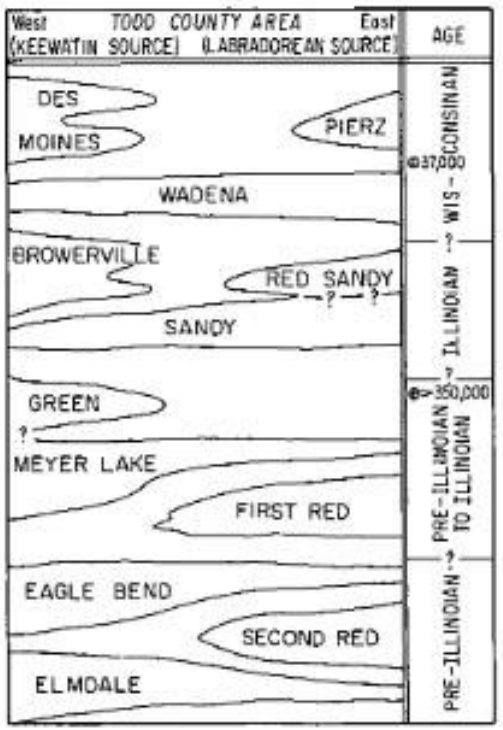
rve — *End moraine; moraine ridges are narrow an*
features.

NASHWAUK MORAINE ASSOCIATION—*n*
till. No end moraine recognized; ice margin u
implies that the ice retreated far enough nort
develop a proglacial lake; the ice then ready
ment, incorporating it into the till.

rng — *Ground moraine; includes areas of thin drift*

rms — *Stagnation moraine; some of the hilly topo*
unit may be inherited from the underlying
tion; some topographic expression is c
surface.

ST. CROIX MORAINE ASSOCIATION—*til*
stony; near the St. Croix moraine it locally in



by Name
(formal and informal)

ciated Group	Associated Formation*
t River group	Huot and Falconer Formations (RRV01 and RRV01)
ke River group	Upper Red Lake Falls Formation (RRV03)
ke River group	Lower Red Lake Falls Formation (RRV04)
Goose River group	St. Hilaire Formation (RRV06 and RRV07)
Goose River group	Dahlen Formation and Heiberg till (RRV08 and RRV09)
Lake Tewaukon group	Gardar Formation (RRV13 and RRV14)
Otter Tail River group	RRV10, RRV11 and RRV12
Crow Wing River group	Marcoux Formation (RRV15, RRV16 and RRV17) and RRV18

hta

Sandy loam diamicton (includes mapped units Qht, Qp)—Pebbly generally yellowish-brown (10YR 5/4) where oxidized and olive-b 3/1) where unoxidized. *Glacial till.*

Pre-Late Wisconsinan (?)

Unnamed formation—Sediment deposited by Riding Mountain-prov Contains gray shale fragments and abundant Cretaceous limestone 8; Table 2). Approximately 25 feet (7.6 meters) of this unit were e in rotary-sonic core WAD-1 (Fig. 5). Because this stratigraphi not been recognized in other regional studies, units *utrm* and *us* identified on cross sections within the immediate vicinity of tl which they were sampled. This unit may correlate to the Shey formation of Harris and Berg (2006).

Sand to gravelly sand—*Outwash.*

Clay loam diamicton—Pebbly, unsorted; calcareous; very dark gra (5Y 3/2). *Glacial till.*

Pre-Late Wisconsinan

Browerville Formation (Johnson and others, 2016)—Sediment de Winnipeg sourced ice. Dark gray Cretaceous limestone is a ke of this unit (Fig. 8; Table 2). Stratigraphic data from water-w and rotary-sonic cores indicate that there are multiple till layers t

Over 100 lithostratigraphic units that have been identified in Minnesota.

MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, *Director*

QUATERNARY LITHOSTRATIGRAPHIC UNITS OF MINNESOTA

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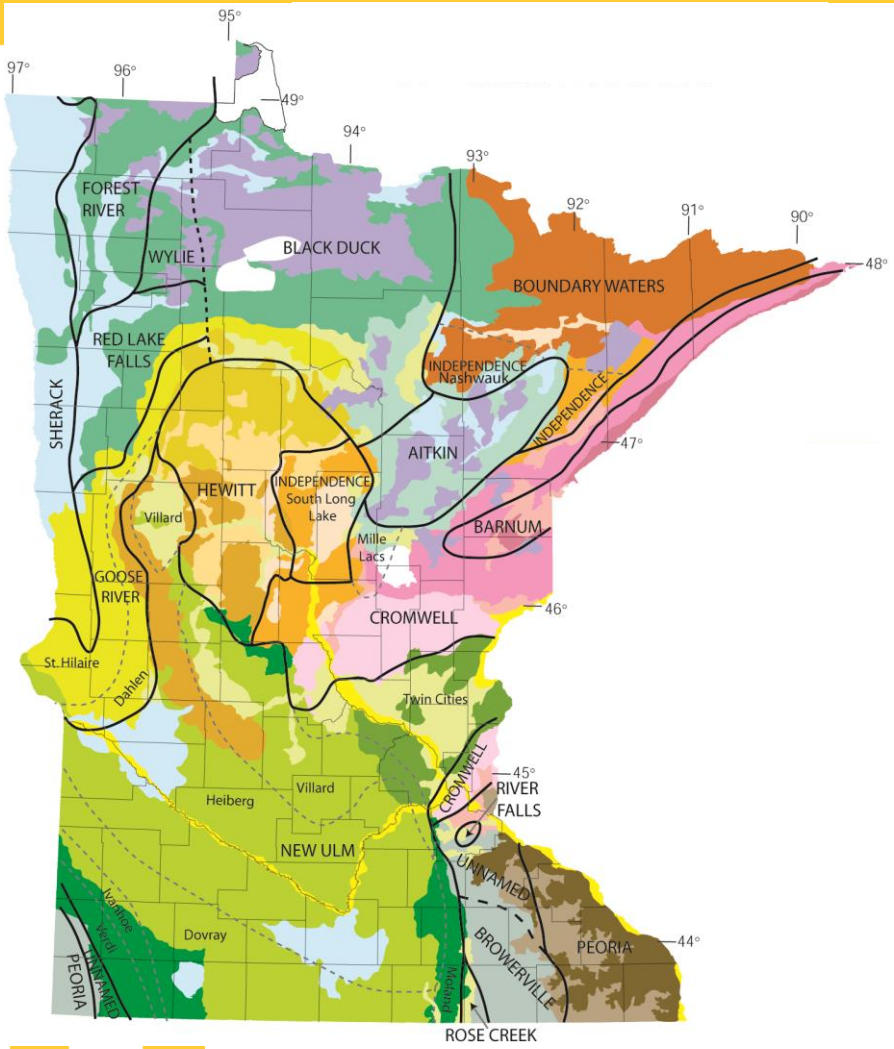
Saint Paul — 2016



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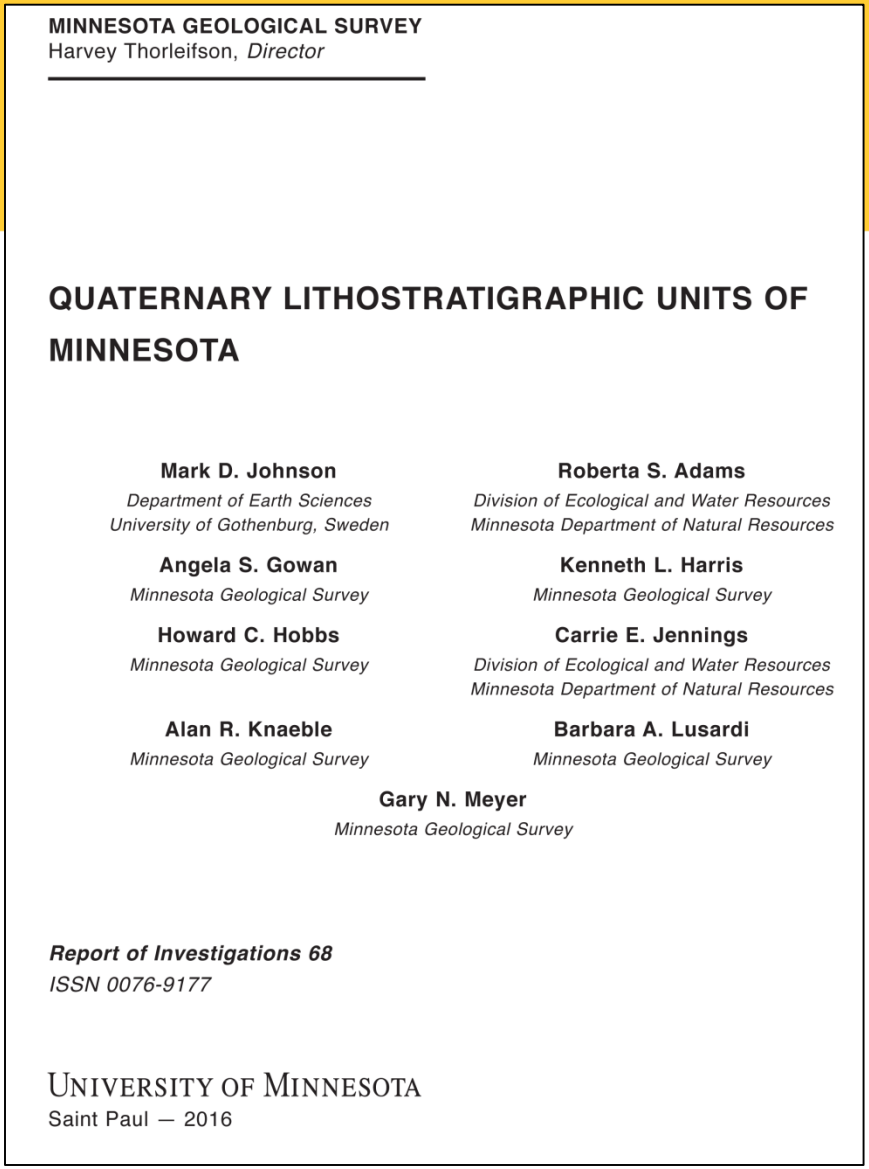


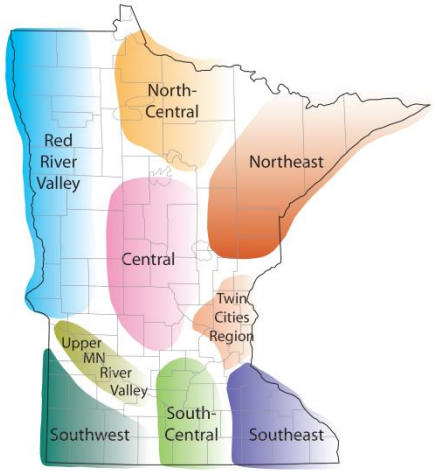
- North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 2005)
- 80 units are accepted and 47 are formally defined, revised, or redefined in this report.
- Some units are abandoned in this report.
- 33 units are recommended to be formally named in the future.

Minnesota Quaternary Lithostratigraphy

Global Correlations	Red River Valley	Upper Minnesota River Valley	Southwest	South-Central	Southeast	Twin Cities Region	Central	North-Central	Northeast
MIS 2-5	SHERACK; POPLAR RIVER; BRENNA; FOREST RIVER: Huot, Falconer; WYLIE; RED LAKE FALLS: Upper, Lower; ARGUSVILLE; GOOSE RIVER: St. Hilaire, Dahlen; NEW ULM: Heiberg, Hawley, Villard, New York Mills; JAMES RIVER; GARDAR; BUFFALO RIVER; CROW WING RIVER: Sebeka, Marcoux	GOOSE RIVER: Dahlen; NEW ULM: *glacial lake Benson sediment*, Heiberg, Villard, Dovray, Ivanhoe, Verdi, New York Mills; 'till unit #7'; 'till unit #8'	NEW ULM: Dovray, Ivanhoe, Verdi; PEORIA	NEW ULM: *glacial lake Minnesota sediment*, Heiberg, Villard, Dovray, Garden City, Moland; TRAVERSE DES SIOUX	NEW ULM: Moland; PEORIA; CROMWELL; ROXANA SILT; TRAVERSE DES SIOUX	NEW BRIGHTON; NEW ULM: Twin Cities, Falun; HILLSIDE SAND; Coon Creek; Sunrise; CROMWELL	AITKIN: *glacial lake Aitkin II sediment*, Nelson Lake, *glacial lake Aitkin I sediment*; HEWITT; INDEPENDENCE: *glacial lake Brainerd sediment*, South Long Lake; Mille Lacs; CROMWELL	BLACKDUCK; INDEPENDENCE	AITKIN: *glacial lake Aitkin II sediment*, Prairie Lake, Alborn, *glacial lake Aitkin I sediment*; BOUNDARY WATERS; BARNUM: Knife River, Wrenshall, Moose Lake, Mahtowa; Nashwauk; INDEPENDENCE; CROMWELL
MIS 6-18	SHEYENNE RIVER; BROWERVILLE; GERVAIS; unnamed unit(s); unnamed unit(s); unnamed unit(s); unnamed unit(s)	'till unit #9' HAWK CREEK; *southern part*: 'till unit #10', 'till unit #11'; *northern part*: 'gastropod silts', WHETSTONE	'SWRA 1'; 'SWRA 2'; 'SWRA 3'; 'SWRA 4'; 'SWRA 5'; 'SWRA 6'; 'SWRA 7'	BROWERVILLE? HAWK CREEK HENDERSON; BROWERVILLE; unnamed unit(s); unnamed unit(s); unnamed unit(s); unnamed unit(s); unnamed unit(s); unnamed unit(s); ELMDALE	BROWERVILLE? unnamed unit(s) LOVELAND; BROWERVILLE; Bennington; ROSE CREEK; unnamed unit(s); ELMDALE	RIVER FALLS; unnamed unit(s); unnamed unit(s)	BROWERVILLE; unnamed unit(s); LAKE HENRY Sauk Centre; ST. FRANCIS; LAKE HENRY Meyer Lake; ST. FRANCIS; EAGLE BEND; SHOOKS; ELMDALE	BROWERVILLE; SAUM; FUNKLEY; ST. FRANCIS; EAGLE BEND; BIG FORK; SHOOKS; WIRT; MULLIGAN	
MIS >18			'SWRA 8'; 'SWRA 9'			PIERCE			

Legend

- silt and clay
- silt
- sand and/or gravel
- Riding Mountain provenance diamicton
- mixed Riding Mountain and Winnipeg
- northwest with reworked Superior
- Winnipeg provenance diamicton
- mixed Winnipeg and Rainy
- Rainy provenance diamicton
- mixed Rainy and Superior
- Superior provenance diamicton
- NEW ULM formation
- Verdi member



supported by Great Lakes Mapping Coalition 2010-2011

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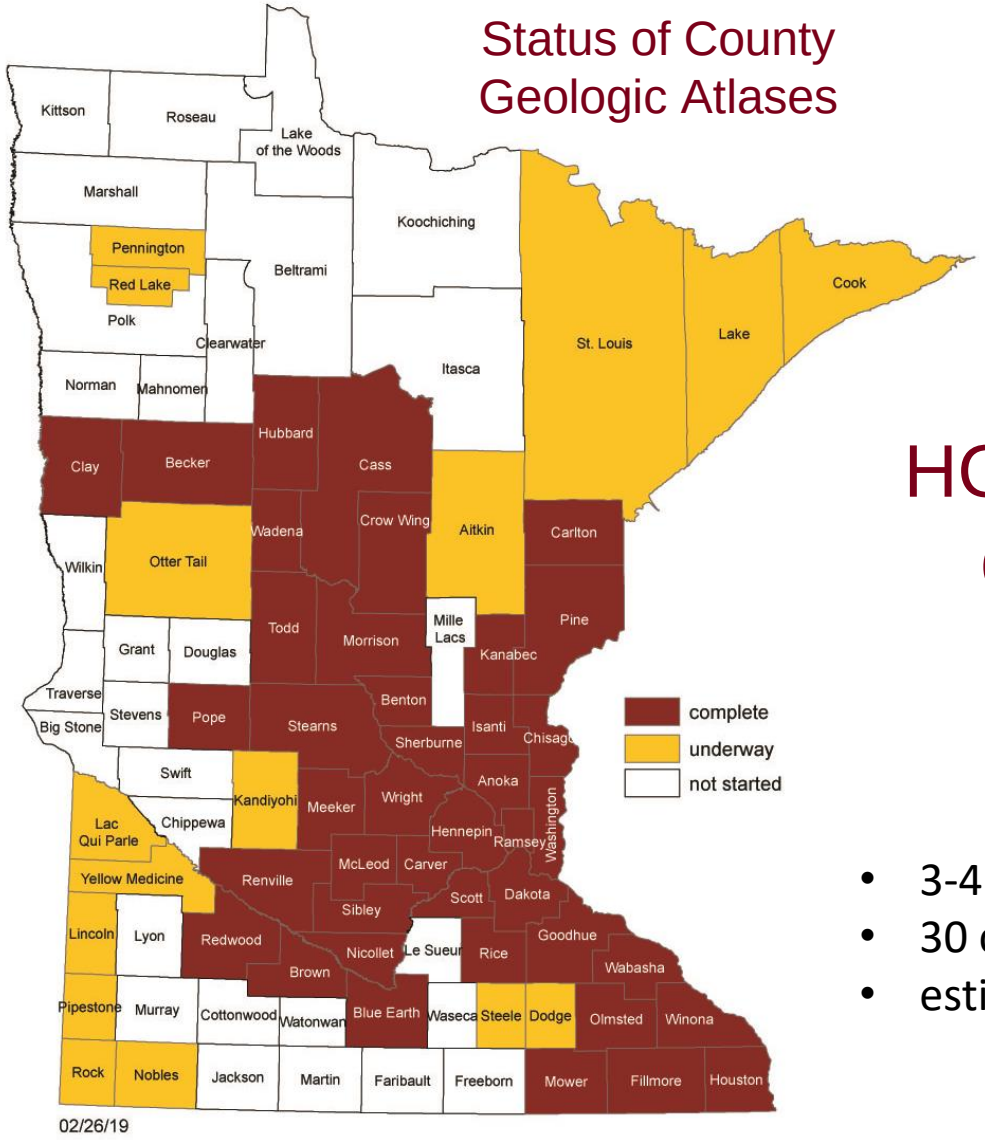
Who are we?

And WHY do we care?

Part of the University of Minnesota, the MGS provides **systematic geoscience information** to support stewardship of **water, land, and mineral resources**.

Status of County Geologic Atlases



HOW do we do that?

- 3-4 years per county
- 30 counties remaining
- estimate 10 years

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

CLEAN WATER LAND & LEGACY AMENDMENT

DEPARTMENT OF NATURAL RESOURCES

USGS

UNIVERSITY OF MINNESOTA

UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

Prepared and Published with the Support of
THE MCLEOD COUNTY BOARD OF COMMISSIONERS AND
THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATERS

COUNTY ATLAS SERIES
ATLAS C-20, PART A
Plate 4—Surficial Geology

McLeod County Geologic Atlas

Links to PDF images of published maps, Part A

Plate 1, Data-Base Map

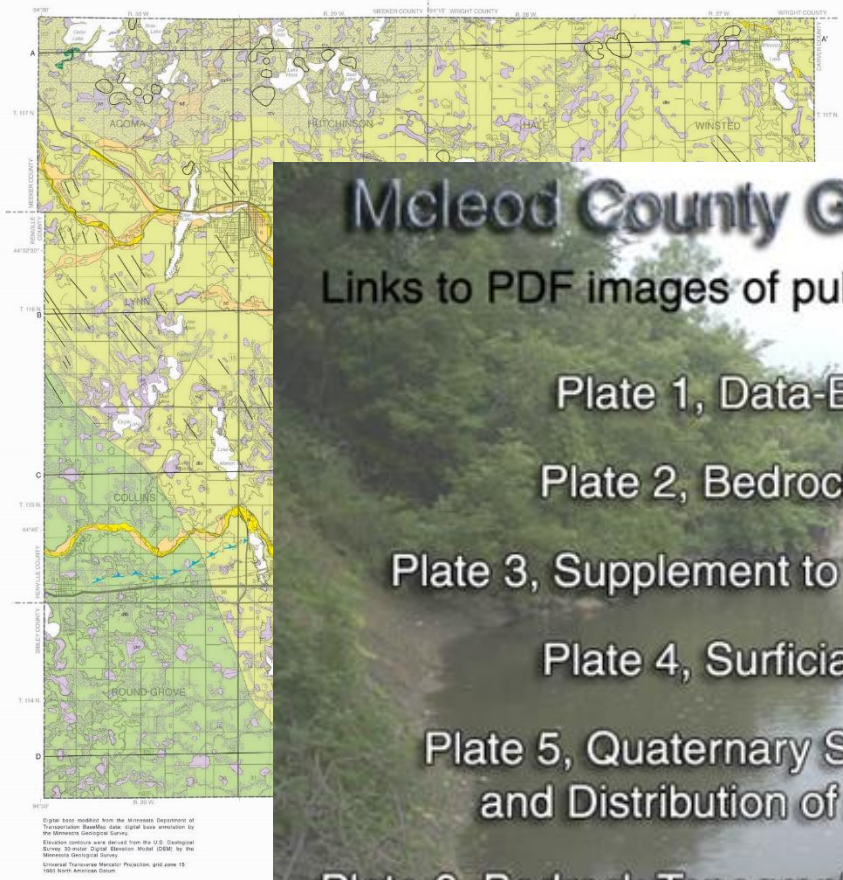
Plate 2, Bedrock Geology

Plate 3, Supplement to Bedrock Geology

Plate 4, Surficial Geology

Plate 5, Quaternary Stratigraphy and Distribution of Sand Bodies

Plate 6, Bedrock Topography, Depth to Bedrock and Mineral Endowment



Digital base modified from the Minnesota Department of Transportation BaseMap data. digital base annotation by the Minnesota Geological Survey.

Elevation contours were derived from the U.S. Geological Survey 30-meter Digital Elevation Model (DEM) by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

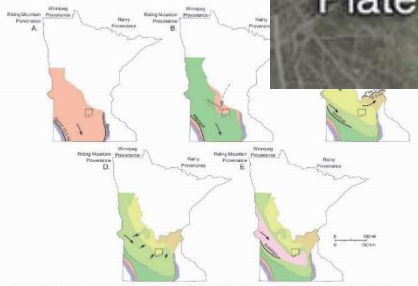


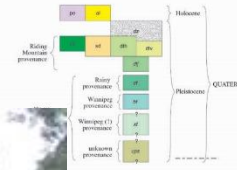
Figure 1. Moraine names are from Patterson and others (1999); dates are from Clayton and Moran (1982); dashed lines are inferred.
A. About 14,000 years ago, Des Moines-lobe ice advanced from the northwest (salmon) forming the Bemis moraine. Older advances (purple) deposited tills at least 20,000 years ago and may include sediments that are much older (possibly units dx, dc, and unit).
B. Between 13,500 and 12,500 years ago, ice again advanced from the northwest forming the Altamont moraine (unit dt). The ice was deflected around stagnant ice that formed the Alexandria moraine (unit et; Rainy Provenance—direction shown by dashed arrow) forming the pronounced hook through McLeod County.
C. Later, two separate ice streams advanced at the same time—one from the Winnipeg provenance (unit dtw) and another from the Riding Mountain region (unit dtr). The northern ice stream was deflected to the northeast, forming the Grantsburg sublobe and the Pine City moraine.
D. Eventually, the Winnipeg ice stream (unit dtw) lost its source, while the ice from the west continued to flow (unit dtr). It expanded over and around stagnating ice that still covered much of McLeod County.
E. Another shift in the upstream source area brought the final pulse of shale-rich till (pink) from the Riding Mountain provenance into southern Minnesota, but not into McLeod County.

SURFICIAL GEOLOGY

By
Barbara A. Lusardi and Carrie E. Jennings

2009

CORRELATION OF MAP UNITS



...ments. The other deposits were derived from a more northerly source and ...tain abundant crystalline rocks (basalt and granite) and various amounts of ...nate rock fragments (limestone, dolostone, and fossil fragments; Fig. 4). These ...sidered, older deposits were sampled only in drill holes and therefore do not ...ear on the map. They are mantled by younger deposits of the Des Moines lobe. ...escription of these older deposits is included herein for comparison with these ...lying deposits and for use when interpreting the cross sections (Plate 5).

...clay loam (Pleistocene; shown only on Plate 5, cross section)—Pebbly, unsorted, ...h scattered cobbles and rare boulders. Shale clasts generally compose less than 7 ...ercent of the very coarse-grained (1 to 2 millimeters) sand fraction. This unit ...milar to shale-bearing tills described above. It was deposited by ice advancing ...o the northwest. The path of this ice was likely deflected by the presence of ...ning ice of an earlier advance depositing unit et (Fig. 1). This unit occurs in ...subsurface only in the southern and eastern portions of the county. Surface ...forms, such as the valley of Buffalo Creek and ice marginal ridges near Stewart ...Plain, may be related to this advance. This unit was sampled at depth in several ...t holes. *Glacial till.*

...ay loam (Pleistocene; shown only on Plate 5, cross section)—Pebbly, unsorted, with ...y cobbles and rare boulders. Shale clasts generally compose less than 7 percent ...he very coarse-grained (1 to 2 millimeters) sand fraction. Pockets of silt, sand, ...gravel occur in places. The sediment is generally sandier and contains more ...stalline rock fragments (basalt, greenstone, granite) than sediments derived from ...northwest. This unit occurs only in the northwestern corner of McLeod County, ...was sampled in rotary-sonic core McLeod #1 (Plate 5, Figs. 1, 4). *Glacial till.*

...leistocene; shown only on Plate 5, cross section)—Sandy, pebbly, unsorted, ...h scattered cobbles and rare boulders. Shale clasts generally compose less than ...rcent of the very coarse-grained (1 to 2 millimeters) sand fraction. Contains ...sidual limestone and fossil fragments. Pockets of silt, sand, and gravel occur ...places. This unit was sampled in rotary-sonic core McLeod #2 (Plate 5, Figs. 2, ... *Glacial till.*

...stocene; shown only on Plate 5, cross section)—Pebbly, unsorted, with scattered ...bles and rare boulders. Shale clasts generally compose less than 2 percent of ...very coarse-grained (1 to 2 millimeters) sand fraction. Pockets of silt, sand, and ...el occur in places. Sediment recovered from this core is extremely consolidated, ...cating that it has been compressed by the weight of overlying ice and sediment ...a long period of time. This unit was sampled in rotary-sonic core McLeod #2 ...e 5, Figs. 2, 4). *Glacial till.*

...ertiated Pleistocene sediment (shown only on Plate 5, cross section)—This ... includes all sediment below the lowermost identified till unit and associated ...erlying sand. Although some water wells extend below this boundary, the data ...too sparse to make meaningful correlations.

ACKNOWLEDGMENT

...bbs drilled the auger holes and described many of the nearly 406 samples ...d County.

REFERENCES

...son, S., 1982, Chronology of the late Wisconsinan glaciation in middle North ...ernary Science Reviews, v. 1, no. 1, p. 55-82.

...99, The geomorphology and interpreted surficial geology of the South Fork ...ver watershed: Minnesota Geological Survey Open-File Report 09-1, scale ...

... Soil survey of McLeod County, Minnesota: U.S. Department of Agriculture, ...ces Conservation Service, scale 1:20,000.

...arbie, A.R., Gran, R.E., and Phippen, S.J., 1999, Surficial geology, pl. 1, *of* ...ed., Regional hydrogeologic assessment, Quaternary geology Upper Minnesota ...Minnesota: Minnesota Geological Survey Regional Hydrogeologic Assessment ...Scale 1:200,000.

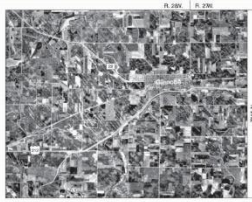


Figure 5. Aerial photograph showing the southeasterly trend of linear features. The area of the photo is indicated on the map. The more prominent features are shown on the map. Mach Hurd aerial survey photograph EKA-439, April 8, 1977 (1:80,000 original scale).

Table 1. Physical characteristics of glacial deposits in the McLeod County region.

SOURCE AREA	NORTHWEST	NORTH-NORTHWEST	NORTH-NORTHEAST
PROVENANCE	RIDING MOUNTAIN	WINNIPEG	RAINY
LOBE	Des Moines (units dtr, dtw, dtj)	Pre-Wisconsin (unit id) (unit ot)	Wadena Rainy (unit of) Bemidji
TILL TEXTURE	Sandy loam to clay loam	Loam to silt loam to clay loam	Sandy loam to loamy sand
TILL COLOR Oxidized Unoxidized	Light olive-brown Gray to dark gray	Light olive-brown Gray to dark gray	Yellow-brown Gray to brown-gray
PEBBLE TYPE Carbonate Gray-green rock Red biotite Gray shale	Common Uncommon to common Absent to rare Uncommon to abundant	Common to abundant Uncommon to common Absent to uncommon Absent to uncommon	Uncommon to common Uncommon to common Rare to uncommon Absent

Every reasonable effort has been made to ensure the accuracy of the factual data on which this map interpretation is based; however, the Minnesota Geological Survey does not warrant or guarantee that there are no errors. Users may wish to verify critical information; sources include both the references listed here and information on file at the offices of the Minnesota Geological Survey in St. Paul. In addition, effort has been made to ensure that the interpretation conforms to sound geologic and cartographic principles. No claim is made that the interpretation shown is rigorously correct, however, and it should not be used to guide engineering-scale decisions without site-specific verification.

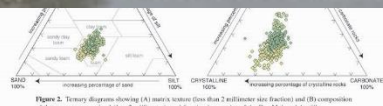


Figure 2. Ternary diagrams showing (A) matrix texture (less than 2 millimeter size fraction) and (B) composition of the very coarse-grained (1 to 2 millimeter) sand fraction in samples of the Des Moines lobe tills.

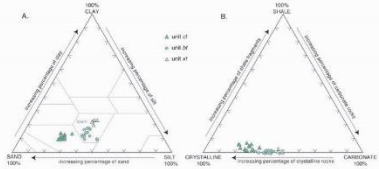


Figure 4. Ternary diagrams showing (A) matrix texture (less than 2 millimeter size fraction) and (B) composition of the very coarse-grained (1 to 2 millimeters) sand fraction in samples of the older till units (shown only on Plate 5, cross section).

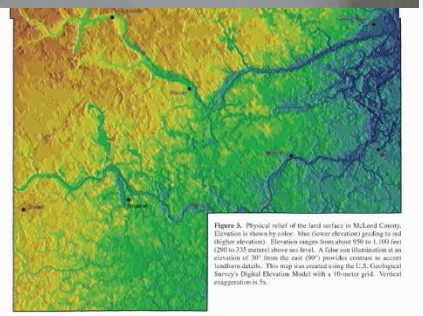


Figure 3. Physical relief of the land surface in McLeod County. Elevation is shown by color: blue (lower elevation) grading to red (higher elevation). Elevation ranges from about 950 to 1,160 feet (290 to 335 meters) above sea level. A false sun illumination at an elevation of 20° from the east (90°) provides contrast to accent landform details. This map was created using the U.S. Geological Survey's Digital Elevation Model with a 10-meter grid. Vertical exaggeration is 5x.

Minnesota AG's lawsuit asks: What did 3M know about PFCs?

Court filing cracks open 3M's internal research on PFCs, raises new questions about risks for residents.

By Josephine Marcotty and Jennifer Bjorhus Star Tribune staff writers | NOVEMBER 27, 2017 — 11:42AM

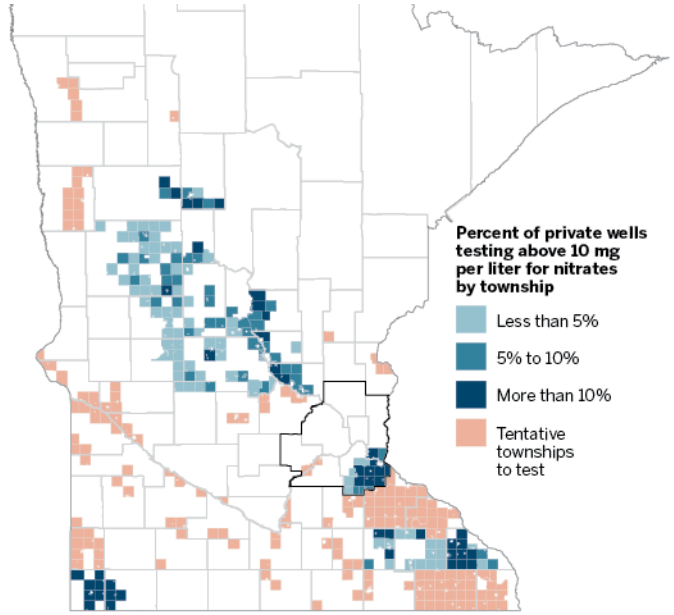
Deep-water wells in neighboring suburbs helped dry up White Bear Lake

Tapping by a few cities around White Bear Lake accounted for much of the drop in the lake's level, the DNR says; lawn watering is less of a culprit.

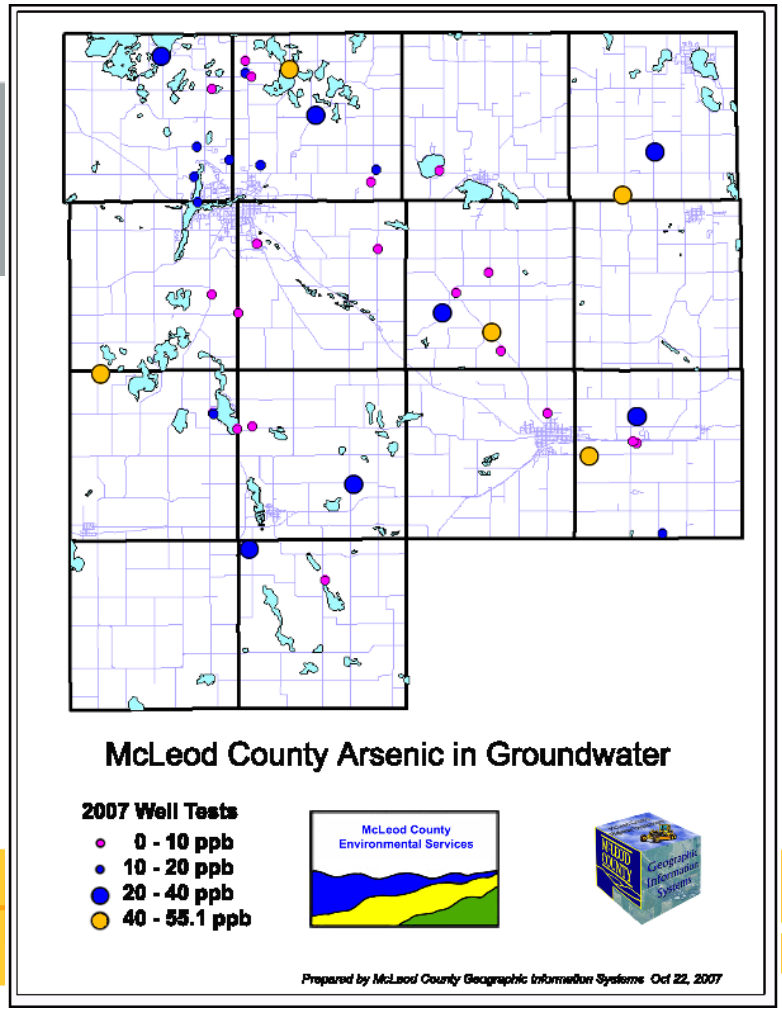
By David Peterson Star Tribune | NOVEMBER 7, 2017 — 10:00AM

Dayton updates plan for lowering nitrate levels in water

By STEVE KARNOWSKI Associated Press | MARCH 6, 2018 — 4:51PM

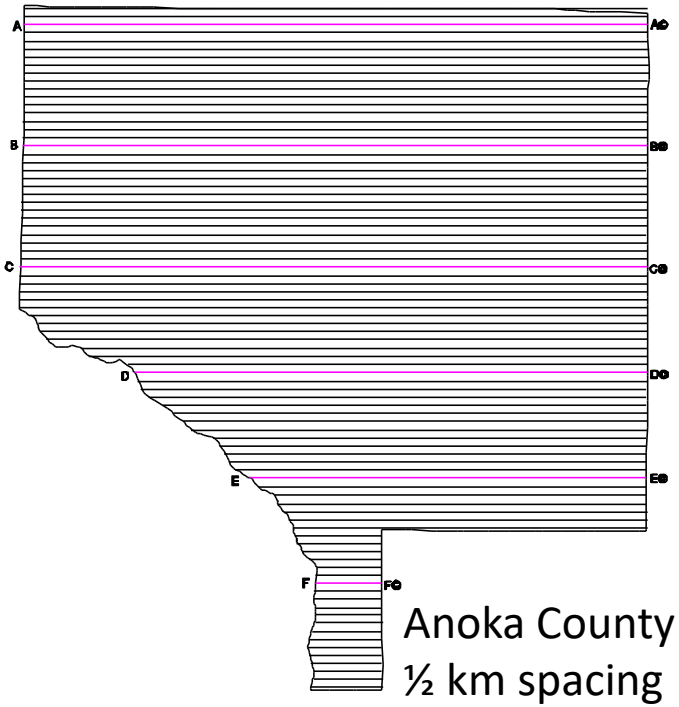


Source: Minnesota Department of Agriculture RAY GRUMNEY • Star Tribune

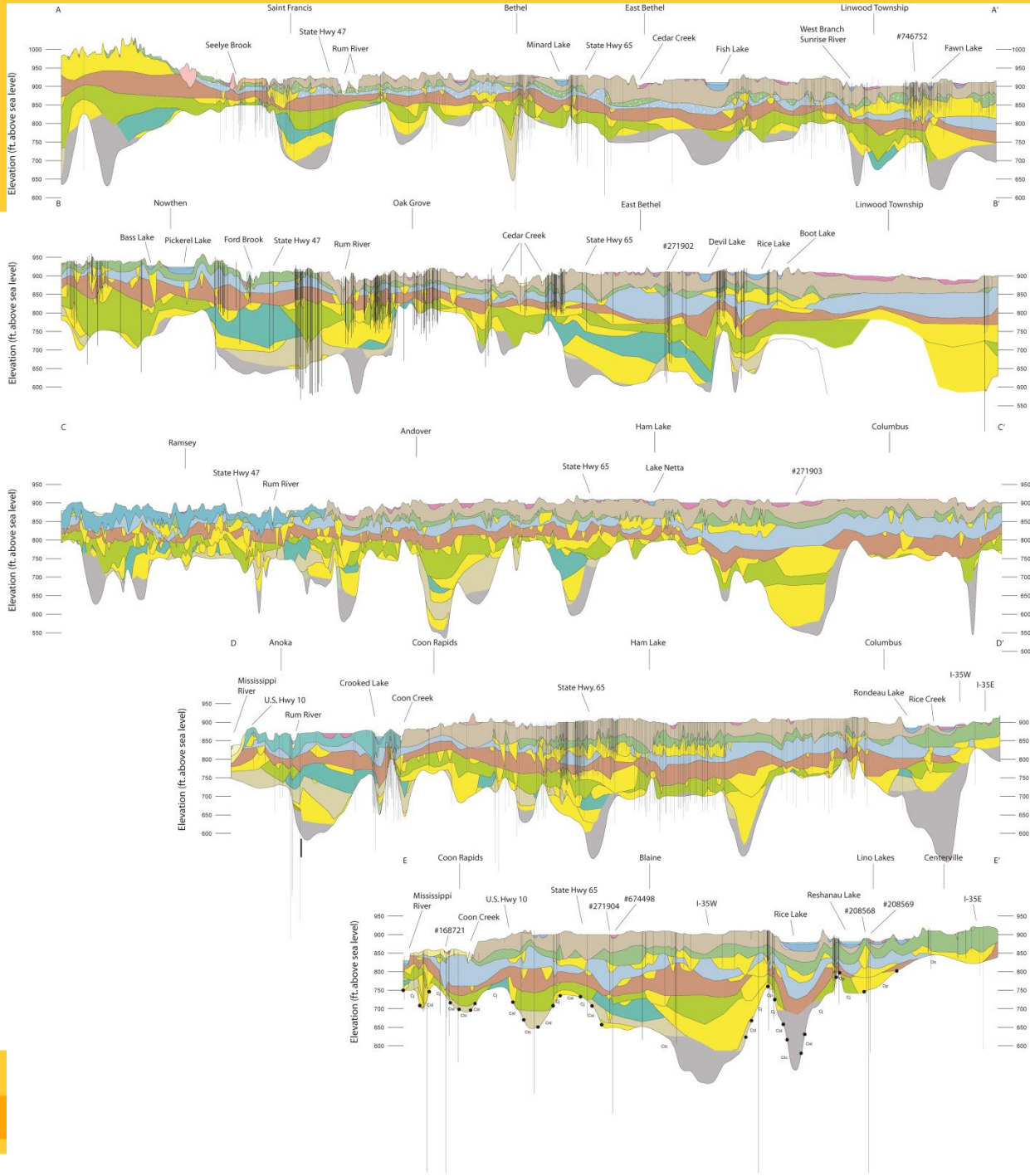


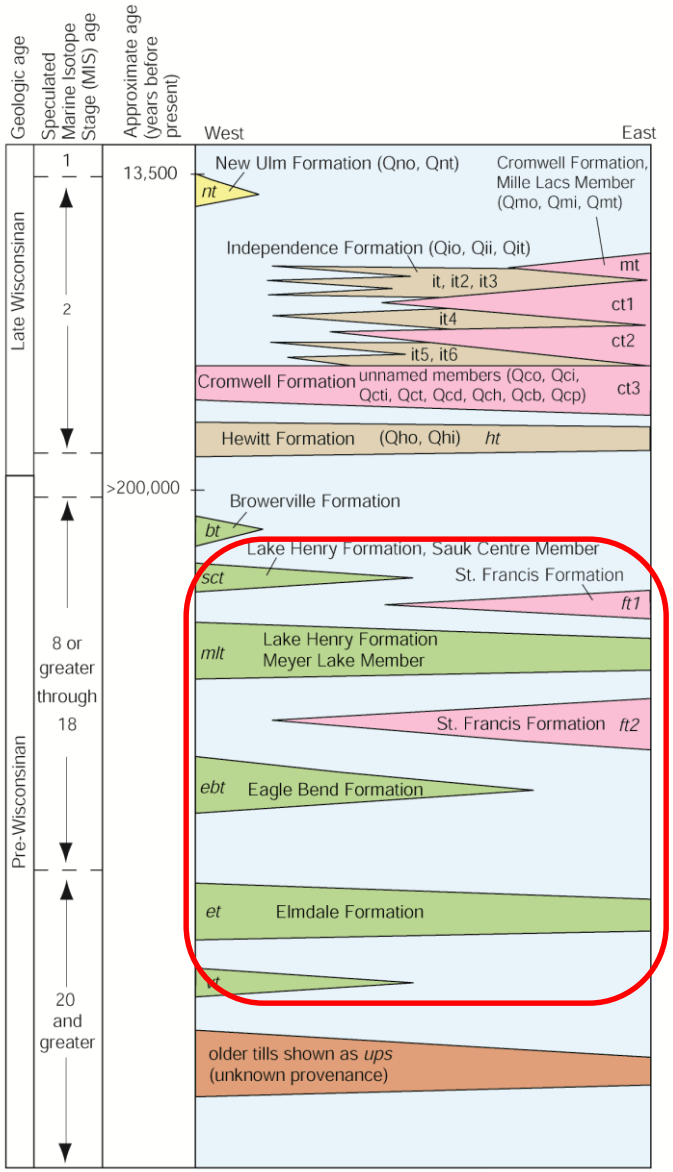
Quaternary Stratigraphy

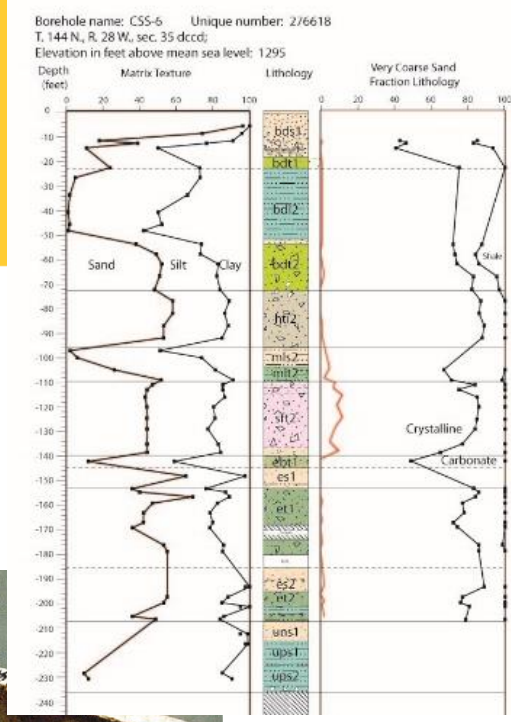
using cross-section lines spaced 1 km apart

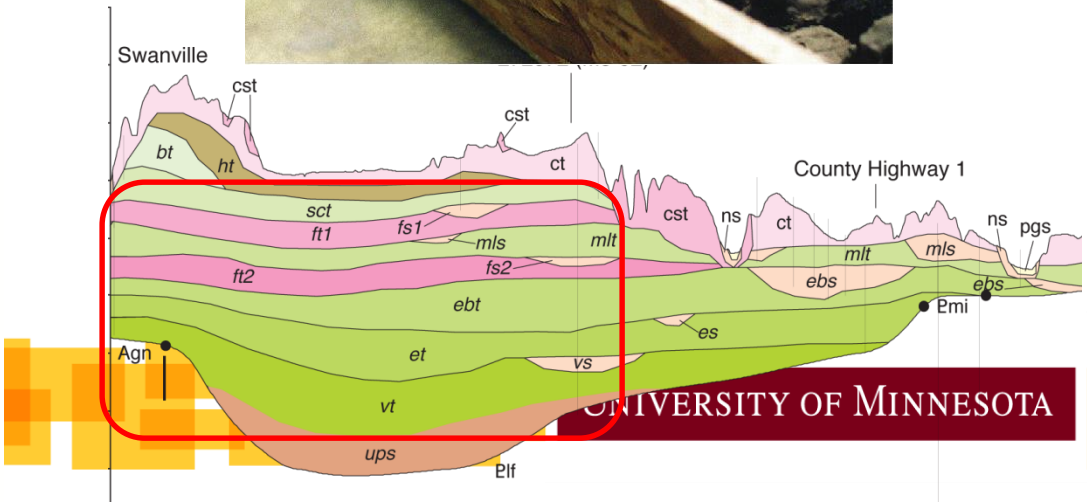


Anoka County
½ km spacing









Department of Natural Resources Groundwater Atlas (Part B)

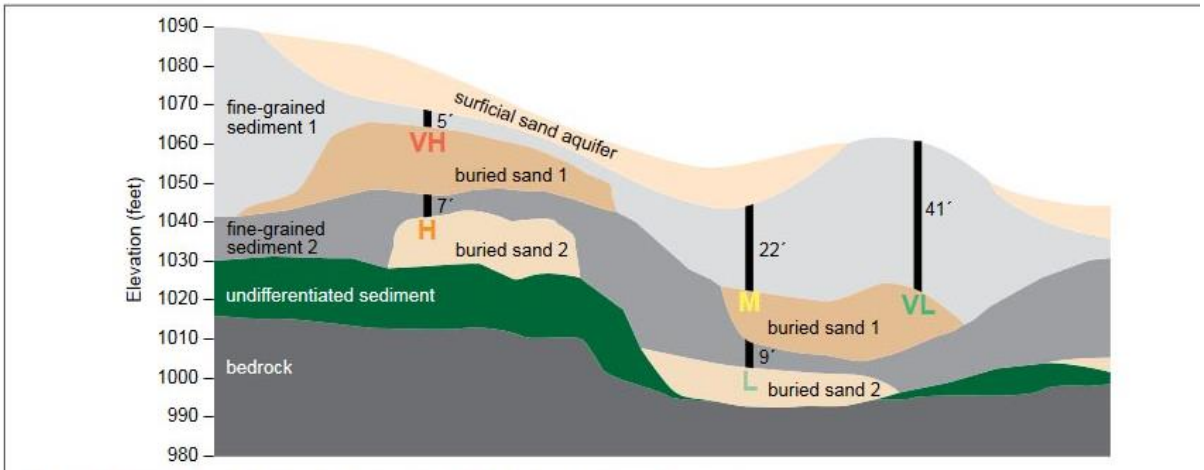


Figure 21. Cross section showing examples of pollution sensitivity ratings

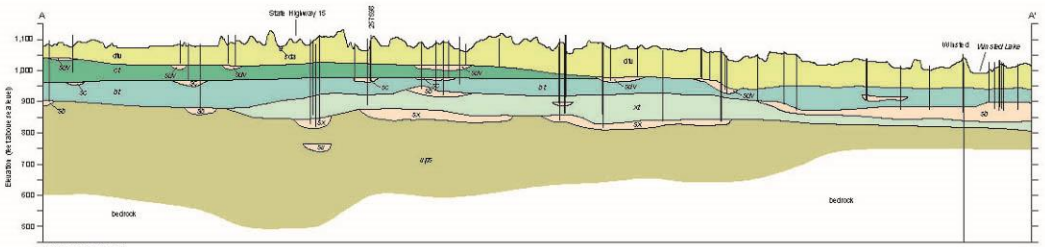
Based on the cumulative thickness of overlying fine-grained sediment. Each vertical black line is labeled with the thickness of fine-grained sediment. The letter at the base of the line indicates the sensitivity rating determined from the cumulative thickness.

Geologic Atlas of Sherburne County, Minnesota, County Atlas Series C-32, Part B

	Part A	Part B
Silt and clay	sc	sc
Surficial sand and gravel	ss	ss
Sandy glacial lake deposits	nbs	
Sand and gravel	ns	
Till (New Ulm)	nt	nt
Sand and gravel	csa	csa
Till (Automba)	*cta*	cta
Sand and gravel	csr	csr
Till (St. Croix)	ctr	ctr
Sand and gravel	*cse*	cse
Till (Emerald)	*cte*	cte
Sand and gravel	*scs*	scs
Till (Sauk Centre)	*sct*	sct
Sand and gravel	*fs1*	fs1
Till (St. Francis)	*ft1*	ft1
Sand and gravel	*mls*	mls
Till (Meyers Lake)	*mlt*	mlt
Sand and gravel	*fs2*	fs2
Till (St. Francis)	*ft2*	ft2
Sand and gravel	*suu*	suu
Undifferentiated Pleistocene sediment	*ups*	ups
bedrock		

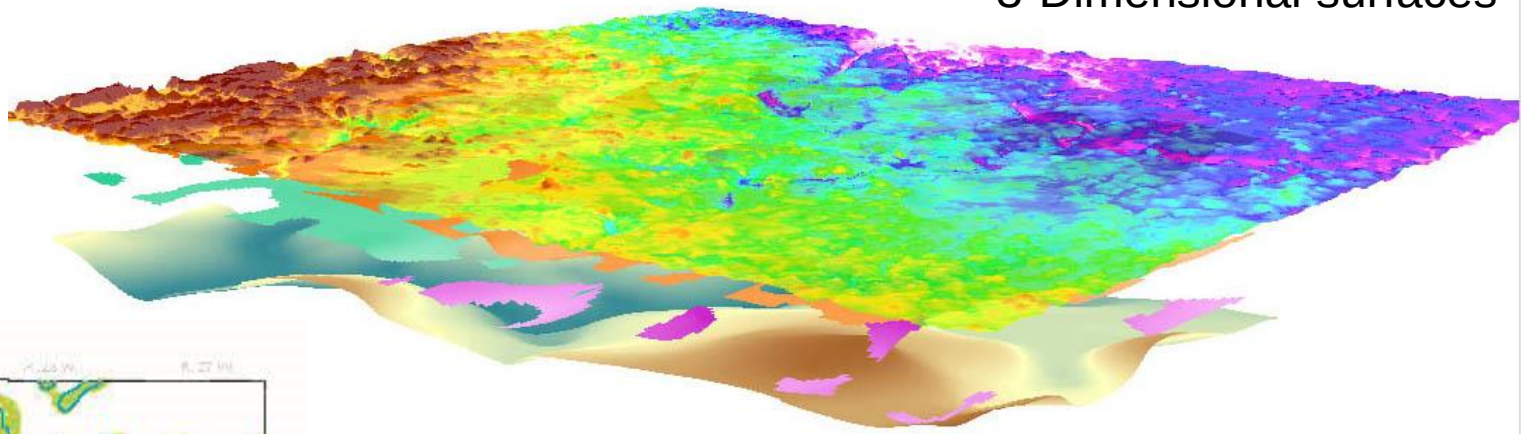
Hydraulically connected combinations of surficial sand and buried sand layers

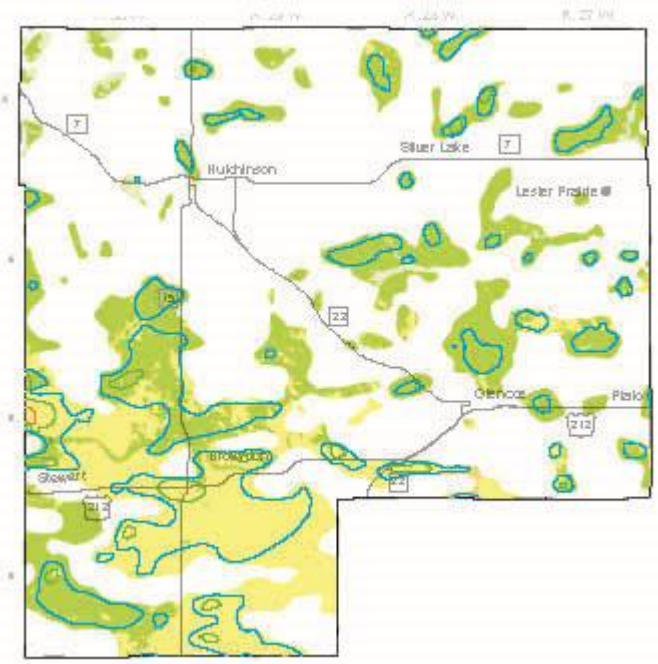
Mapping Buried Glacial Aquifers



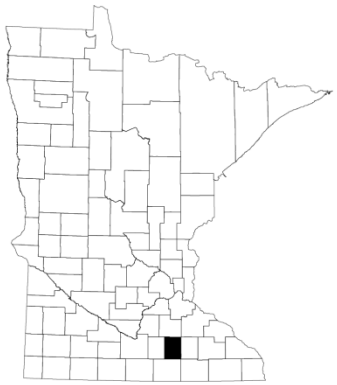
2-Dimensional cross sections

3-Dimensional surfaces





3-Dimensional models of buried sand layers



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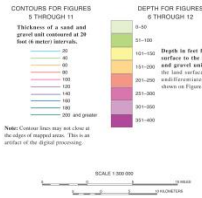
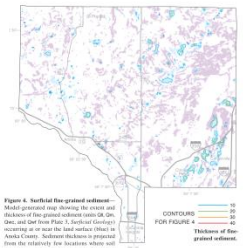
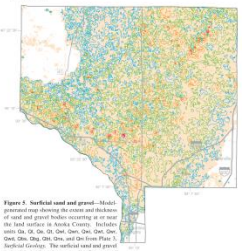
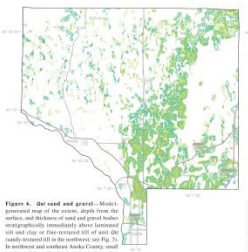
Sand Distribution Model

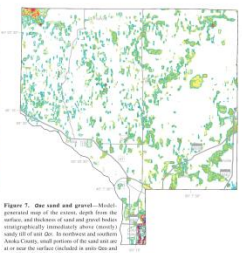
using data from the cross sections to map extent, depth to, and thickness of glacial sand bodies which may be aquifers

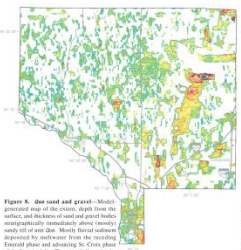


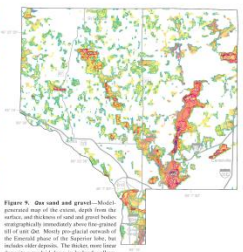


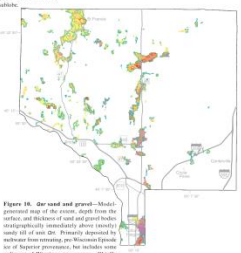


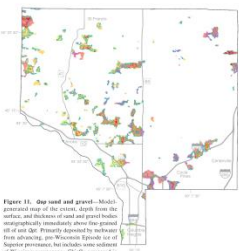


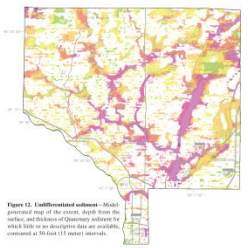




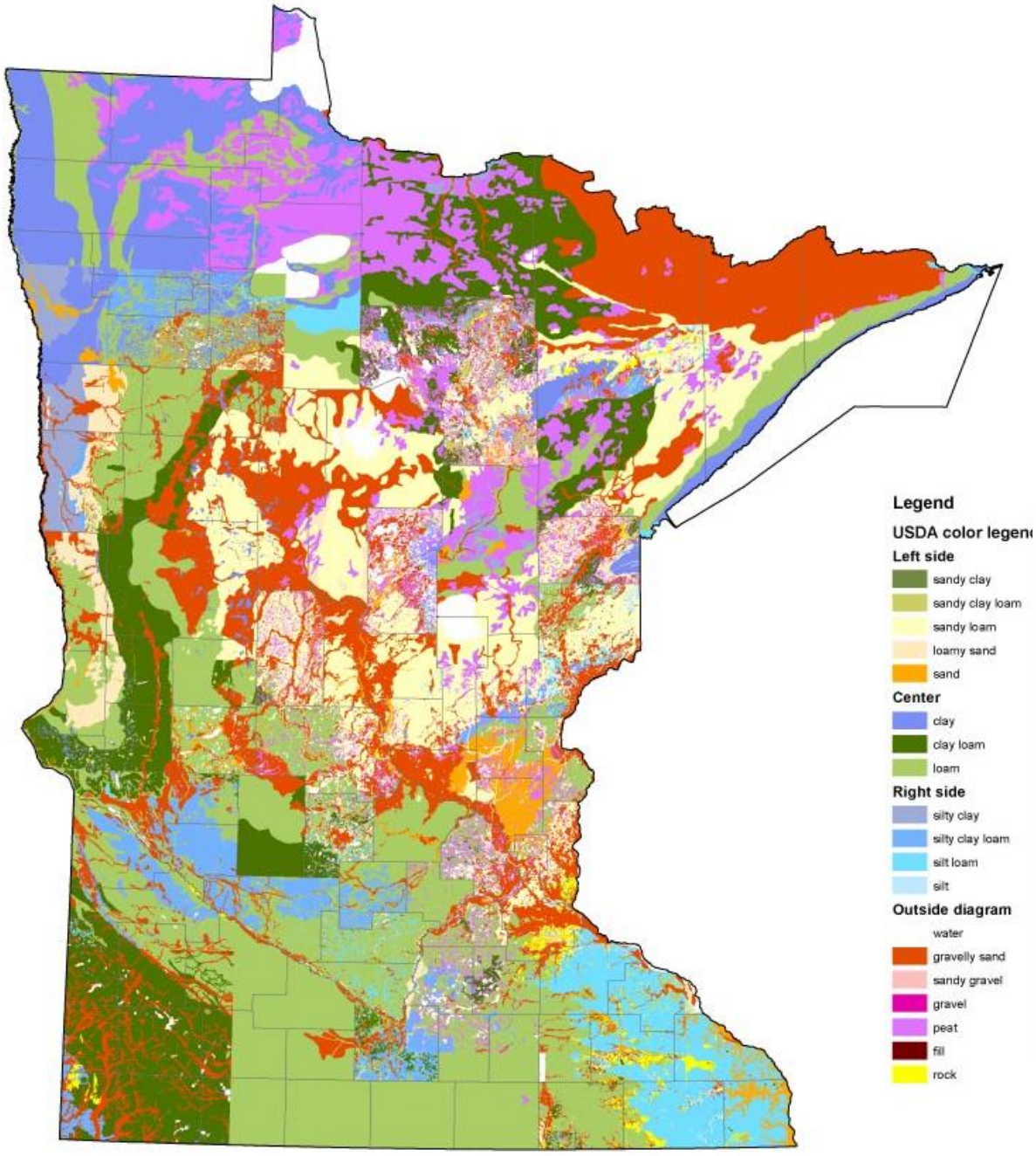


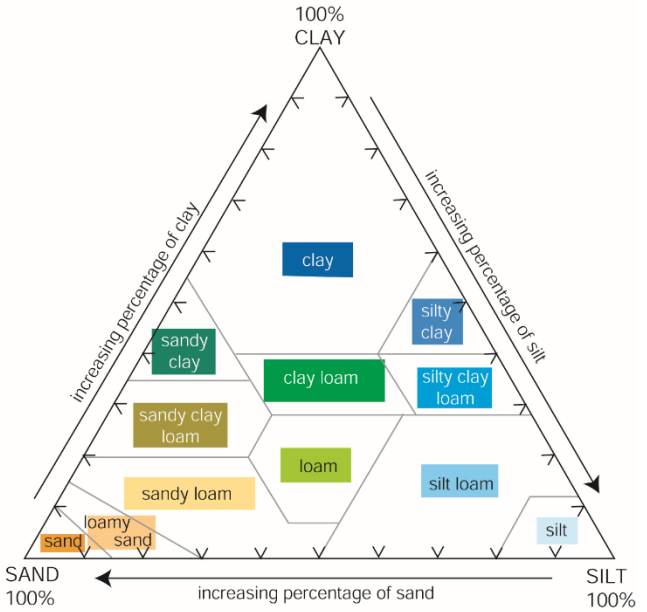






USDA Texture





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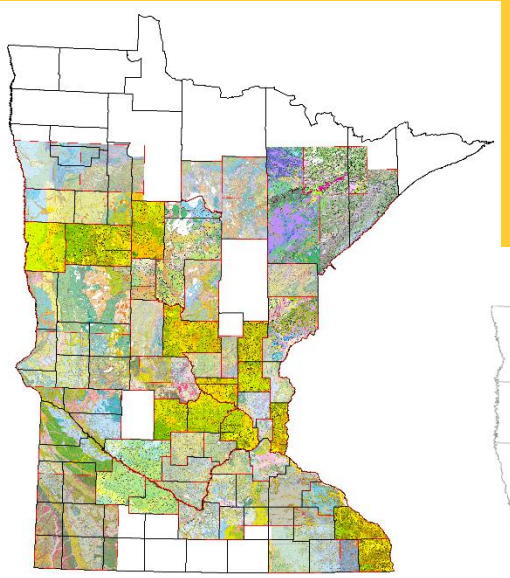
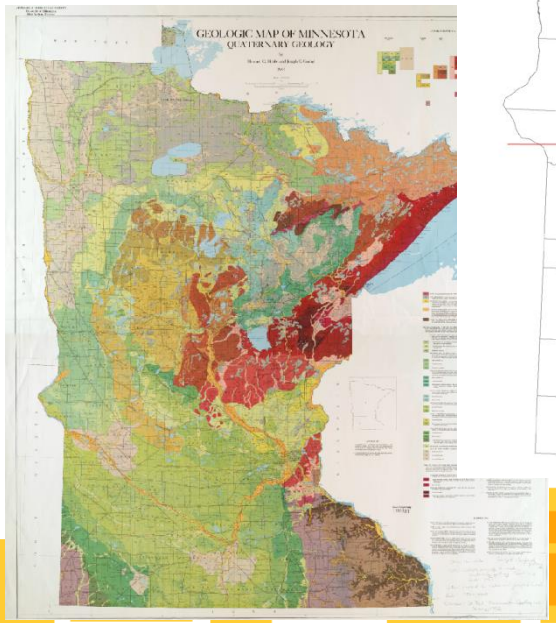
Geologic Map of Minnesota
Quaternary Geology



MGS mapping projects

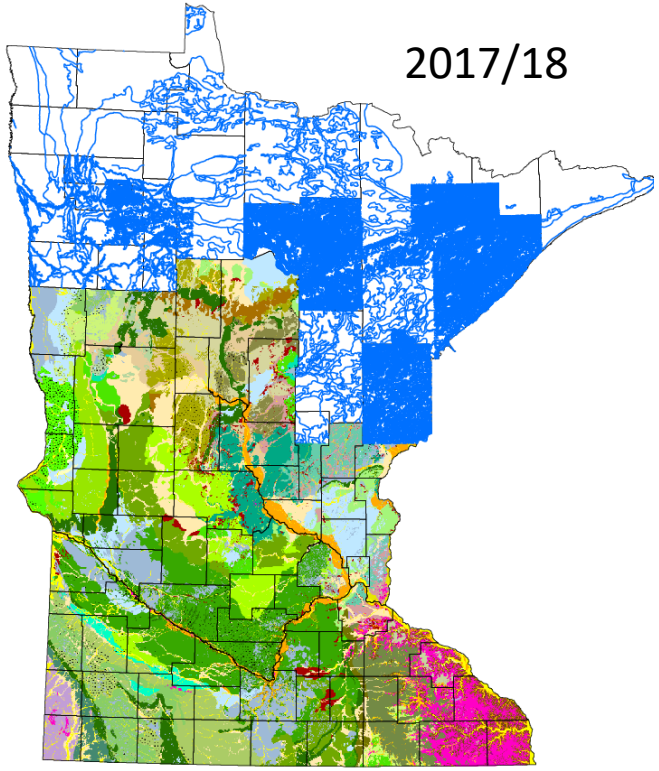
2015/16

2016/17

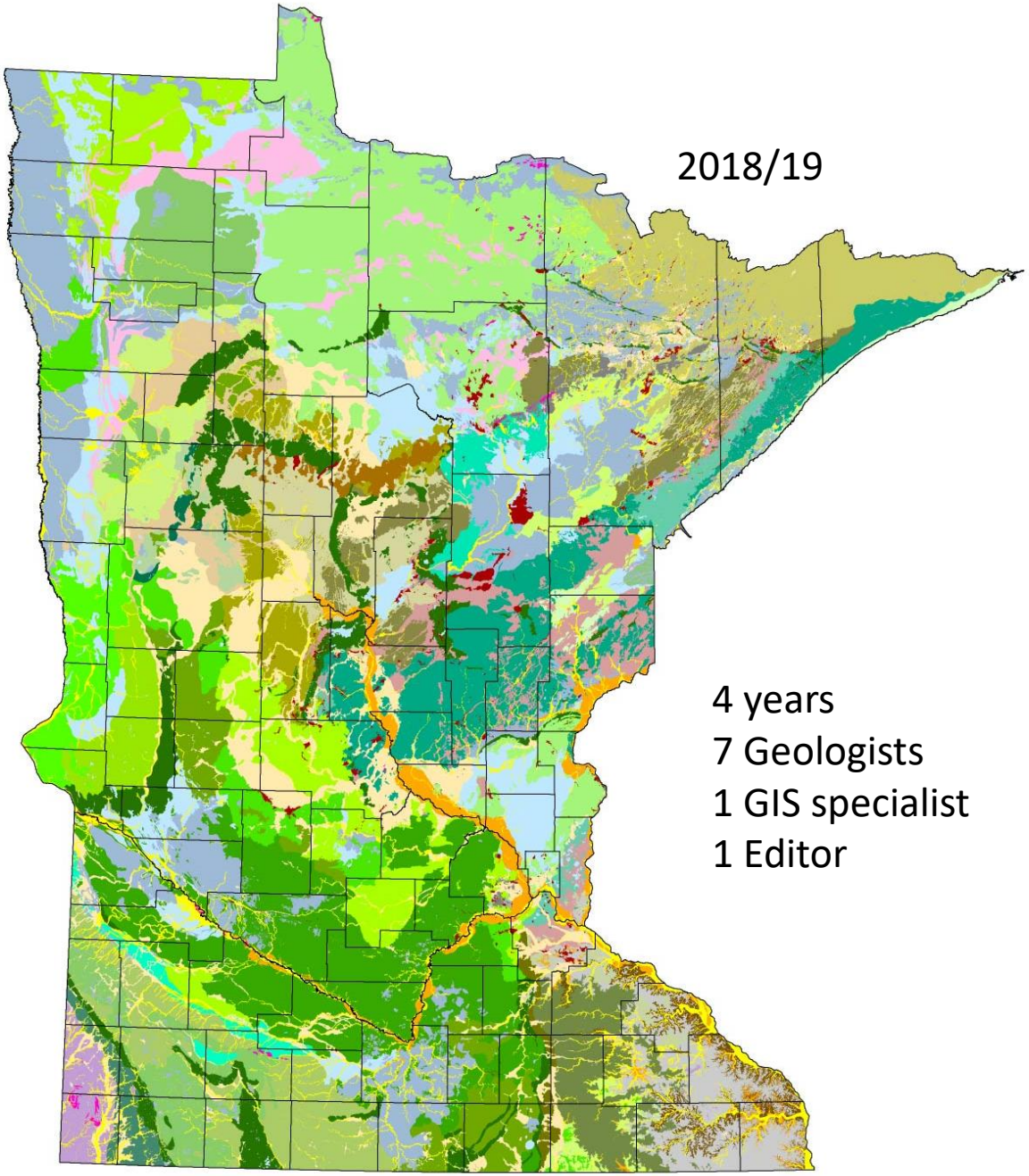


Hobbs and Goebel, 1982

supported by Great Lakes Mapping Coalition

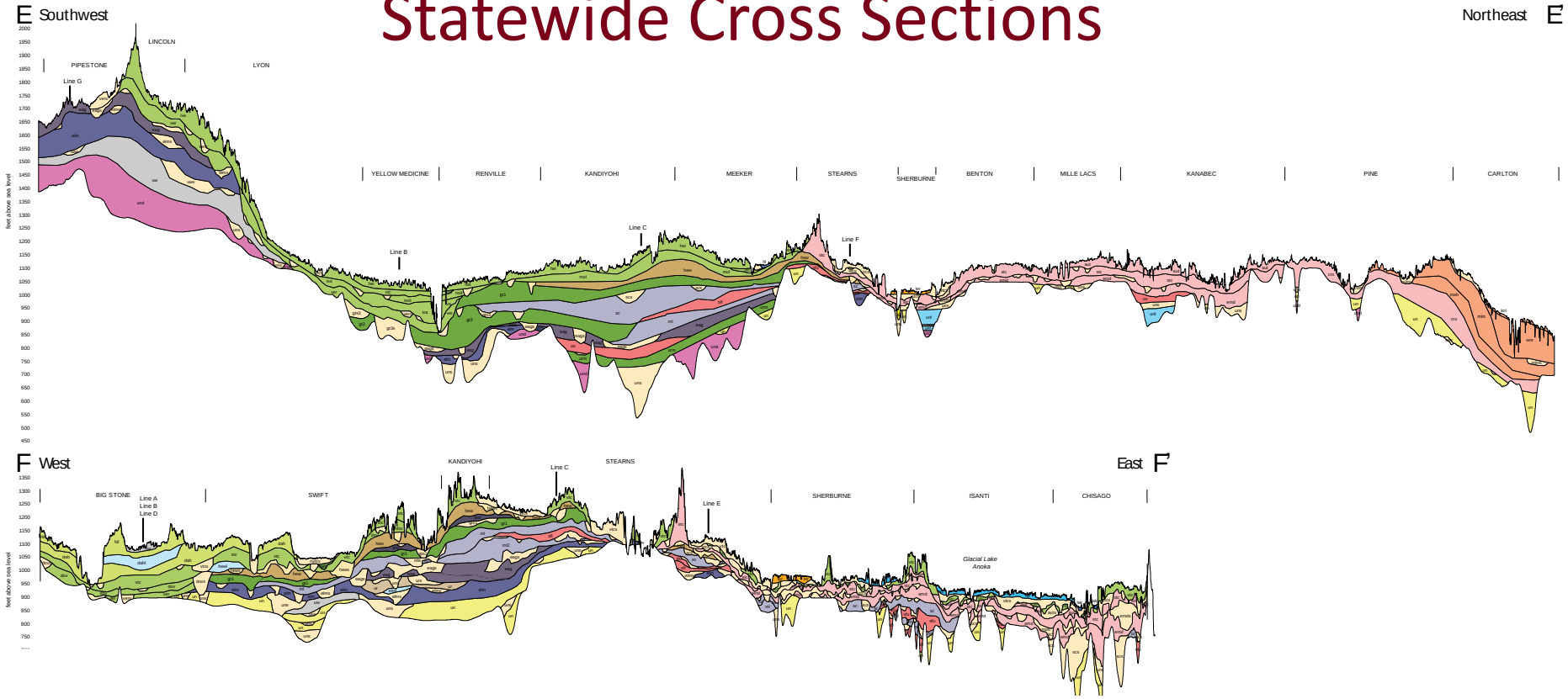


Digital (and 500k print)
1:100k and 500k scales
Complete Attribute table
- Texture
- Provenance
- Formation/Member



4 years
7 Geologists
1 GIS specialist
1 Editor

Statewide Cross Sections



cuc **Blackduck Formation**—Loamy diamicton associated with at least three advances of the Koochiching lobe and St. Louis sublobe. Predominant source area is the Winnipeg/Riding Mountain provenance. May correlate to the Falconer Member of the Forest River Formation and to the Red Lake Falls Formation. *Glacial sediment.*

New Ulm Formation—Deposited by ice of the Des Moines lobe from the northwest, Riding Mountain provenance.

hei ***Heiberg Member***—Clayey diamicton; pebbly. Lake sediment associated with glacial Lake Minnesota. *Glacial sediment.*

Otter Tail River formation (modified from Harris and Berg, 2006)—Deposited by ice of the Red River lobe from the north/northwest, Riding Mountain and Winnipeg provenances.

hawi ***Hawley member***—Loamy diamicton; pebbly. *Glacial sediment.*

nyms ***New York Mills member***—Sandy loam diamicton; pebbly. *Glacial sediment.*

nb **New Brighton Formation**—Fine-grained sand. Deposited in glacial Lake Anoka. *Glacial lacustrine sediment.*

New Ulm Formation—Deposited by ice of the Des Moines lobe from the northwest, Riding Mountain provenance.

fal ***Falun Member***—Silty clay. Deposited in glacial Lake Grantsburg. *Glacial lacustrine sediment.*

vtc ***Villard/Twin Cities Members***—Sandy loam diamicton; pebbly; may alternate brown and red layers in the eastern portion, where it is defined as the Twin Cities Member. This eastern portion was deposited by ice of the Grantsburg sublobe of the Des Moines lobe and is associated with the Pine City moraine. *Glacial sediment.*

gc ***Garden City Member***—Loamy diamicton; pebbly. Contains a high percentage of Pierre Shale fragments. This unit has been defined in southern Minnesota (Blue Earth County; Johnson and others, in press). For convenience,

cro ***Undifferentiated***—May include sediment from the following members:

mll ***Mille Lacs Member***—Silty diamicton; red. *Glacial sediment associated with the Mille Lacs moraine.*

snr ***Sunrise Member***—Silty clay; red. Deposits of glacial Lake Lind. *Glacial lake sediment.*

aut ***Unnamed member (Automba phase)***—Sandy diamicton; pebbly; red. *Glacial sediment.*

stc ***Unnamed member (St. Croix phase)***—Sandy diamicton; rocky; red. *Glacial sediment associated with the St. Croix moraine.*

emd ***Unnamed member (Emerald phase)***—Sandy diamicton; rocky; red. *Glacial sediment associated with the Emerald moraine.*

ind **Independence Formation**—Sandy diamicton; cobbly. Deposited by ice of the Rainy lobe from the north/northeast, Rainy provenance. Lake sediment associated with glacial Lake Brainerd. *Glacial sediment.*

sll ***South Long Lake Member***—Sandy diamicton; cobbly. *Glacial sediment associated with the St. Croix moraine.*

buf **Buffalo River formation** (Harris and Berg, 2006)—Clayey diamicton; pebbly. Deposited by ice from the north, or Winnipeg provenance. *Glacial sediment.*

hew **Hewitt Formation [Traverse des Sioux Formation]**—Sandy diamicton; pebbly. Deposited by ice from the north, northeast, or Rainy provenance. Defined as separate formations in Johnson and others (in press) but interpreted in cross sections as laterally equivalent units, perhaps representing earlier (Traverse des Sioux Formation) and later (Hewitt Formation) phases of the same ice. Herein considered to be equivalent to the Crow Wing River group of Harris and Berg (2006) in the Red River Valley. *Glacial sediment in southern Minnesota (Traverse des Sioux Formation); Glacial sediment associated with the Alexandria moraine and the Wadena drumlin field (Hewitt*

gt1 ***Good Thunder member 1***—Sandy diamicton; pebbly. Contains dark, fossiliferous limestone. from the northwest, Riding Mountain provenance. *Glacial sediment.*

gt3 ***Good Thunder member 3***—Sandy diamicton; pebbly. Contains dark, fossiliferous limestone Deposited by ice from the northwest, Riding Mountain provenance. *Glacial sediment.*

Lake Henry Formation—Deposited by ice from the north/northwest, or Winnipeg provenanc commonly found above and/or between members of the St. Francis Formation.

sc ***Sauk Centre Member***—Loamy diamicton; pebbly. Carbonate rich. Herein considered to be Gervais Formation (Harris and others, 1974) and the Funkley Formation (Johnson and others be equivalent to Good Thunder members 2 and 4. *Glacial sediment.*

ml ***Meyer Lake Member***—Loamy diamicton; pebbly. May be equivalent to Good Thunder me *sediment.*

St. Francis Formation—Deposited by ice of the Superior lobe from the northeast, Supe Members are commonly found between and/or below members of the Lake Henry Formation

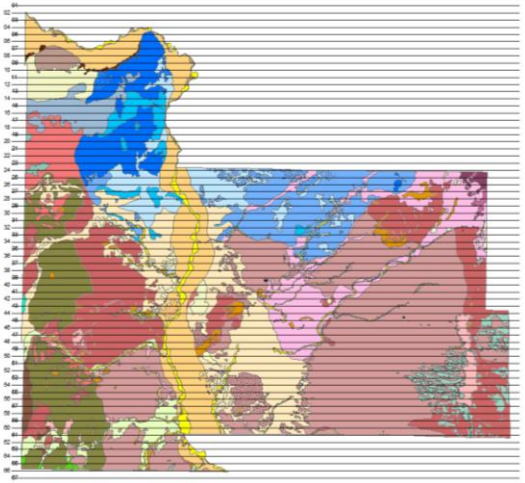
sfu ***Upper member***—Sandy diamicton; pebbly; red. *Glacial sediment.*

sfl ***Lower member***—Sandy diamicton; pebbly; red. Contains carbonate. *Glacial sediment.*

eagc **Eagle Bend Formation**—Clayey diamicton; pebbly. Carbonate rich. Deposited by ice from the or Winnipeg provenance. *Glacial sediment.*

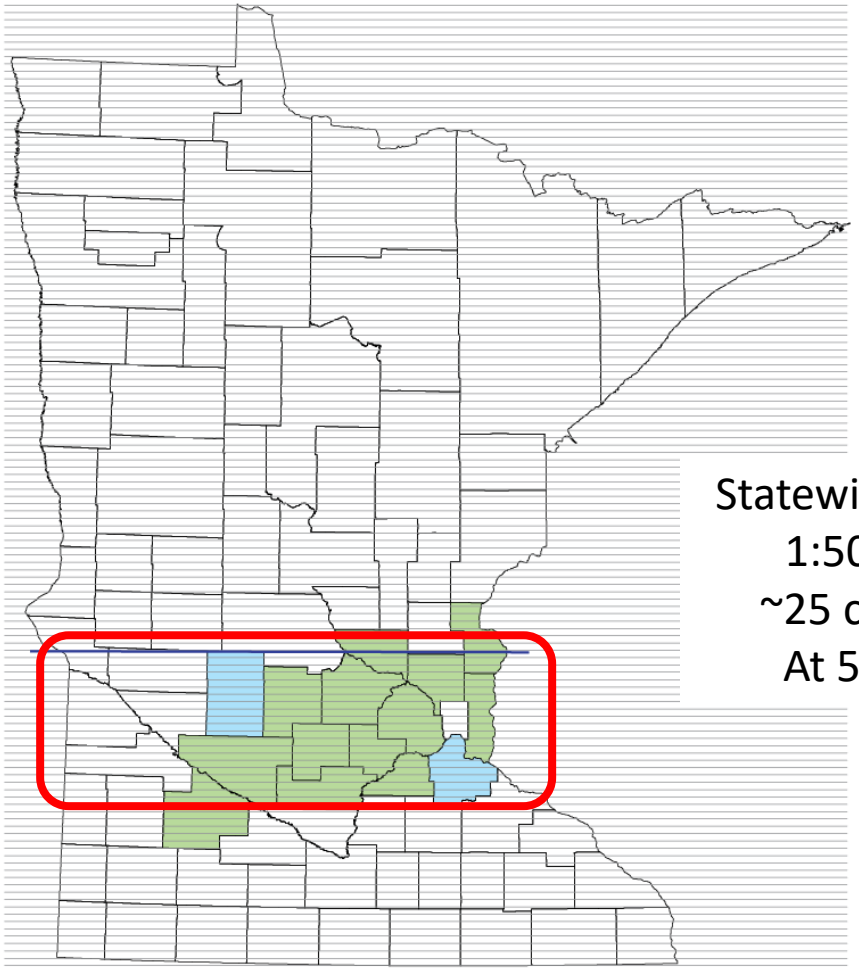
shc **Shooks Formation**—Sandy loam diamicton; pebbly. Deposited by ice from the north, nor

Statewide Cross Sections at 5-km spacing



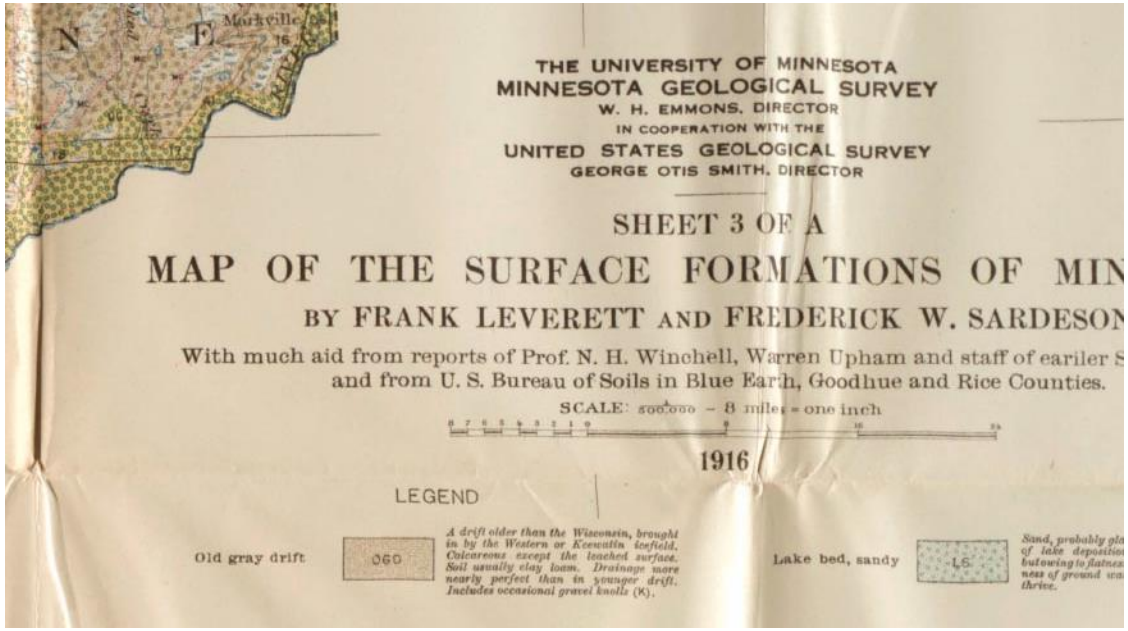
CGA Quaternary Stratigraphy
1:100,000 scale
67 cross sections at 1 km spacing

Phase one:
High-priority region
Previous work available
Mixture of old/new methods



Statewide Stratigraphy
1:500,000 scale
~25 cross sections
At 5 km spacing

So what is the 'Old Gray till' now?


THE UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
W. H. EMMONS, DIRECTOR
IN COOPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

SHEET 3 OF A

MAP OF THE SURFACE FORMATIONS OF MIN

BY FRANK LEVERETT AND FREDERICK W. SARDESON

With much aid from reports of Prof. N. H. Winchell, Warren Upham and staff of earlier S
and from U. S. Bureau of Soils in Blue Earth, Goodhue and Rice Counties.

SCALE: 500,000 – 8 miles = one inch

1916

LEGEND

Old gray drift — OGD — A drift older than the Wisconsin, brought in by the Western or Keewatin icefield. Calcareous except the leached surface. Soil usually clay loam. Drainage more nearly perfect than in younger drift. Includes occasional gravel knolls (K).

Lake bed, sandy — LS — Sand, probably gla of lake deposition butowing to flatnes ness of ground wa thrice.

OGD—*A drift older than the Wisconsin, brought in by the Western or Keewatin icefield. Calcareous except the leached surface. Soil usually clay loam. Drainage more nearly perfect than in younger drift. Includes occasional gravel knolls (K).*

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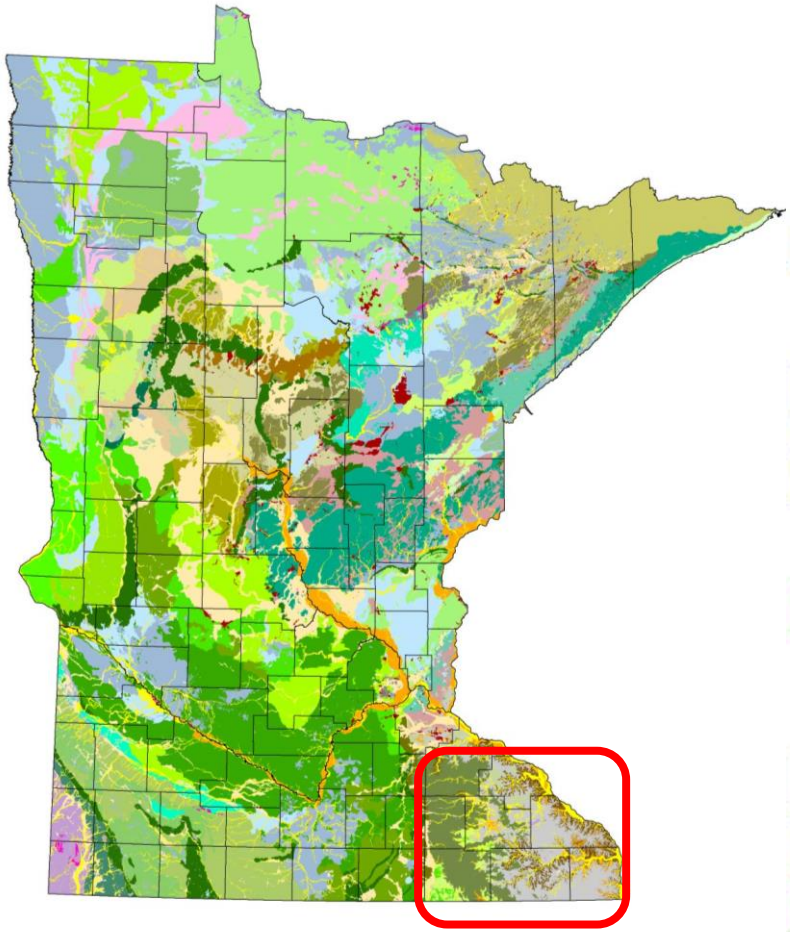


bv bvo — **Browerville Formation**—Loamy diamicton; pebbly. Deposited by ice from the north/northwest, or Winnipeg provenance. Contains Cretaceous limestone and gray shale.

rc rco — **Rose Creek [Saum Formation]**—Sandy loam diamicton; pebbly. Defined as separate formations in Johnson and others (2016) but interpreted here to be equivalent units. Deposited by ice from the northeast, or Rainy provenance.

rb — **Bennington Member**—Peat to organic-rich silt; silty clay to loam. Interpreted as paleosol and underlying fine-grained sediment at the top of the Rose Creek Formation.

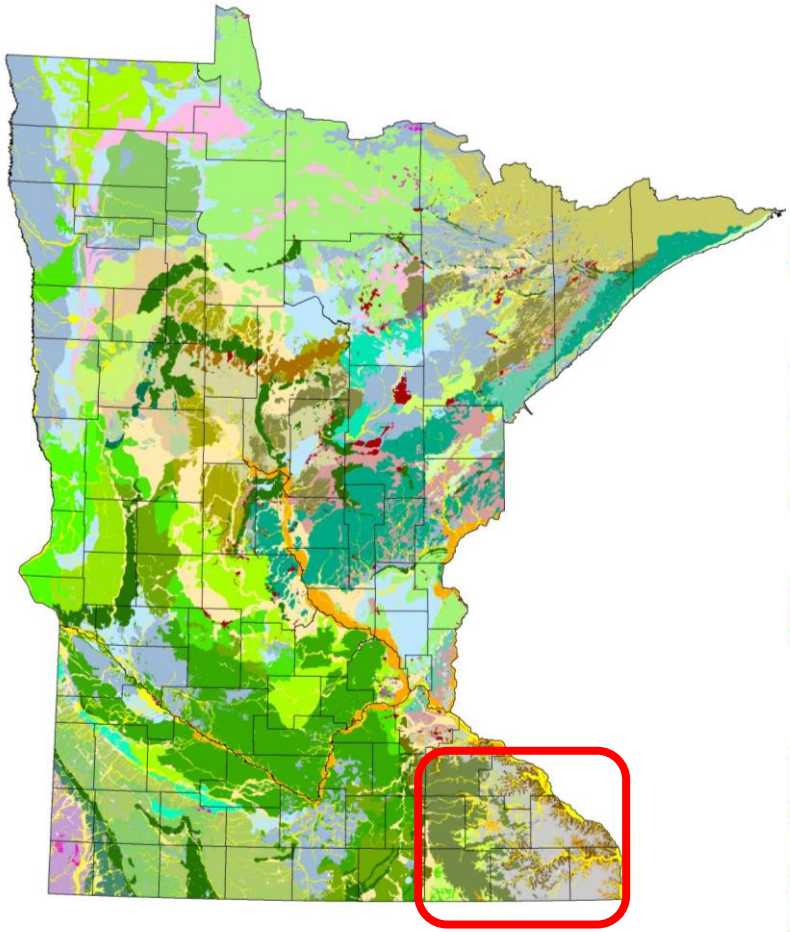
el — **Elmdale Formation**—Clayey diamicton; pebbly. Deposited by ice from the north/northwest, or Winnipeg provenance. May be equivalent to the Big Fork and Wirt Formations in north-central Minnesota.

ot oo — **Old tills**—Undifferentiated. *Generally described as pre-Wisconsinan and may include any formation or combination of formations. Often referred to as "Old Red" or "Old Grey" tills.*

pi pio — **Pierce Formation** (Baker, R.W., 1984a)—Sandy, clay loam diamicton; red-brown; pebbly. Deposited by ice from the northeast, or Superior provenance. Defined in Wisconsin.

rf rfo — **River Falls** (Baker, R.W., 1984b)—Clay loam diamicton; gray; calcareous; pebbly. Deposited by pre-Illinoian ice from the north, or Winnipeg provenance. Defined in Wisconsin.

So what is the 'Old Gray till' now?



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The more things change. . .

the more they stay the same. . .

https://insightbyseymour.com/2014/01/10/the-old-gray-mare/