Wisconsin's geology & aquifers

Wisconsin Geological and Natural History Survey
DIVISION OF EXTENSION
UNIVERSITY OF WISCONSIN–MADISON

Amy Wiersma

Hydrogeologist

amy.wiersma@wisc.edu

Mel Reusche

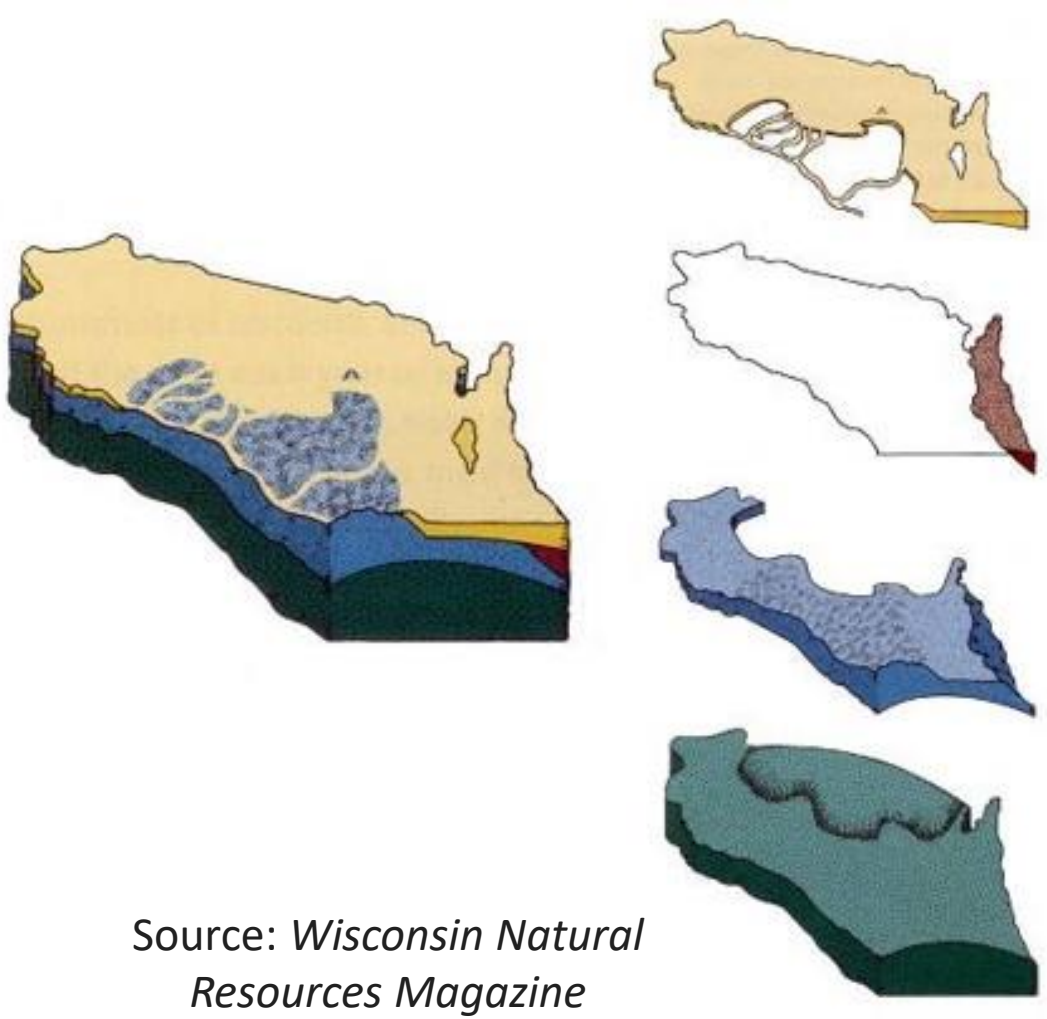
Communications & Outreach Specialist

reusche@wisc.edu

Groundwater Education Workshop

April 16, 2025

Objectives



Source: *Wisconsin Natural Resources Magazine*

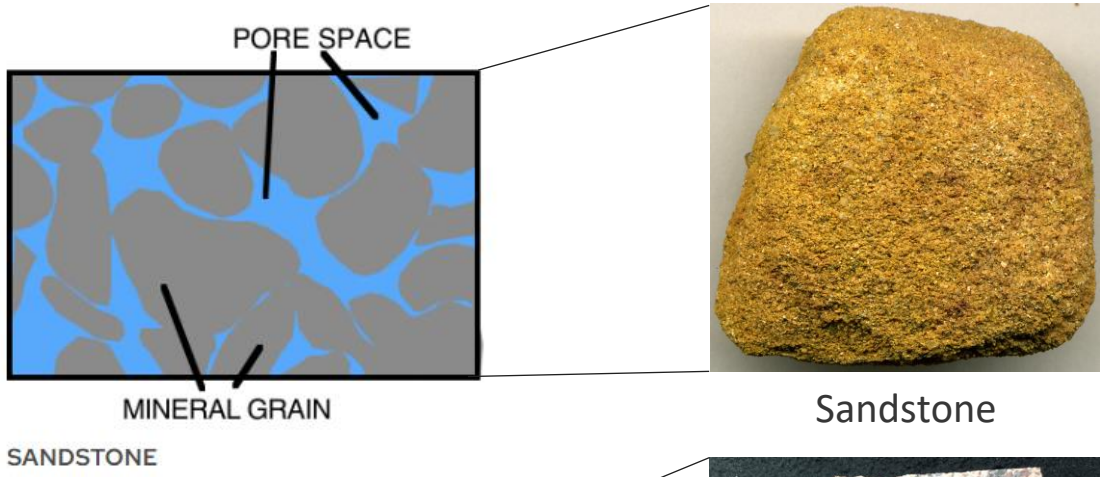
- What makes a rock or sediment a good aquifer?
- What are the three main stages in Wisconsin's geologic history?
- What are Wisconsin's four aquifers?

Takeaway: Wisconsin's geology controls the availability of groundwater.

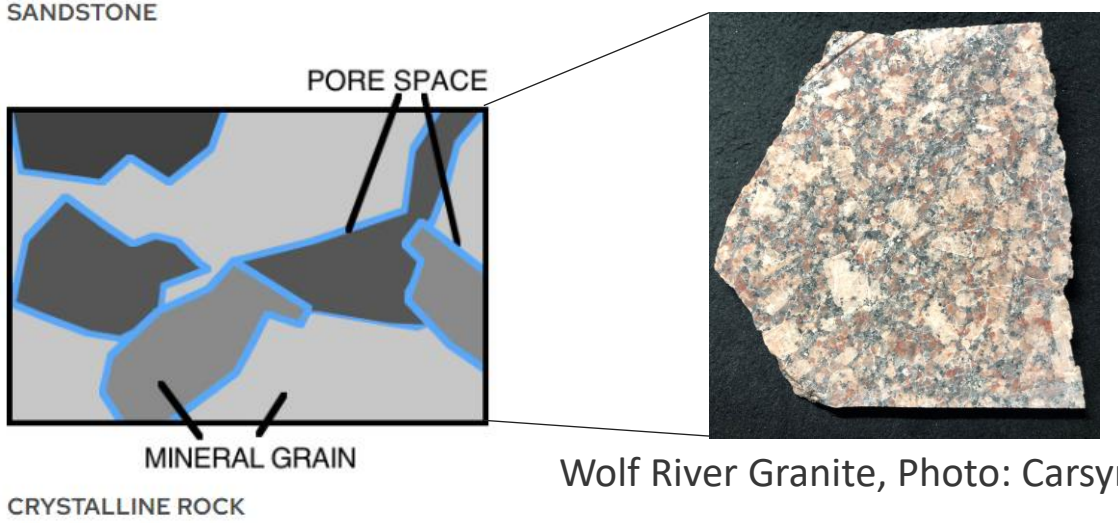
What makes a rock or sediment a good aquifer?

Photo: Carsyn Ames

Porosity is the ability of rocks to ***store*** water



Sandstone

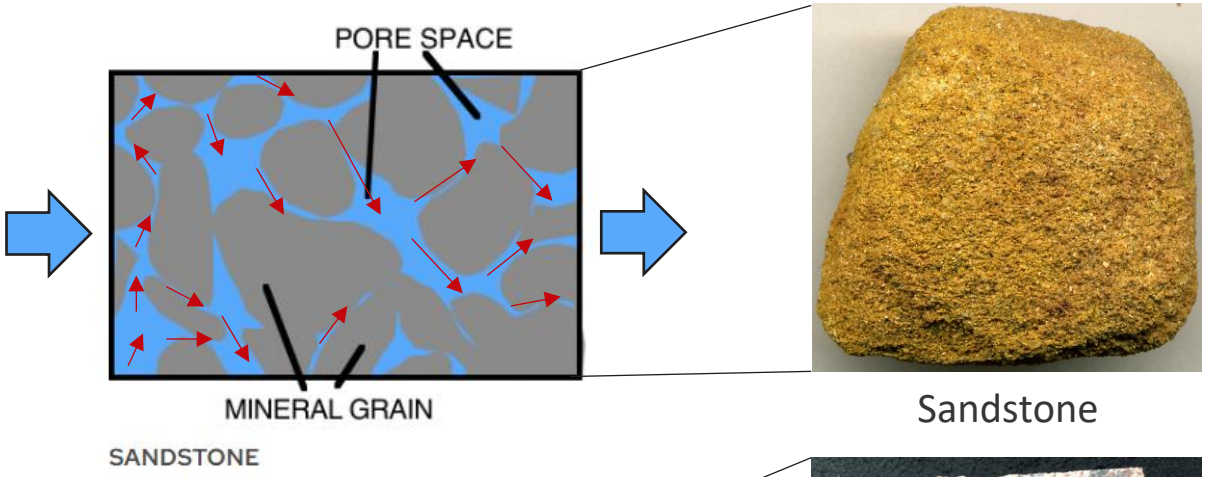


Wolf River Granite, Photo: Carsyn Ames

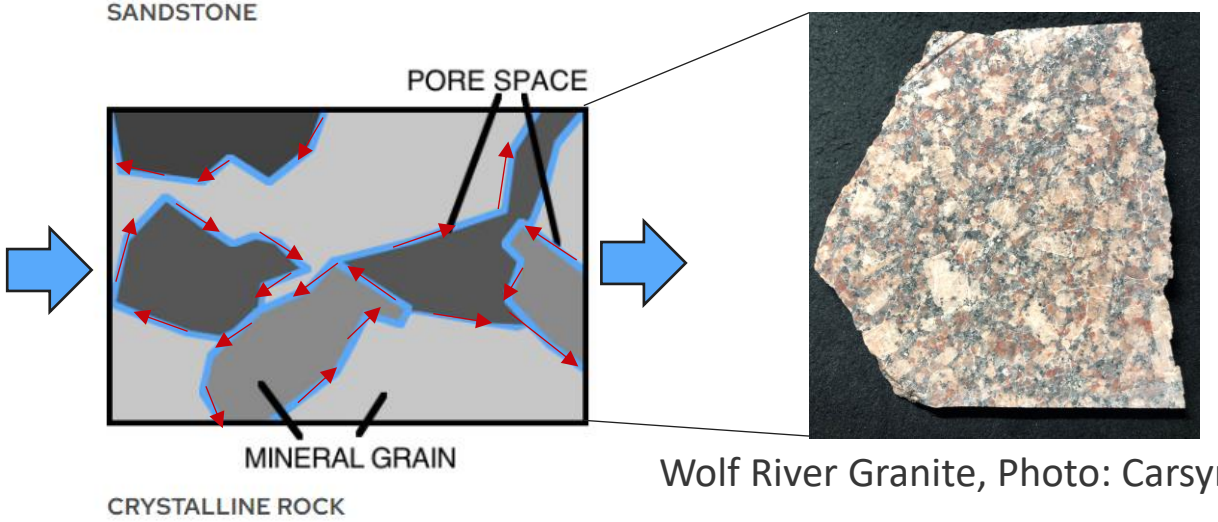
- Percent of open space in a rock or sediment
- For most rocks, porosity ranges from <1% to 40%

What makes a rock or sediment a good aquifer?

Hydraulic conductivity is the ability of rocks to ***transmit*** water



Sandstone

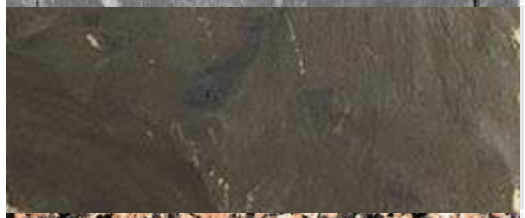


Wolf River Granite, Photo: Carsyn Ames

- How well are the pore spaces or fractures are connected to one another?
- Units of length over time
- Ranges over 12 orders of magnitude!

What makes a rock or sediment a good aquifer?

Rocks & sediments with high **porosity** ***and*** **conductivity** are the best aquifers

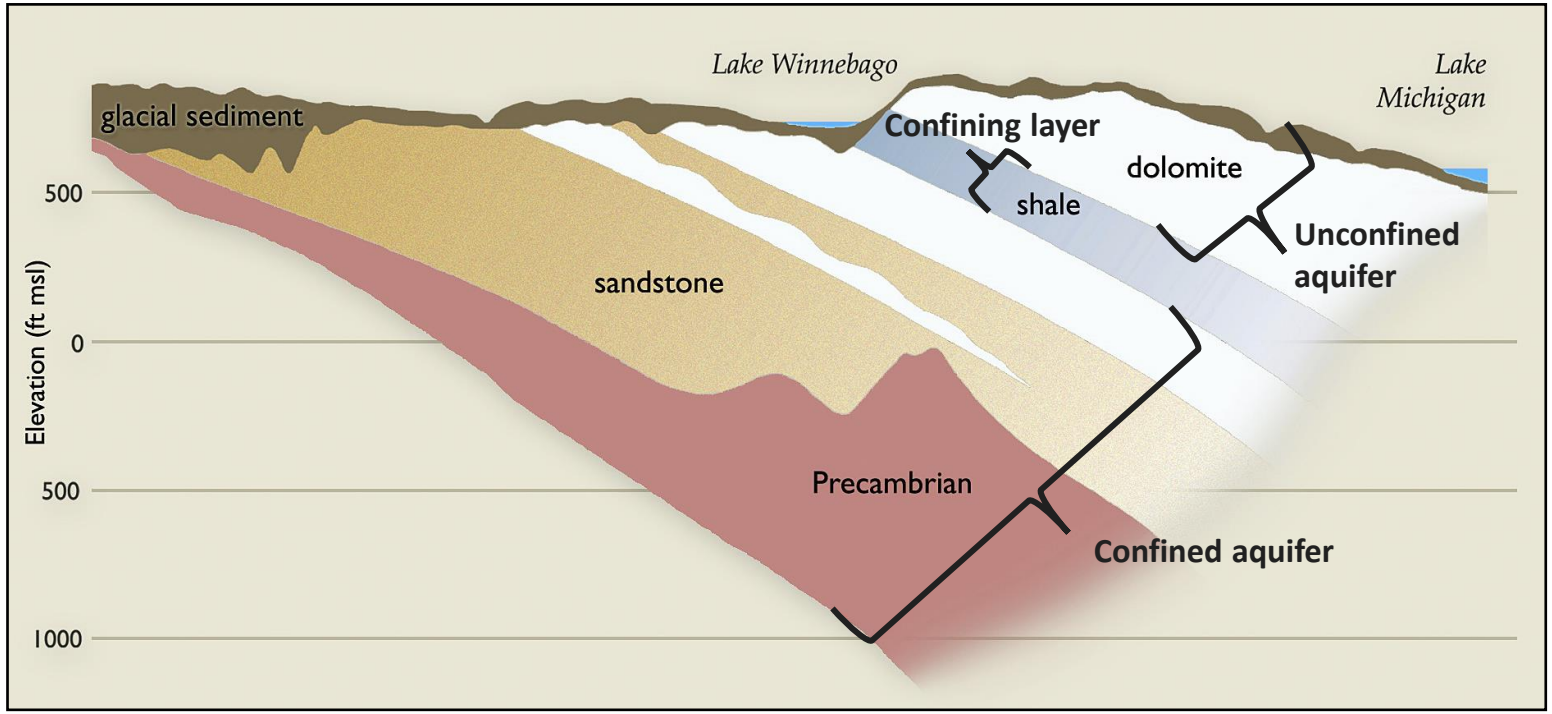
	Rock	Rock Type	Porosity	Conductivity	Aquifer?
	Sandstone	Sedimentary	High	High	😍
	Dolostone	Sedimentary	Low	High	😊
	Shale	Sedimentary	High	Low	😟
	Granite, and others	Igneous and Metamorphic	Low	Low	😭

What makes a rock or sediment a good aquifer?

Shales/clays are ***aquitards*** or ***confining layers***

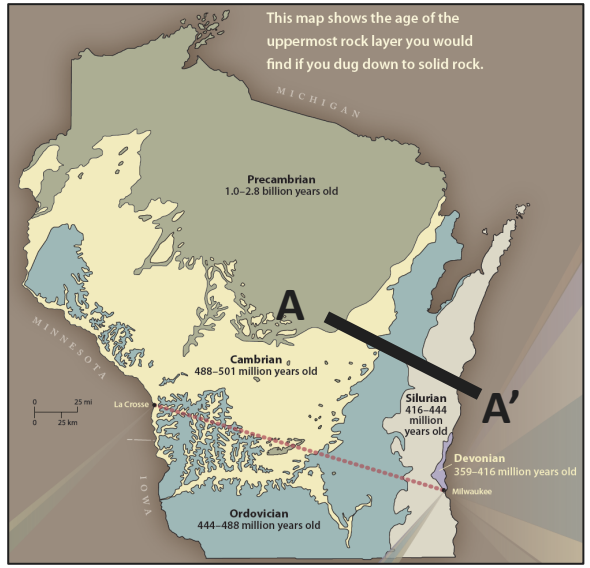
A
West

A'
East



Wisconsin Geological and Natural History Survey

- Water moves **very slowly** through confining layers
- Provides protection of underlying aquifers
- Example: Maquoketa shale



What makes a rock or sediment a good aquifer?

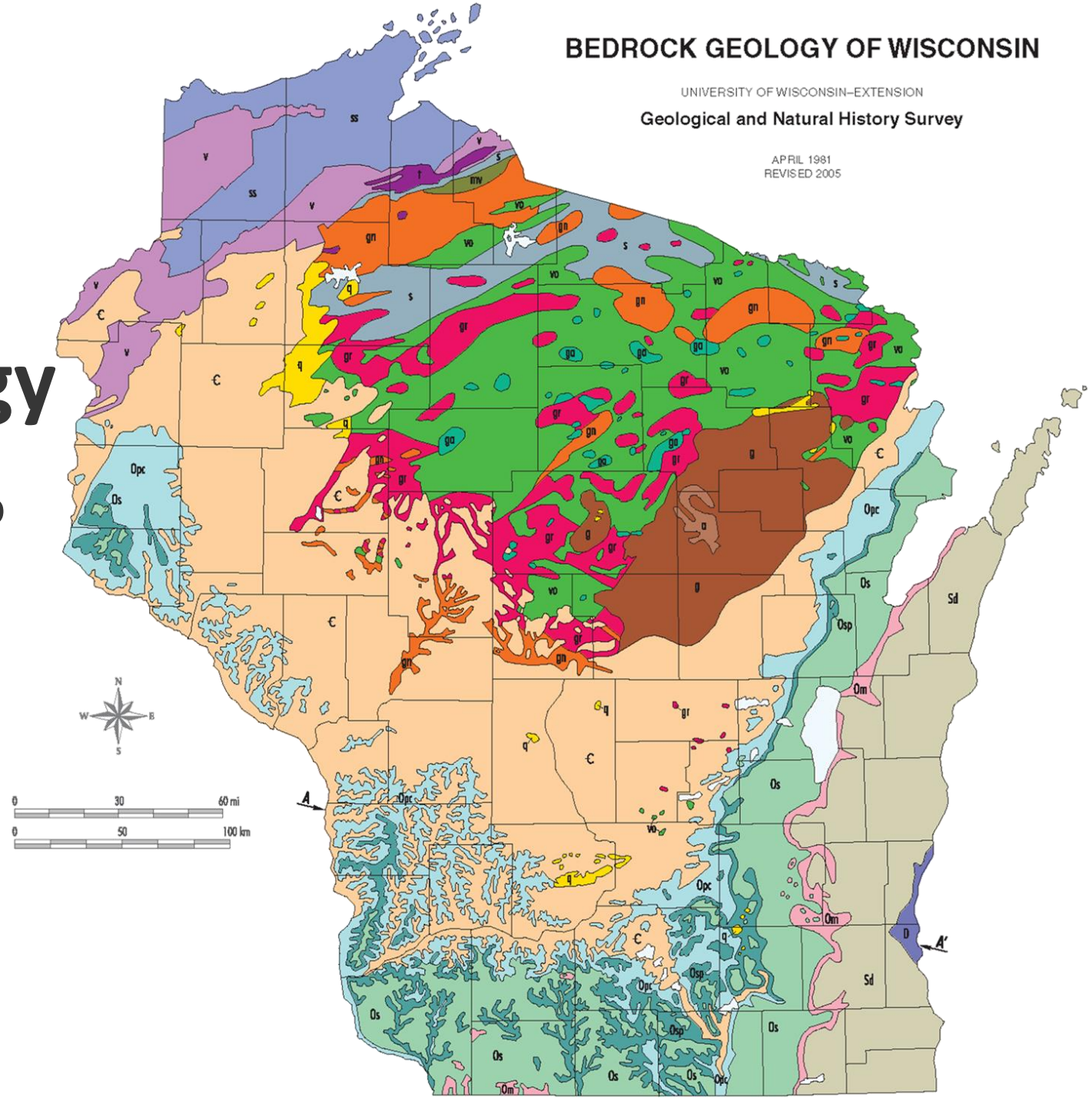
Wisconsin's subsurface (bedrock) geology

- Shows rock type closest to the land surface

Youngest

Devonian
Silurian
Ordovician
Cambrian
Precambrian

Oldest



Wisconsin's subsurface (bedrock) geology

- Shows rock type closest to the land surface

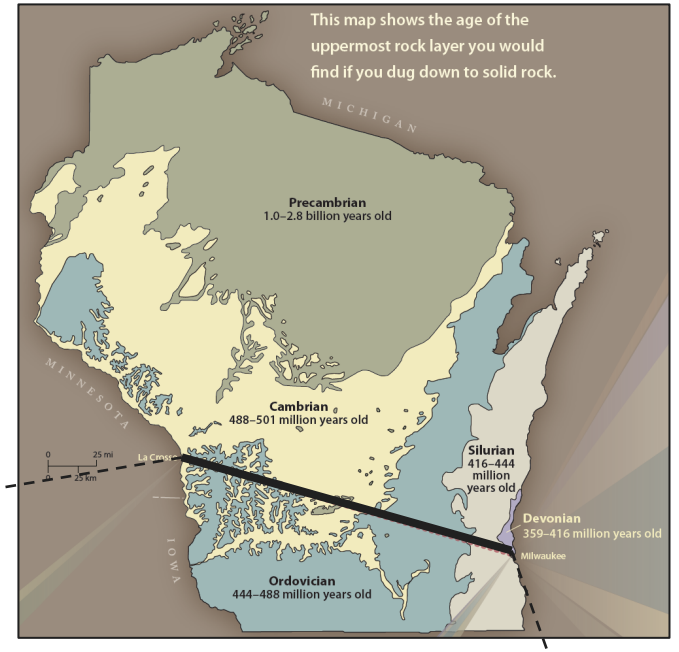
Youngest

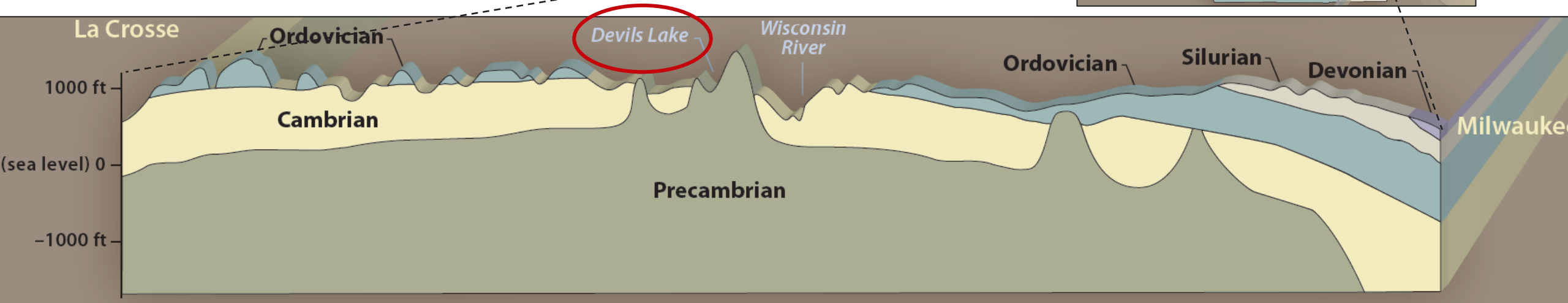
Devonian
Silurian
Ordovician
Cambrian
Precambrian

Oldest

Wisconsin's subsurface (bedrock) geology

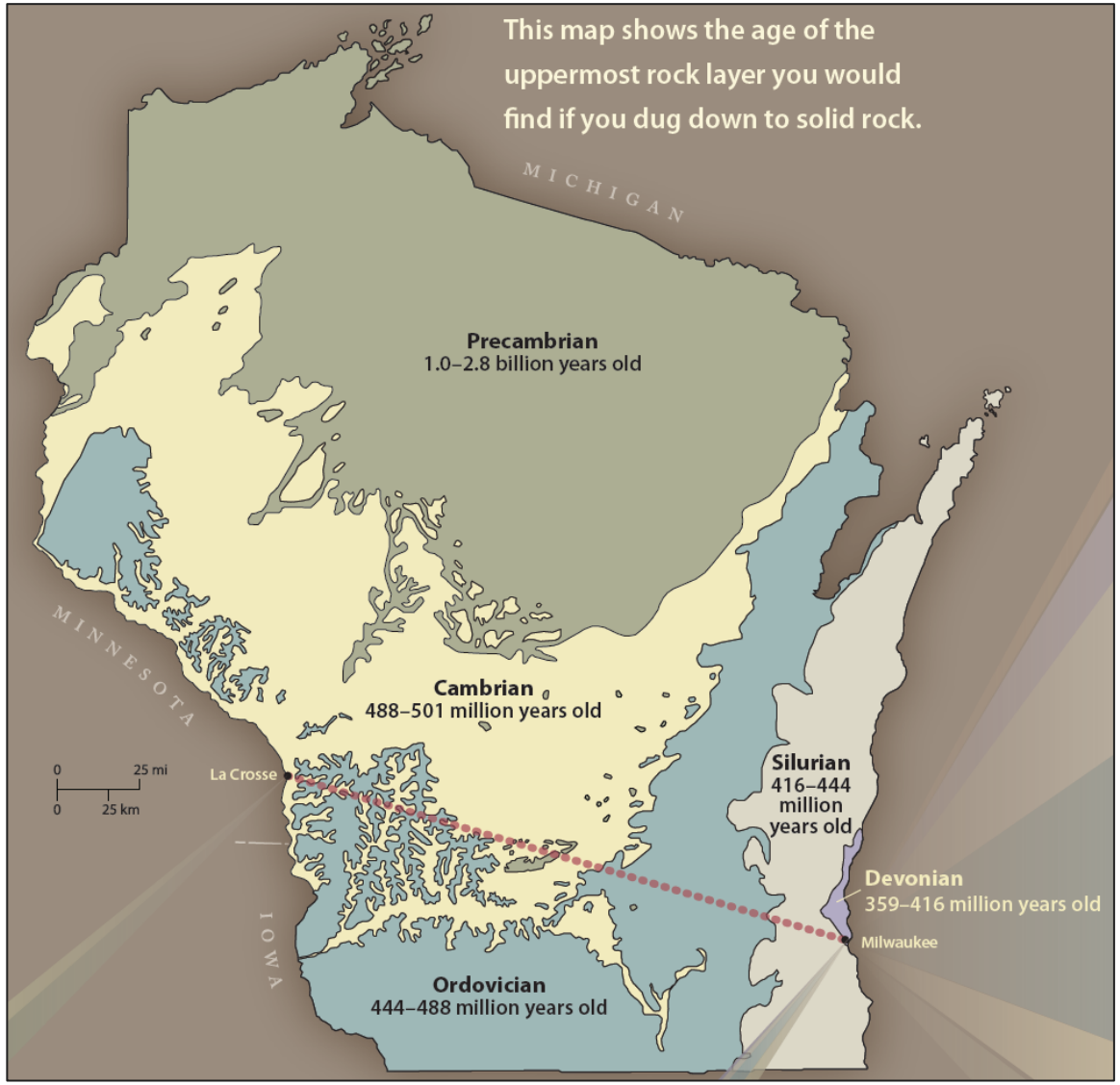
- Cross section shows layers of rock underground

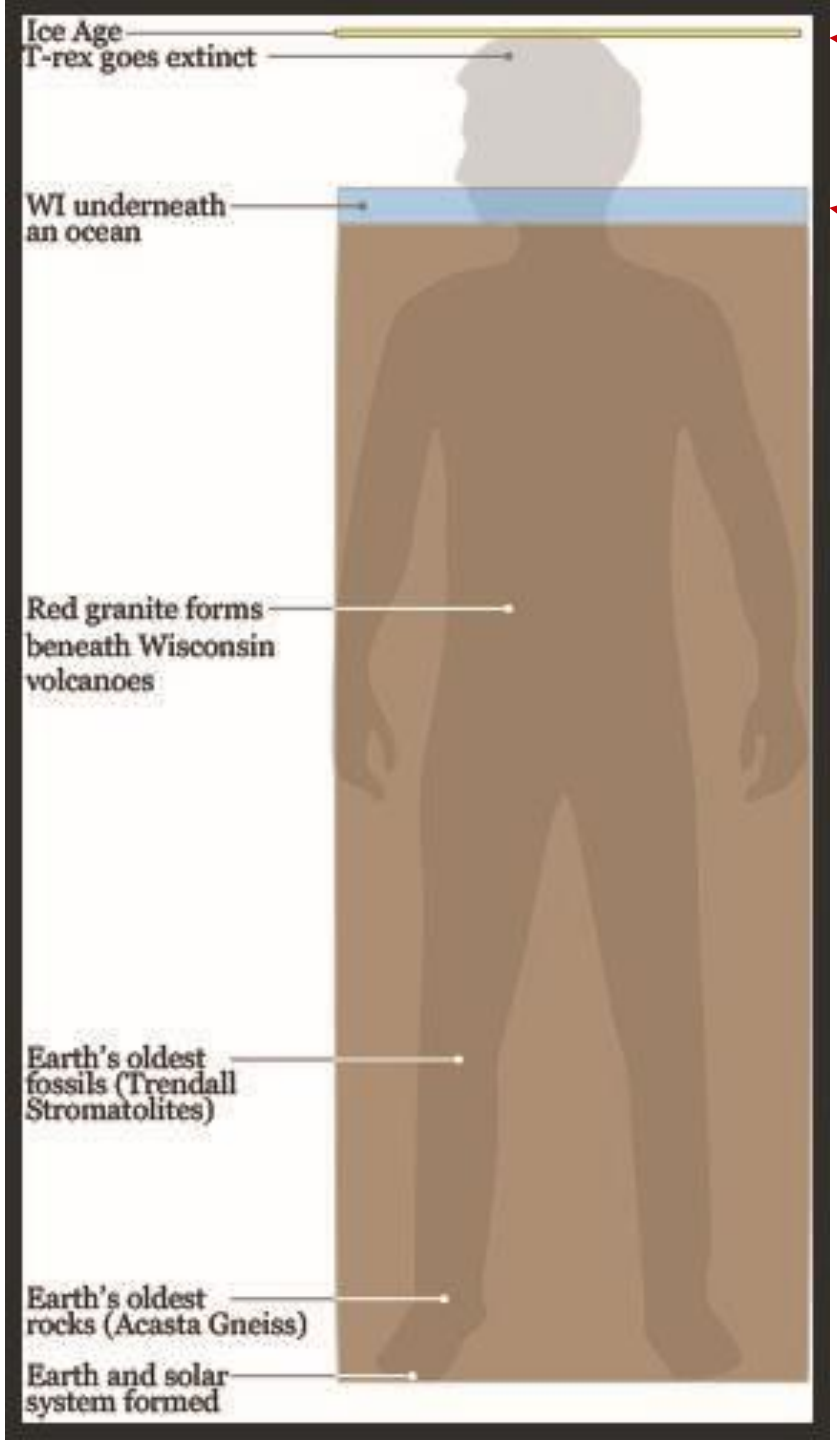




Slice of earth If you made a slice through the ground from La Crosse to Milwaukee, this is what the rock layers would look like.

How old are WI rocks?



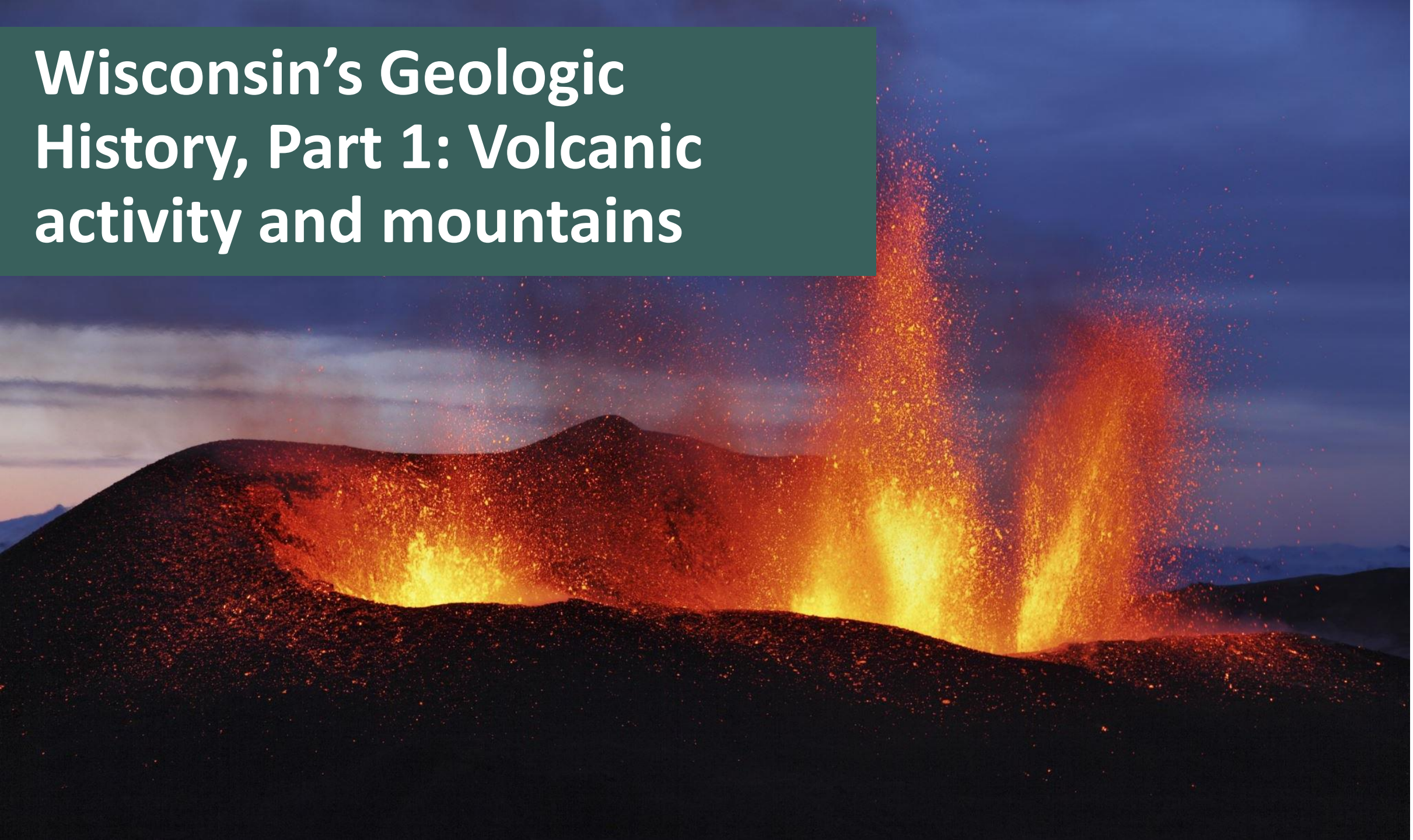


Quaternary

Cambrian, Ordovician, Silurian & Devonian

Precambrian

Wisconsin's Geologic History, Part 1: Volcanic activity and mountains



Wisconsin's Geologic History, Part 1: Volcanic activity and mountains

Youngest

Devonian
Silurian
Ordovician
Cambrian
Precambrian

Oldest

Part 1 creates the crystalline *"foundation"* of Wisconsin

Three major events:

1) Volcanic activity forms initial North American continent

- *Crystalline bedrock* = igneous and metamorphic rocks

Part 1 creates the crystalline *"foundation"* of Wisconsin

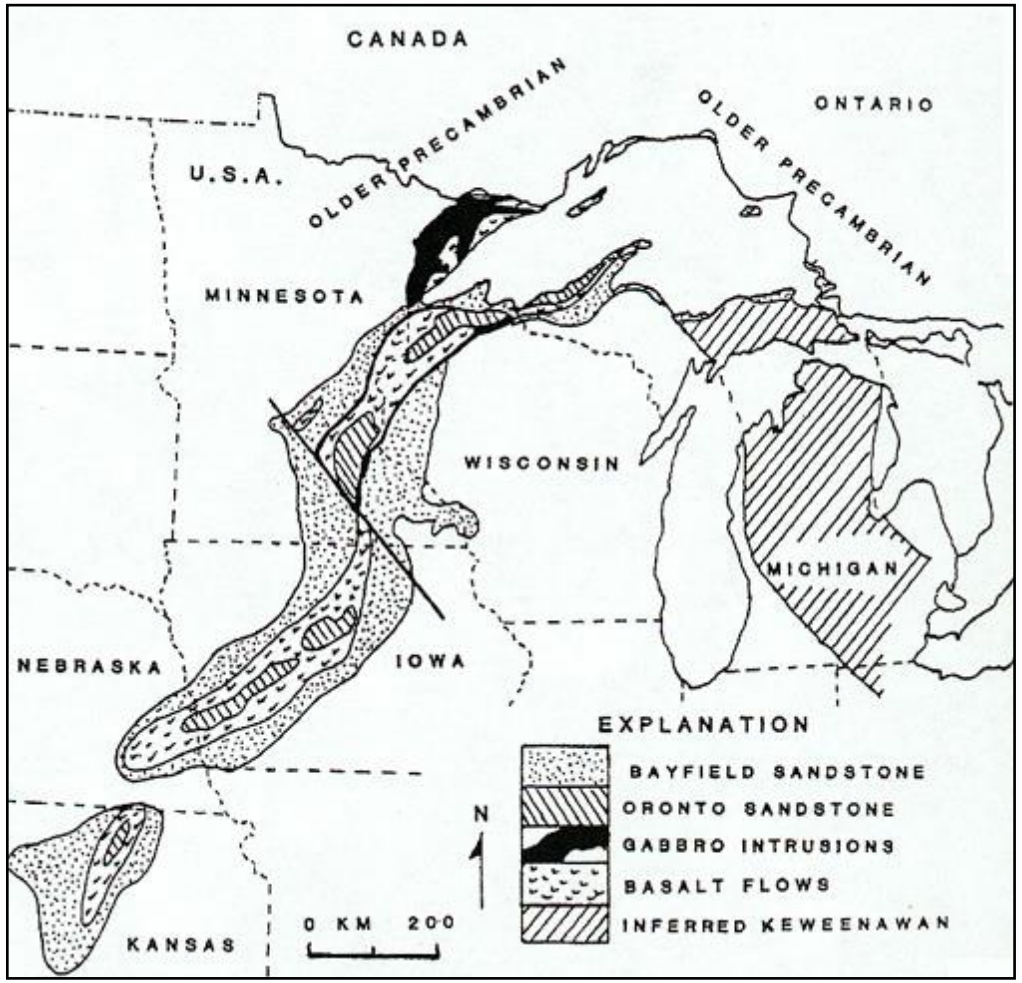
Three major events:

1) Volcanic activity forms initial North American continent

2) Continent collides with volcanic islands; mountains form!

- *Crystalline bedrock* = igneous and metamorphic rocks

Part 1 creates the crystalline *"foundation"* of Wisconsin



LaBerge (1994) Geology of the Lake Superior Region

Three major events:

1) Volcanic activity forms initial North American continent

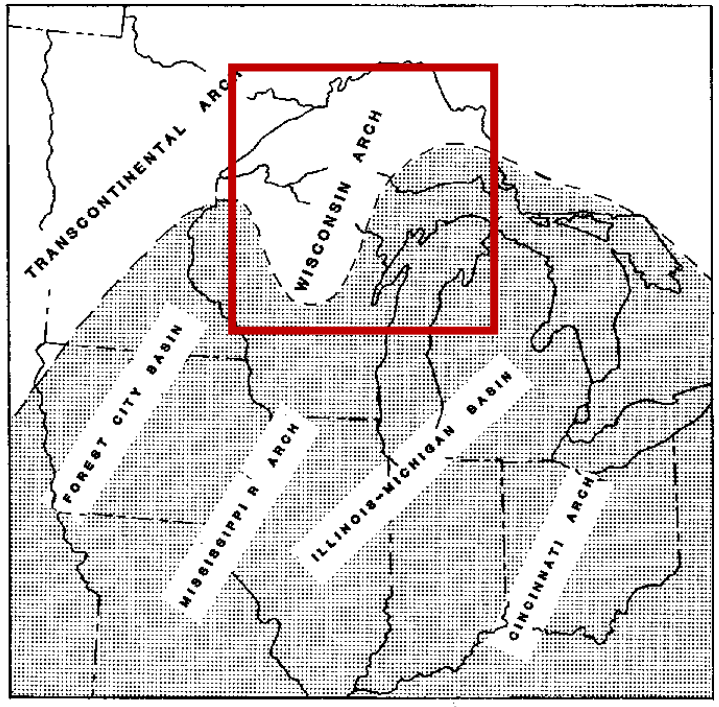
2) Continent collides with volcanic islands; mountains form!

3) Rifting threatens to split the continent, but fails

- *Crystalline bedrock* = igneous and metamorphic rocks

The Wisconsin Dome in N. Wisconsin is where these ancient rocks are ***near the surface***

Map view



LaBerge (1994) Geology of the Lake Superior Region

This map shows the age of the uppermost rock layer you would find if you dug down to solid rock.

MICHIGAN

Precambrian
1.0–2.8 billion years old

A

A'

MINNESOTA

Cambrian
488–501 million years old

0 25 mi
0 25 km

La Crosse

Silurian
416–444 million years old

Devonian
359–416 million years old

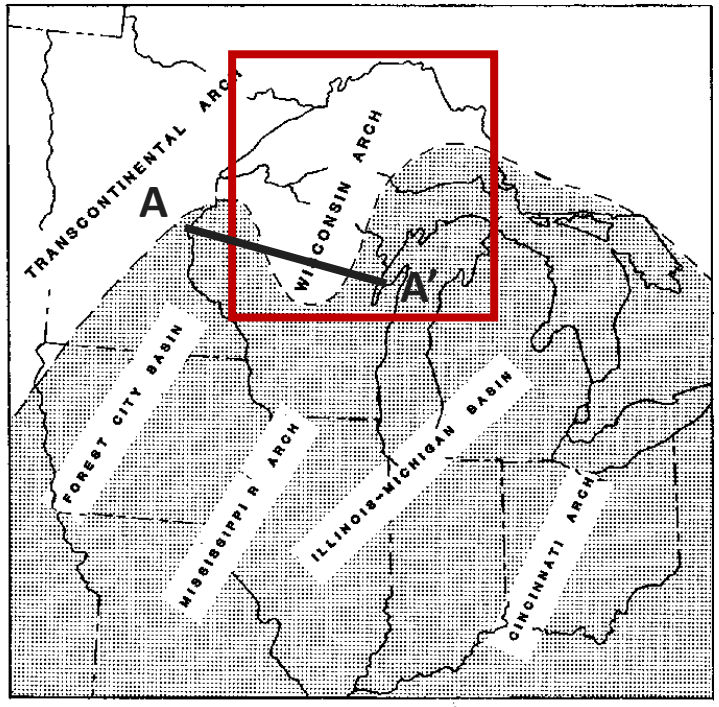
Milwaukee

IOWA

Ordovician
444–488 million years old

The Wisconsin Dome in N. Wisconsin is where these ancient rocks are ***near the surface***

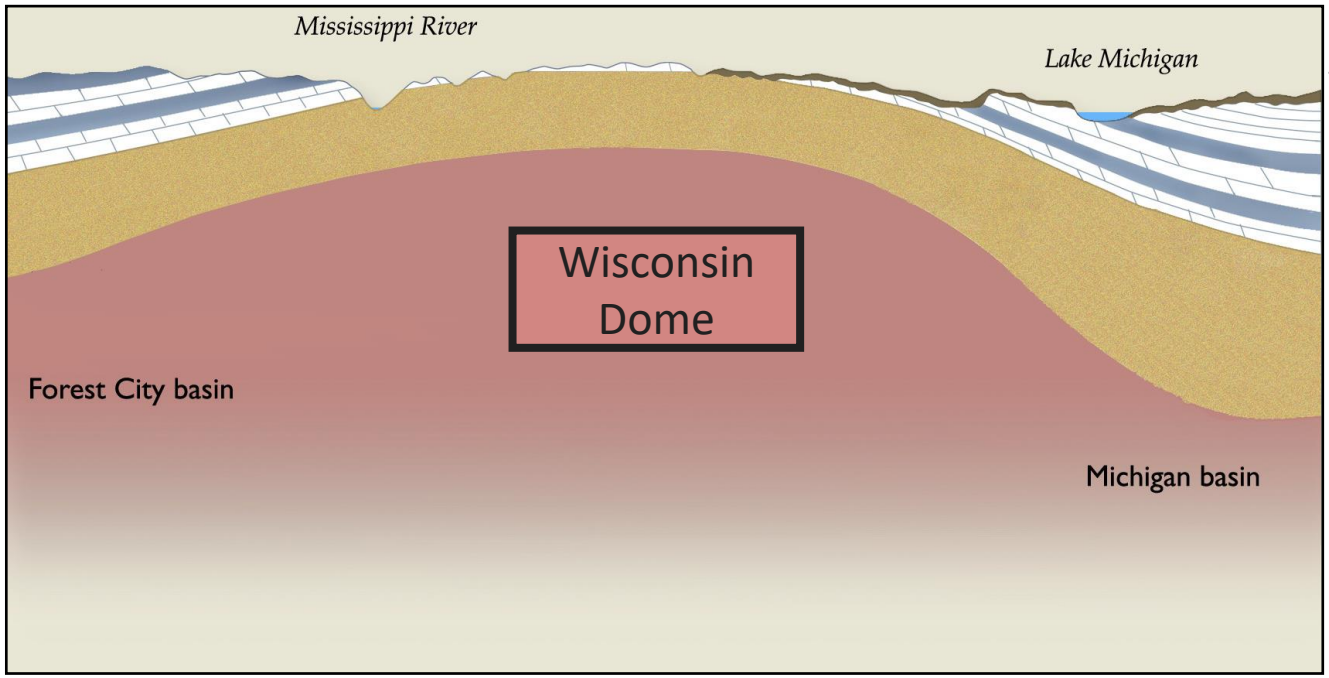
Map view



A West

LaBerge (1994) Geology of the Lake Superior Region

Cross section view



A' East

Wisconsin Geological and Natural History Survey

Check in!

Who here has observed igneous and/or metamorphic rocks in northern WI?

Who has been to Lake Superior, Rib Mountain, Devil's Lake? Any memories of the rock?

Wisconsin's Geologic History, Part 2: Shallow seas

Wisconsin's Geologic History, Part 2: Shallow seas

Youngest

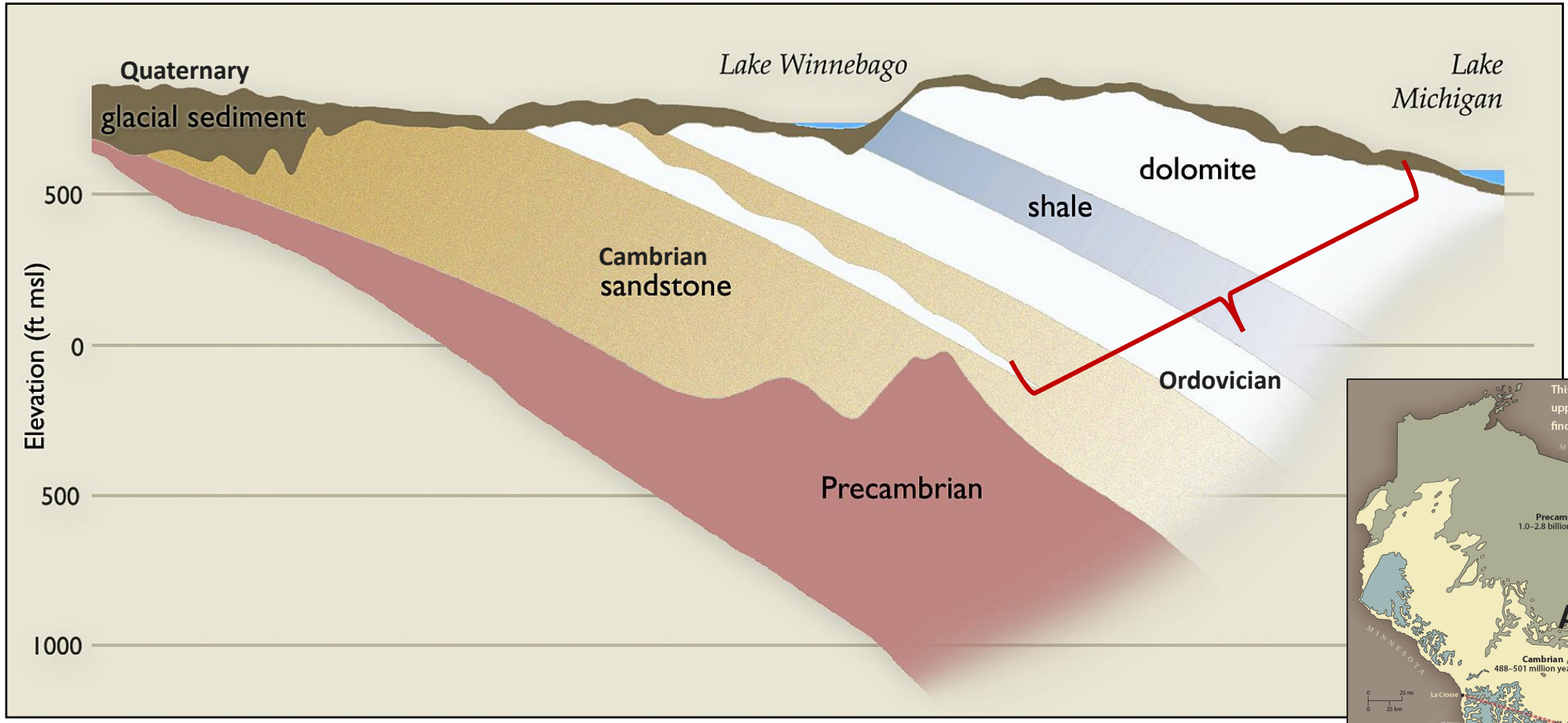
Devonian
Silurian
Ordovician
Cambrian

Oldest

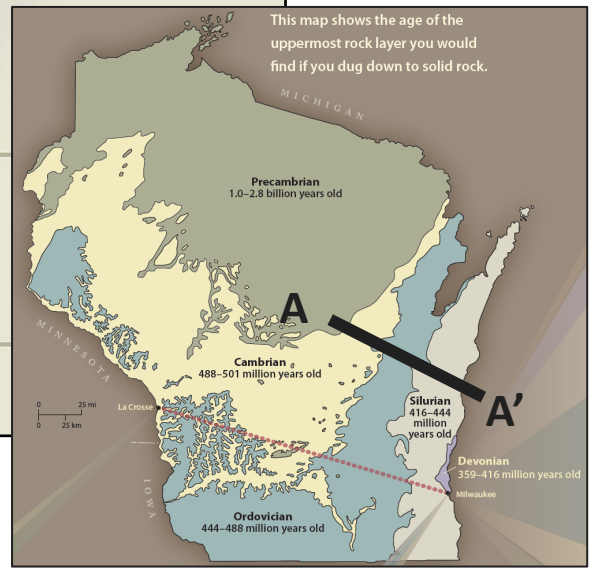
Precambrian

In ***eastern Wisconsin***, all of these rocks are present

A
West

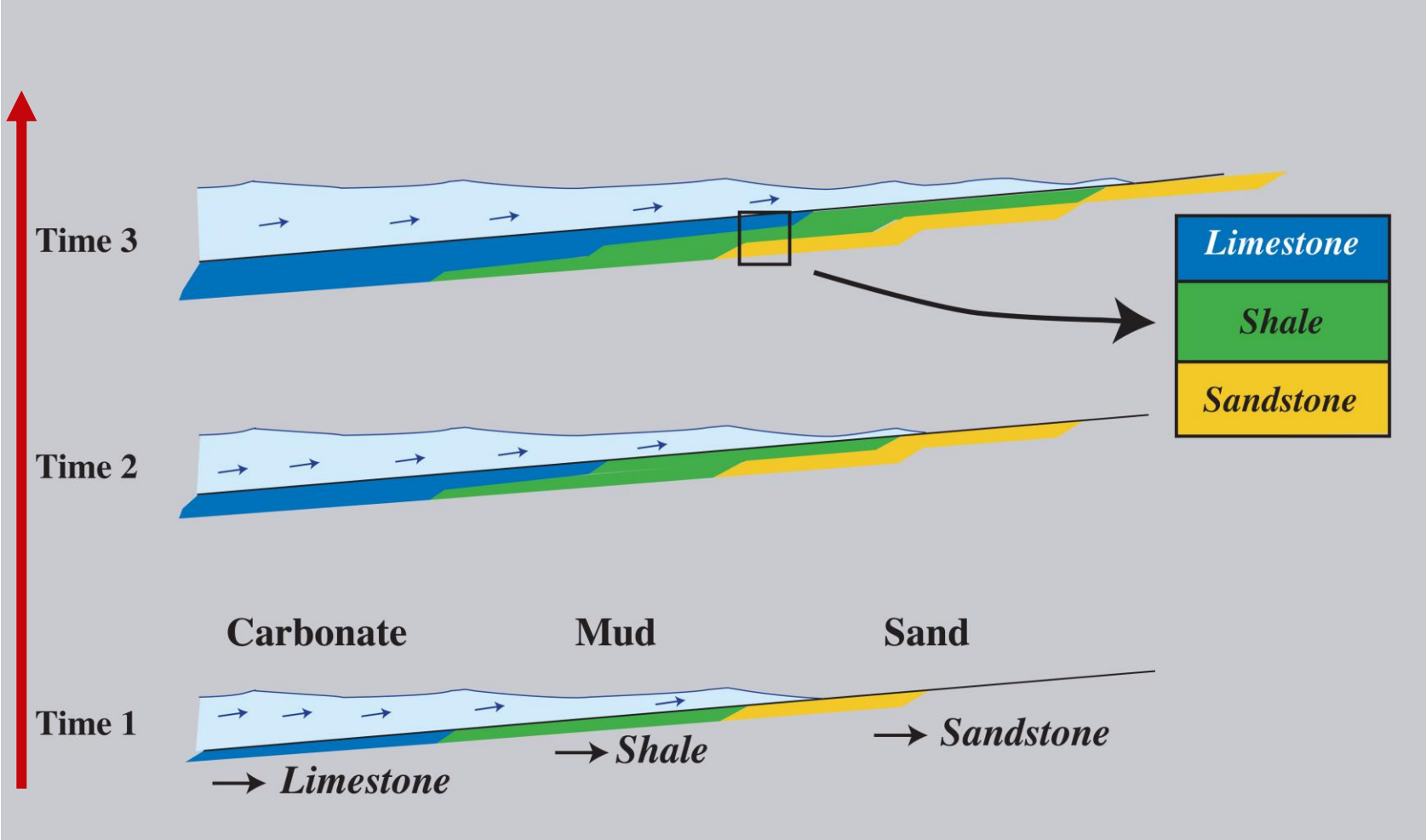


A’
East



Wisconsin Geological and Natural History Survey

Sandstone, shale, and carbonate rocks are formed in a ***marine environment***



http://geologictimepics.files.wordpress.com/2012/04/transgression.jpg

- Beach = deposition of sandstone
- Deep water = deposition of limestone/dolomite (carbonate)

Sea level changes are recorded in these rock layers

Rise in sea level

Dolomite

Sandstone

St Peter-Sinnipee Contact, Cty Hwy EE near Albany, WI. Credit: Google Earth

Fossils record marine life from this time

Trilobite, Wisconsin's state fossil

Coral

Brachiopod

Stromatolite

Wisconsin's subsurface (bedrock) geology

Youngest

Devonian
Silurian
Ordovician
Cambrian

Oldest

Precambrian

2

1

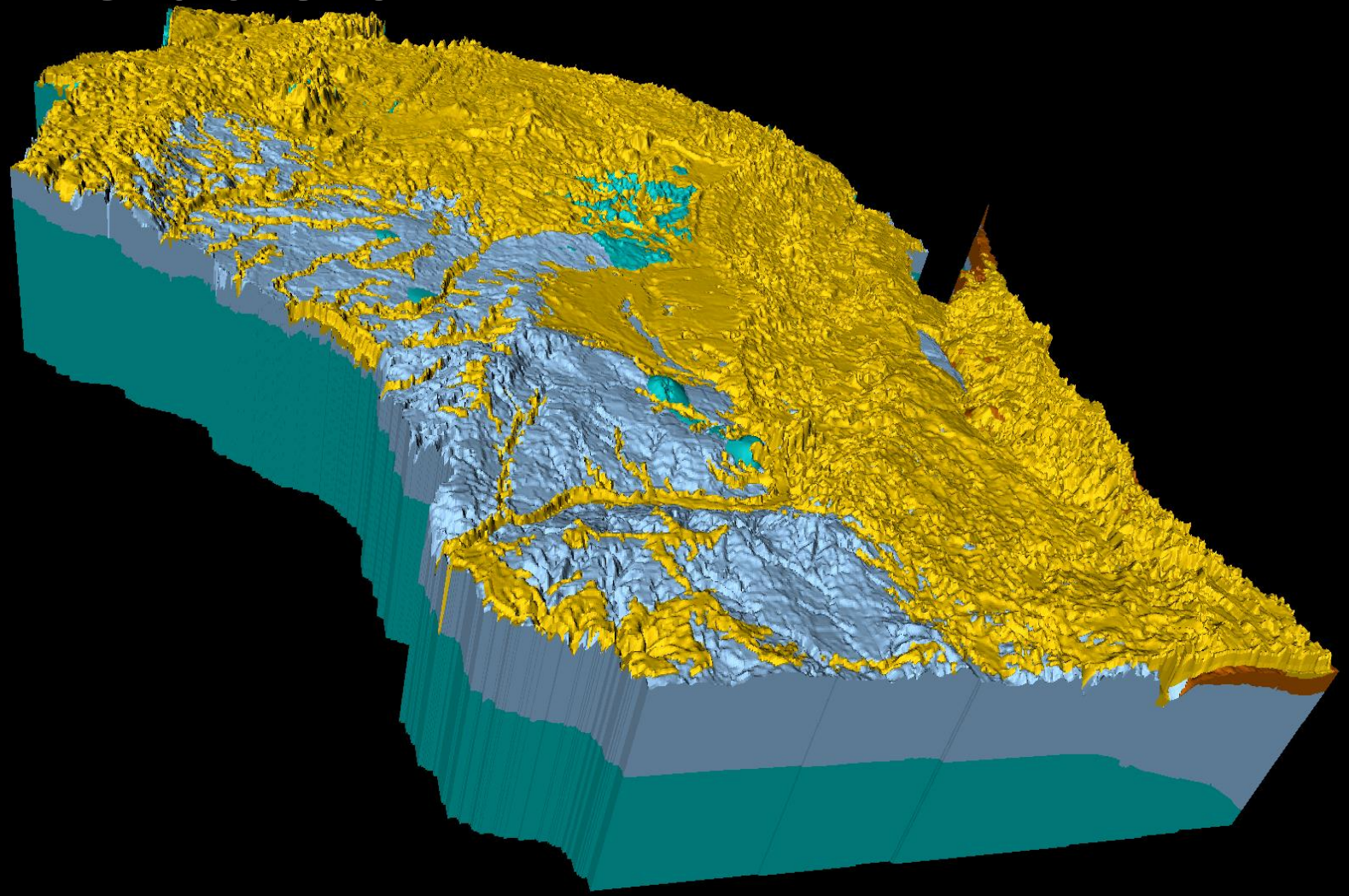
Check in!

Who here has observed carbonate (limestone/dolomite), sandstone in WI? Any fossils?

Who has been to Door County, the Driftless Area, the Dells?

Any observations?

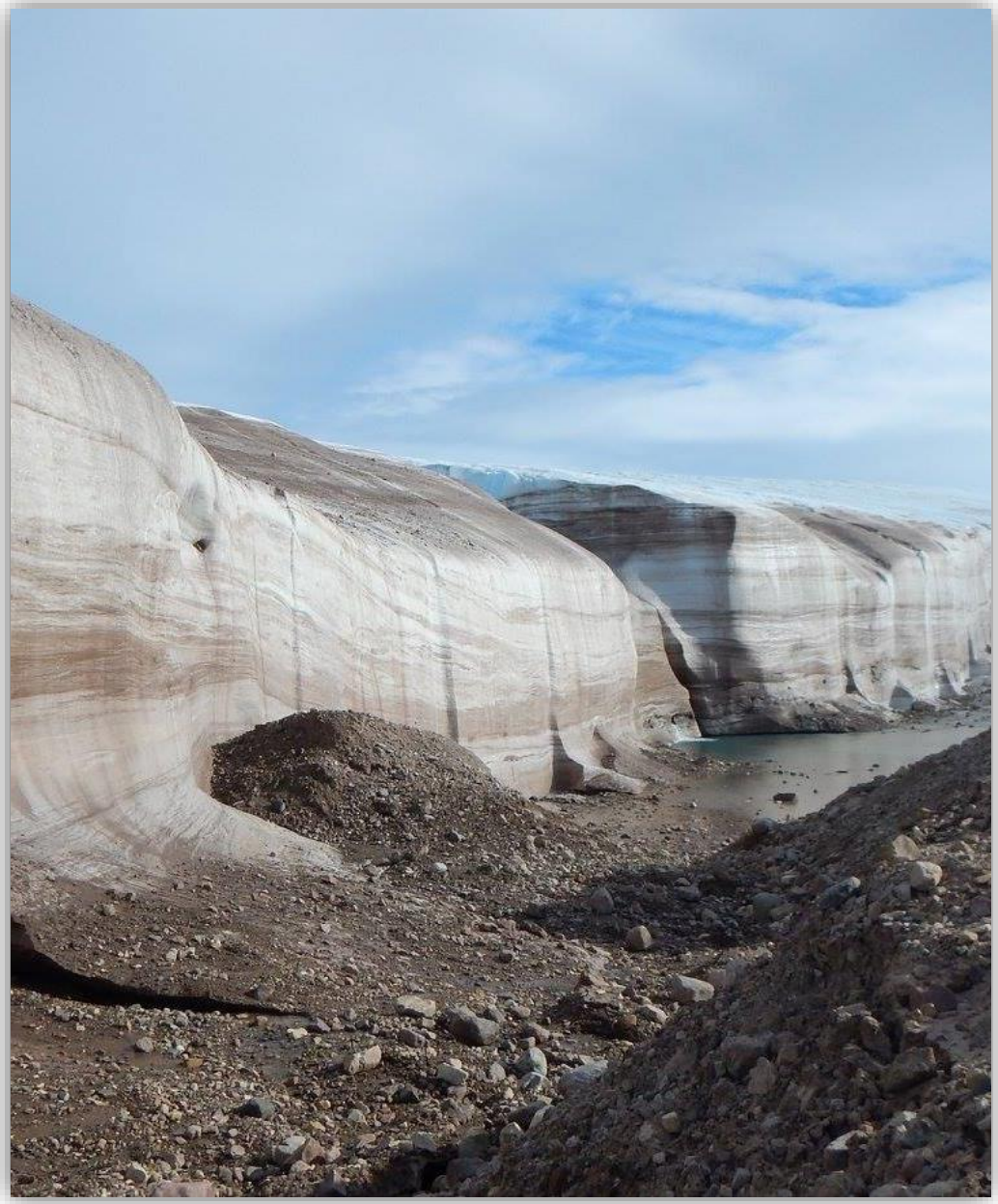
Wisconsin's Geologic History, Part 3: Glaciers



Youngest

Quaternary
Devonian
Silurian
Ordovician
Cambrian
Precambrian

Oldest



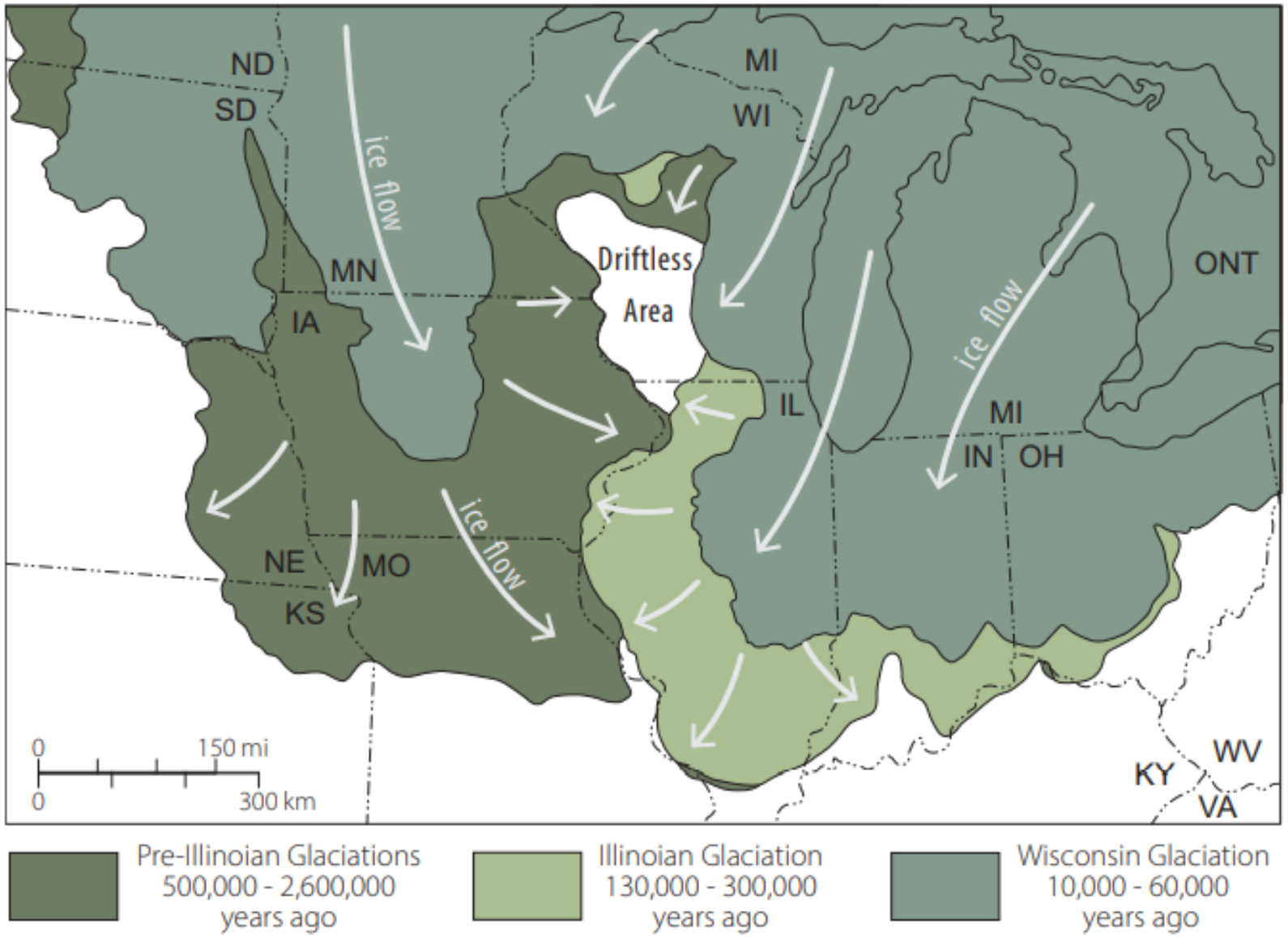
Petermann Glacier, Greenland Ice Sheet Photo: Mel Reusche

Glaciers shaped the Wisconsin landscape

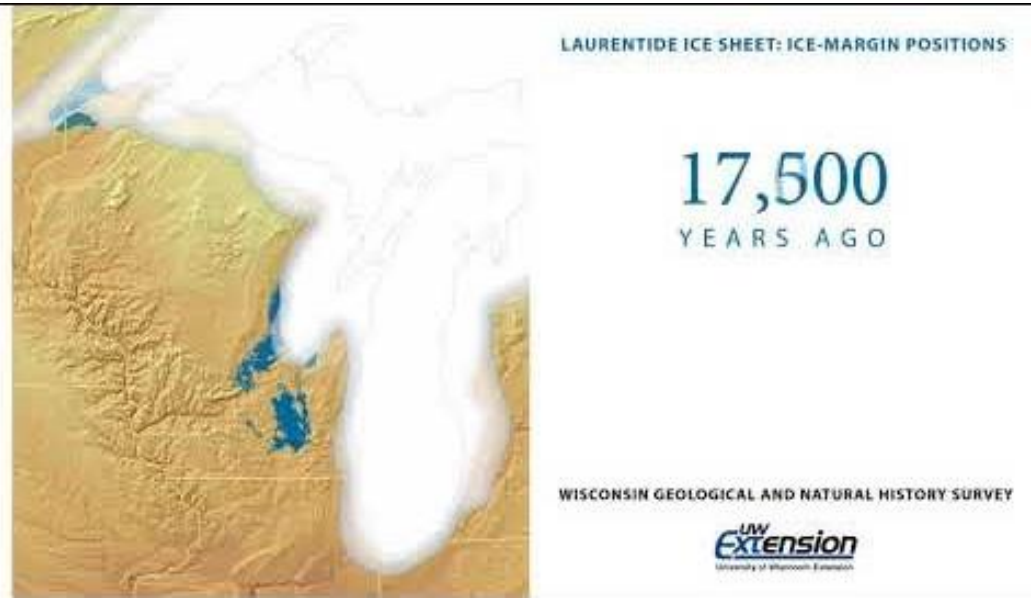
- 2.58 million to 10,000 years ago
- Large ice sheet covered Canada and northern U.S.
- Over several ice ages, the ice sheet advanced into and retreated out of Wisconsin at least 4, maybe 10 times!

There were ***three*** major phases of glaciation in Wisconsin

- Driftless Area = untouched by glaciers



Wisconsin's landscape is shaped by ***glaciers***

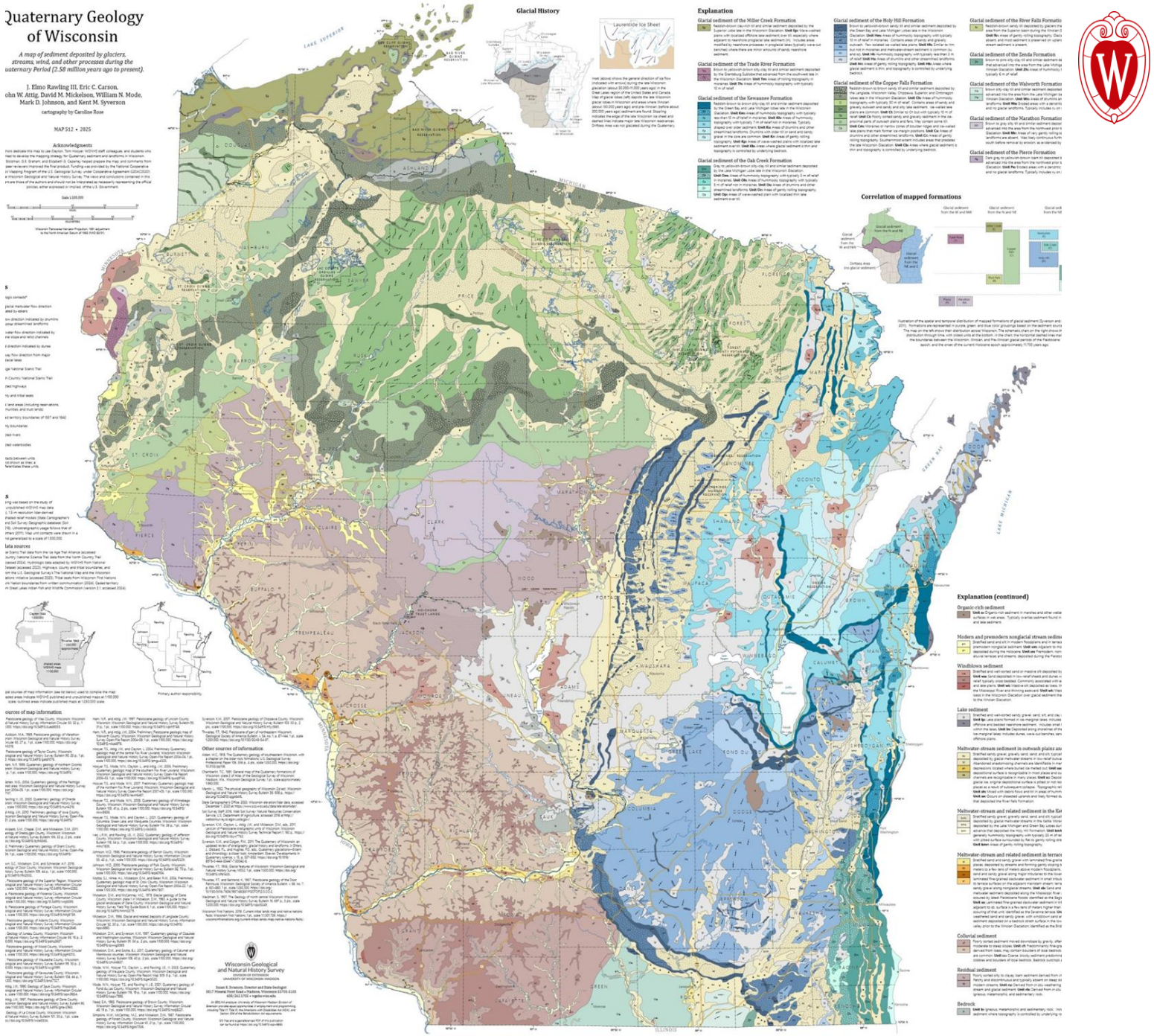


Check in!

What glacial landscapes have you witnessed?

Who has been to Kettle Moraine, Devil's Lake, Minoqua area?

Any observations?

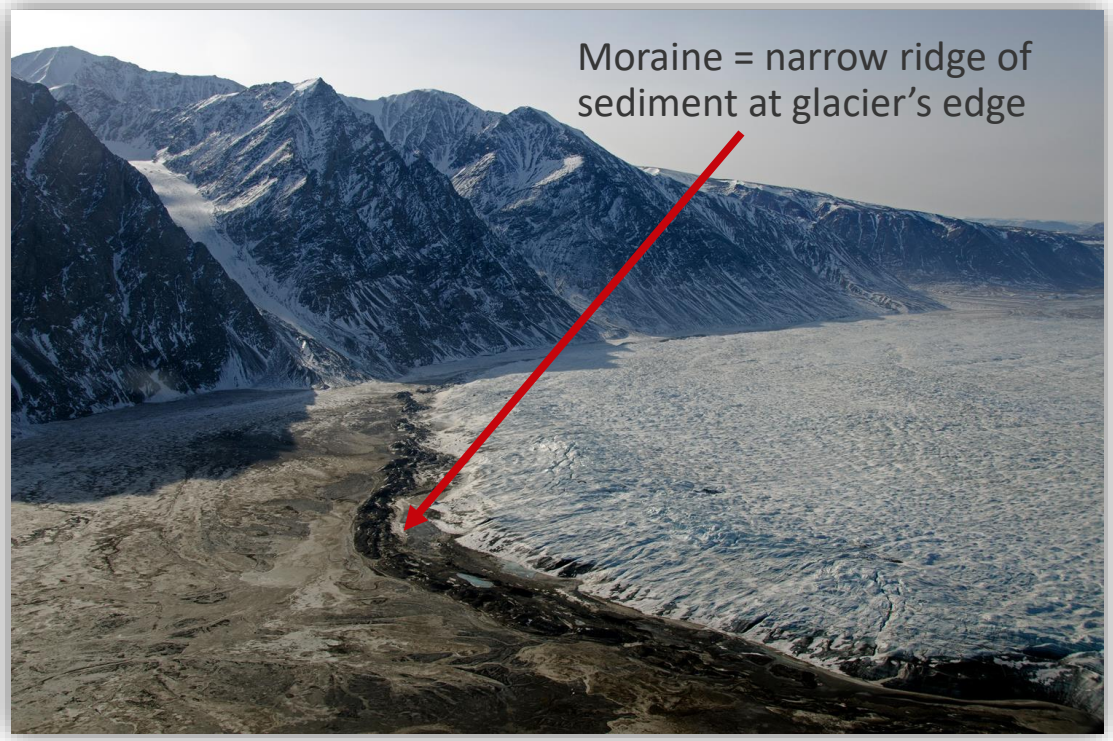


Glaciers deposit ***till*** sediments

Till deposition

Petermann Glacier, Greenland Ice Sheet. Credit: Mel Reusche

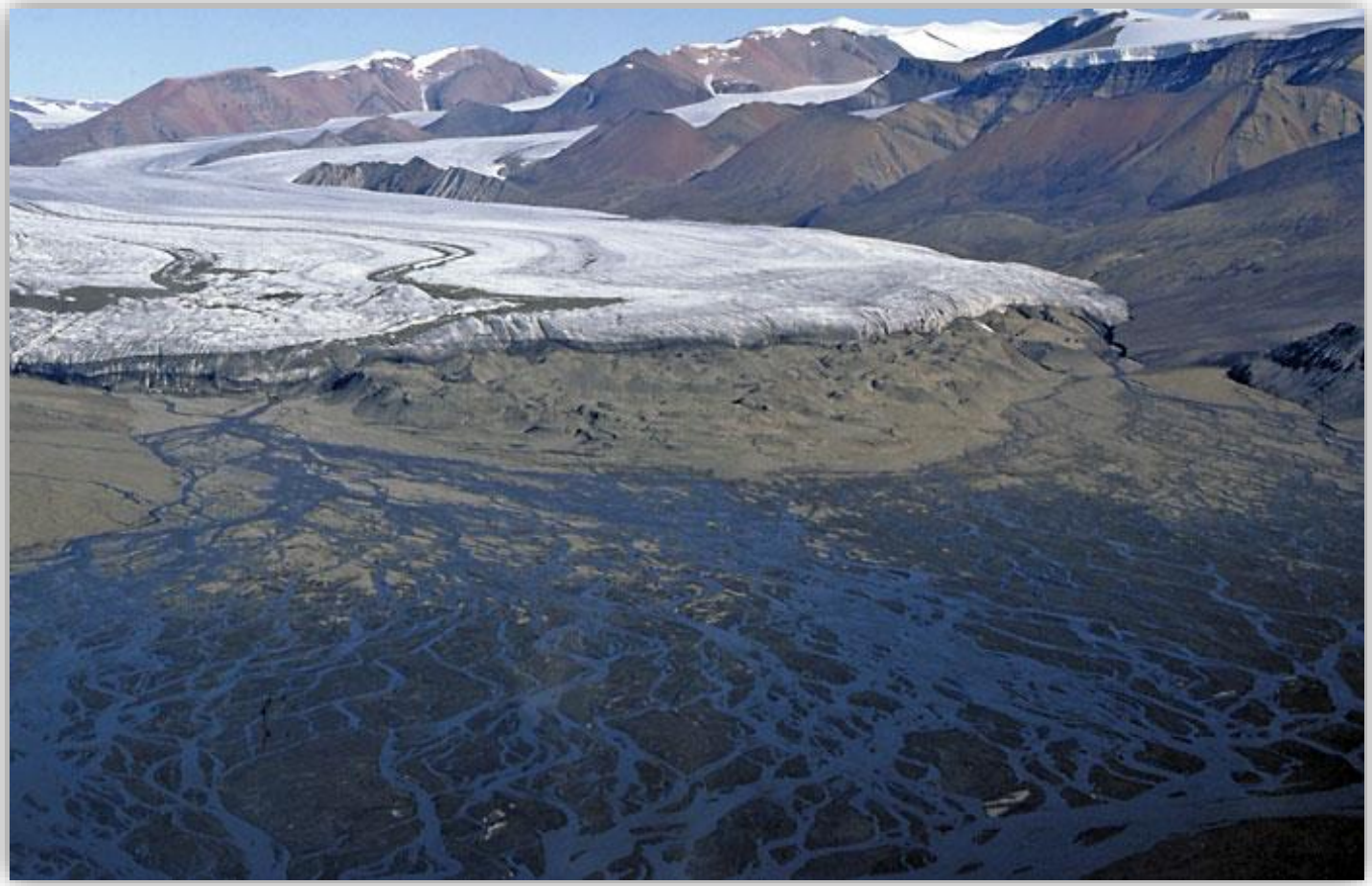
- *Till* = Unsorted sediments that range in composition



NASA/Michael Studinger - http://www.nasa.gov/mission_pages/icebridge/index

Glaciers deposit ***outwash*** sediments in stream riverbeds

Outwash plain



- *Outwash* = sandy sediments
- Rivers sort sediment by size/density

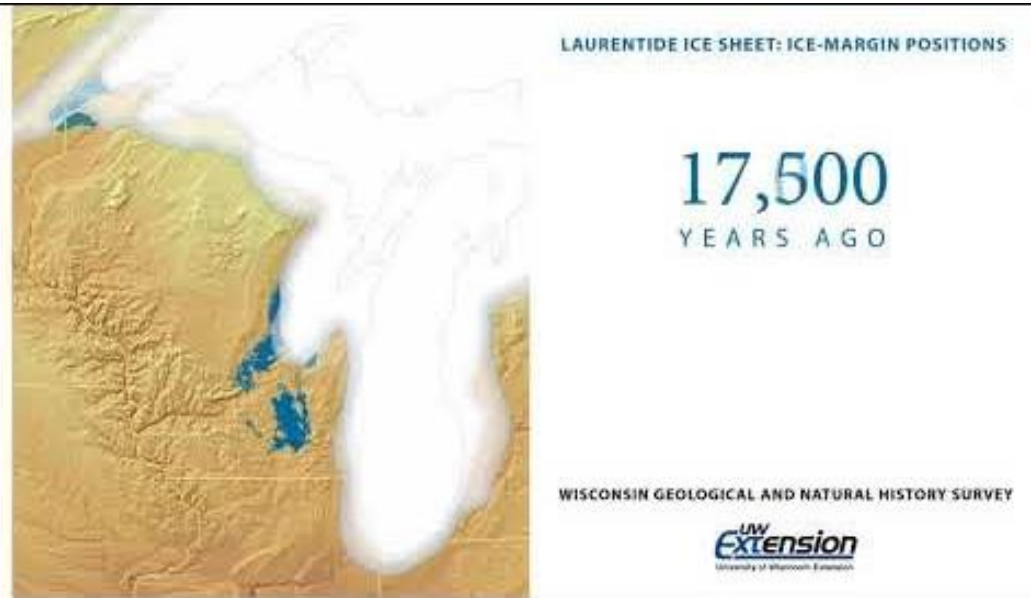
Glaciers deposit ***lake*** sediments at the bottom of glacial lakes

Glacial lake

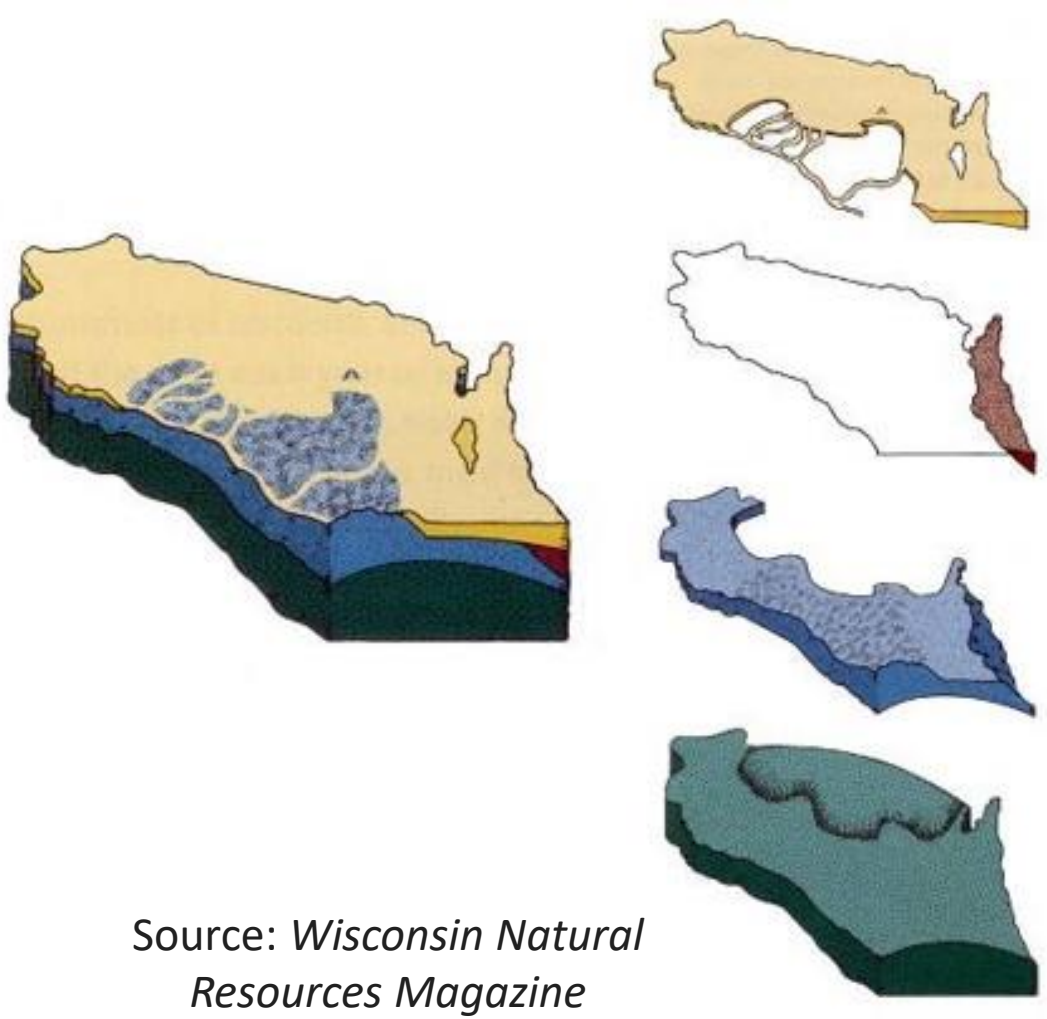
Kvíájökull, Vatnajökull Ice Cap, Iceland. Credit: Mel Reusche

- *Lake sediments* = clay-rich or fine-grained

Wisconsin's landscape is shaped by ***glaciers***



Objectives

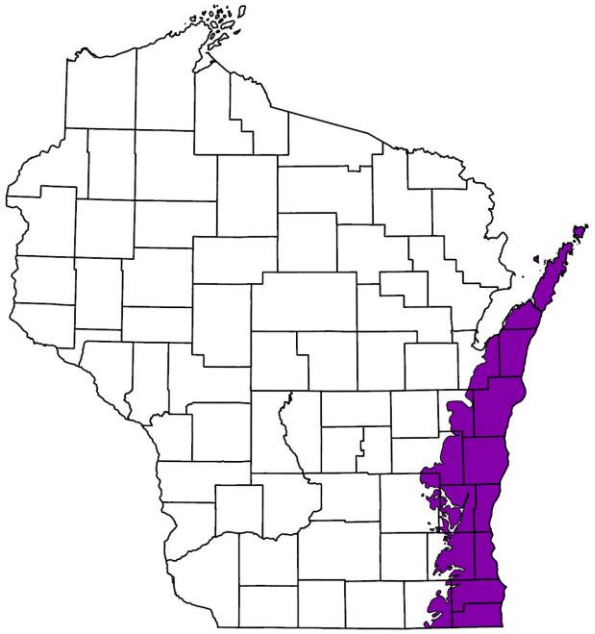


Source: *Wisconsin Natural Resources Magazine*

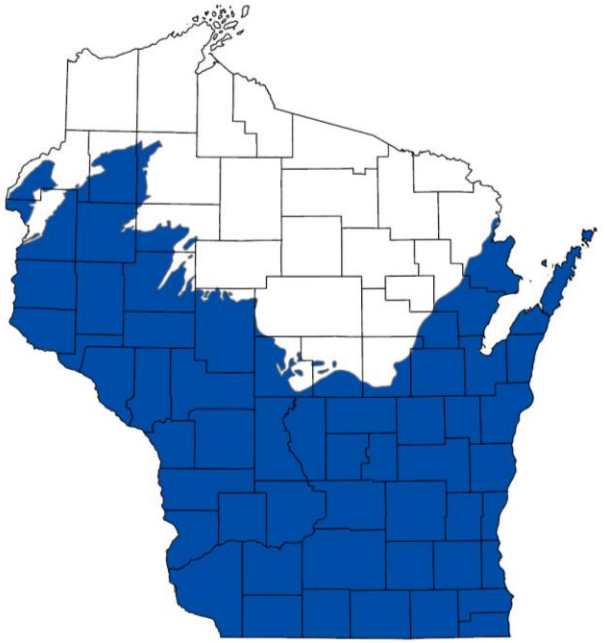
- What makes a rock or sediment a good aquifer?
- What are the three main stages in Wisconsin's geologic history?
- What are Wisconsin's four aquifers?

Takeaway: Wisconsin's geology controls the availability of groundwater.

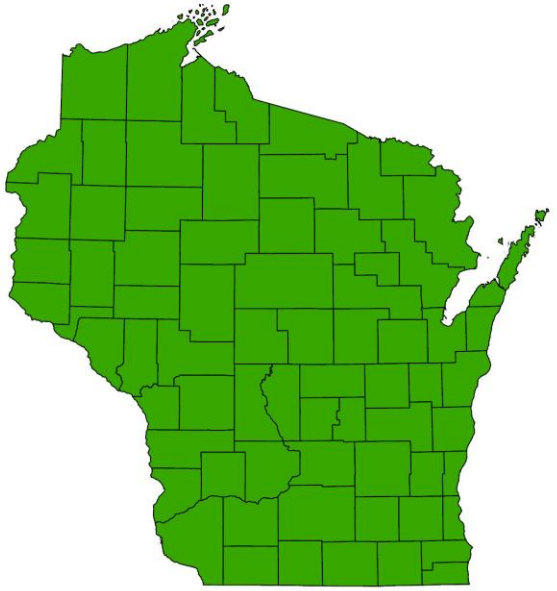
Wisconsin’s bedrock aquifers



Eastern dolomite

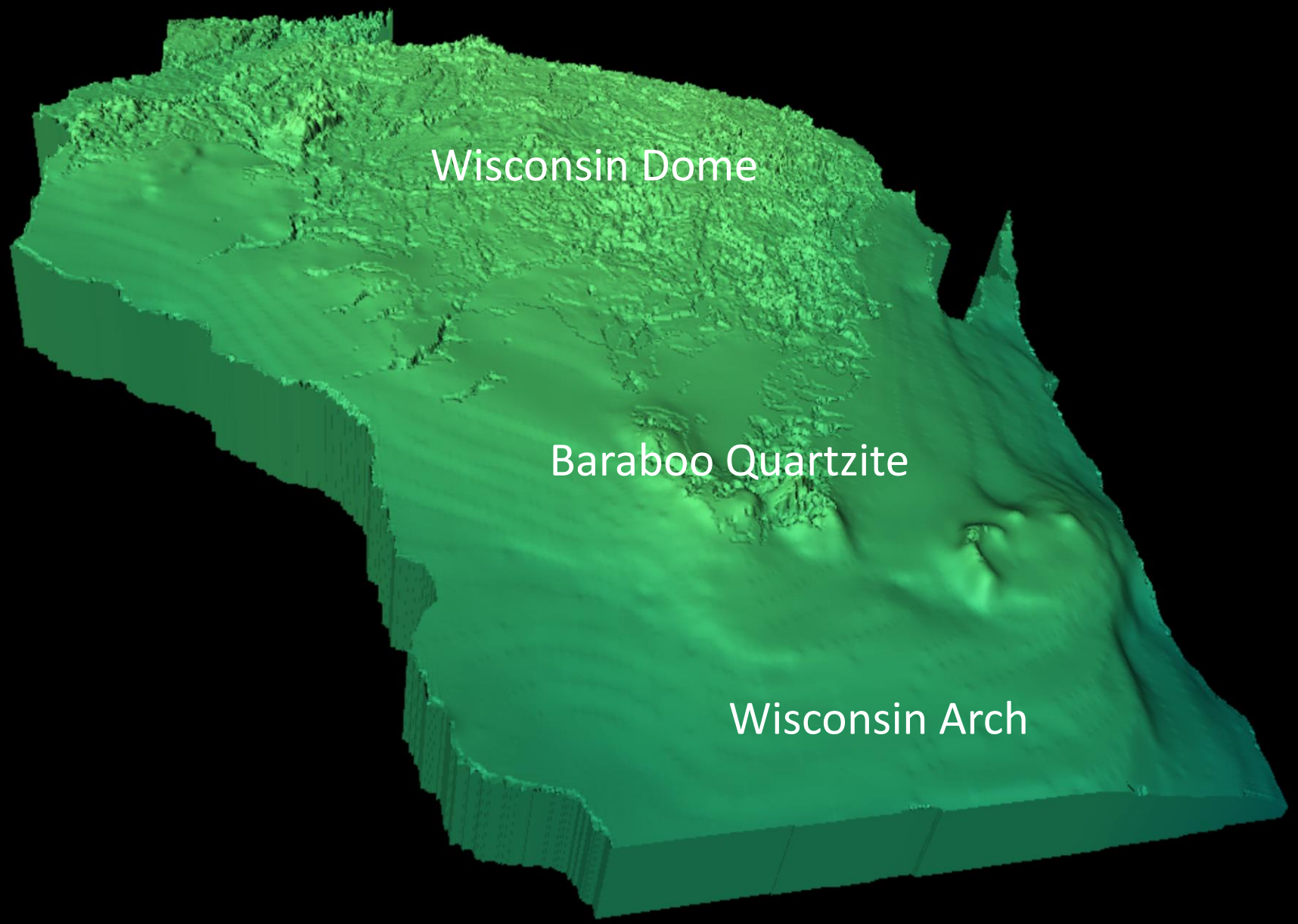


Sandstone & dolomite



Crystalline bedrock

Precambrian bedrock underlies the ***whole*** state



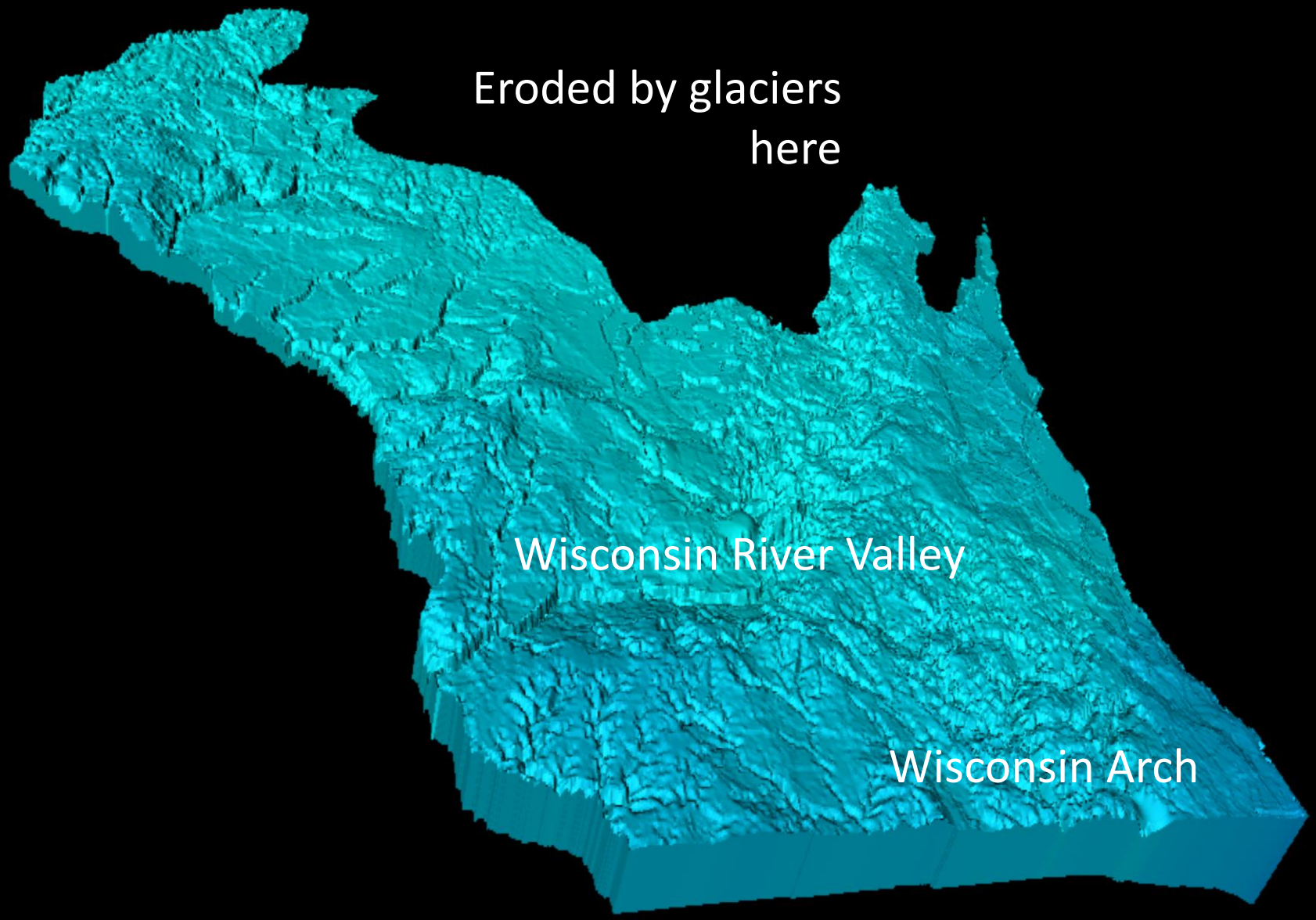
The crystalline bedrock is a ***poor*** aquifer

Rhyolite schist, Dells of the Eau Claire

- Also referred to as “crystalline basement” or “Precambrian basement”
- At the surface in N Wisconsin
- Very low well yields, but can supply households

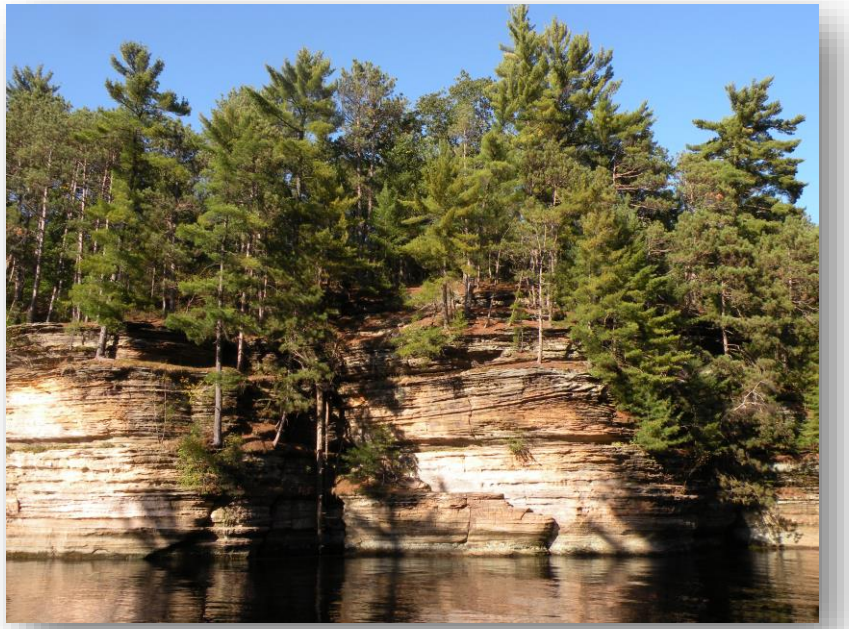
Basaltic lava flows, Interstate State Park

Cambrian-Ordovician sandstone & dolomite aquifer covers ***2/3*** of the state



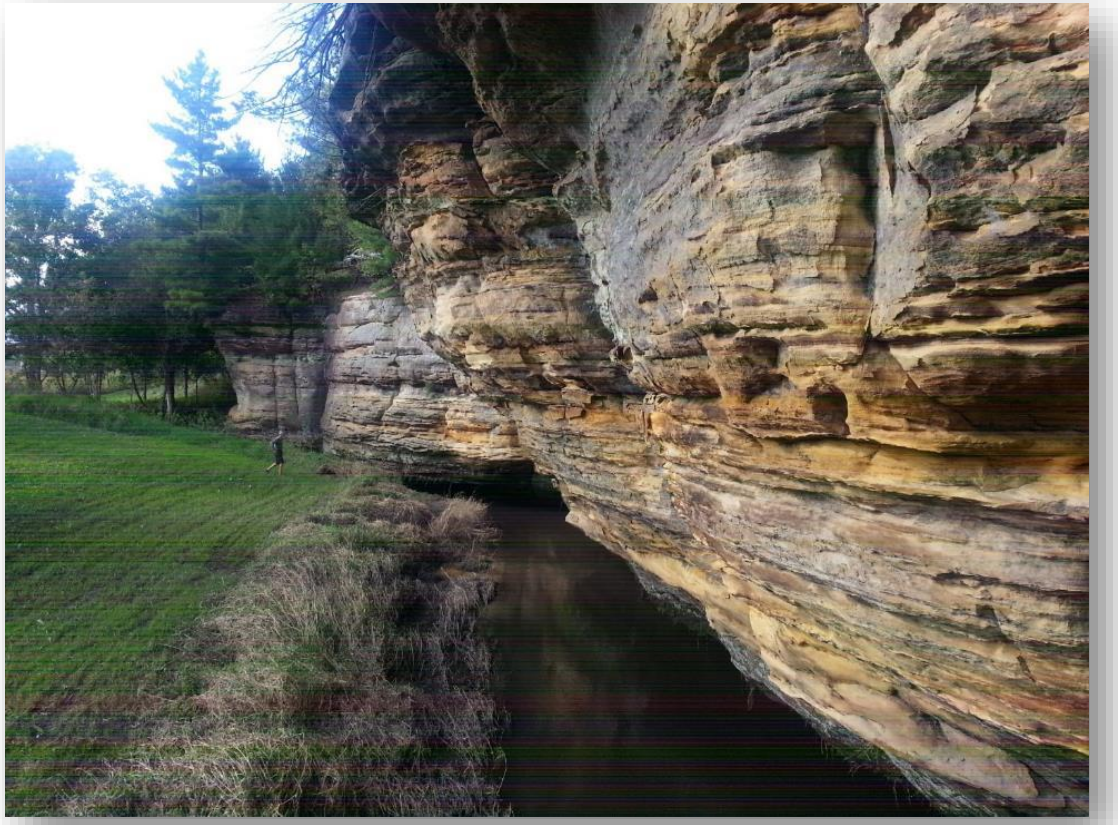
The sandstone & dolomite aquifer is an ***important*** water source for many municipalities

Sandstone, Wisconsin Dells

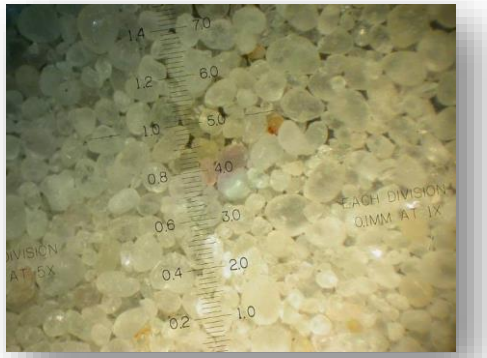


- Also referred to as the “sandstone aquifer”
- Supplies many high-capacity wells

Cambrian sandstone at Rockbridge, WI



Clean, well-rounded quartz grains



Well yields for the sandstone aquifer are ***high***

PROBABLE WELL YIELDS

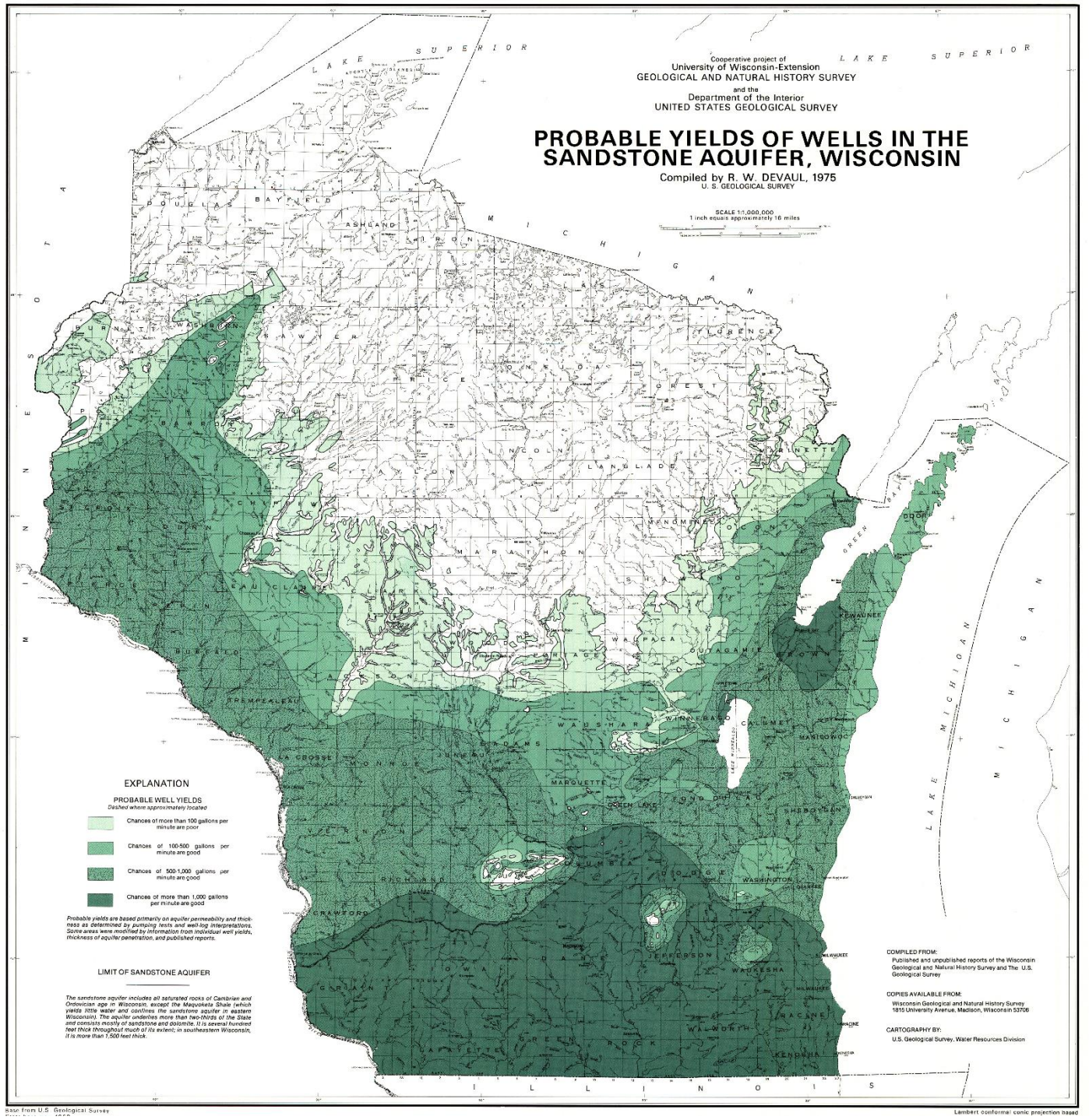
Dashed where approximately located

- Chances of more than 100 gallons per minute are poor
- Chances of 100-500 gallons per minute are good
- Chances of 500-1,000 gallons per minute are good
- Chances of more than 1,000 gallons per minute are good

Probable yields are based primarily on aquifer permeability and thickness as determined by pumping tests and well-log interpretations. Some areas were modified by information from individual well yields, thickness of aquifer penetration, and published reports.

LIMIT OF SANDSTONE AQUIFER

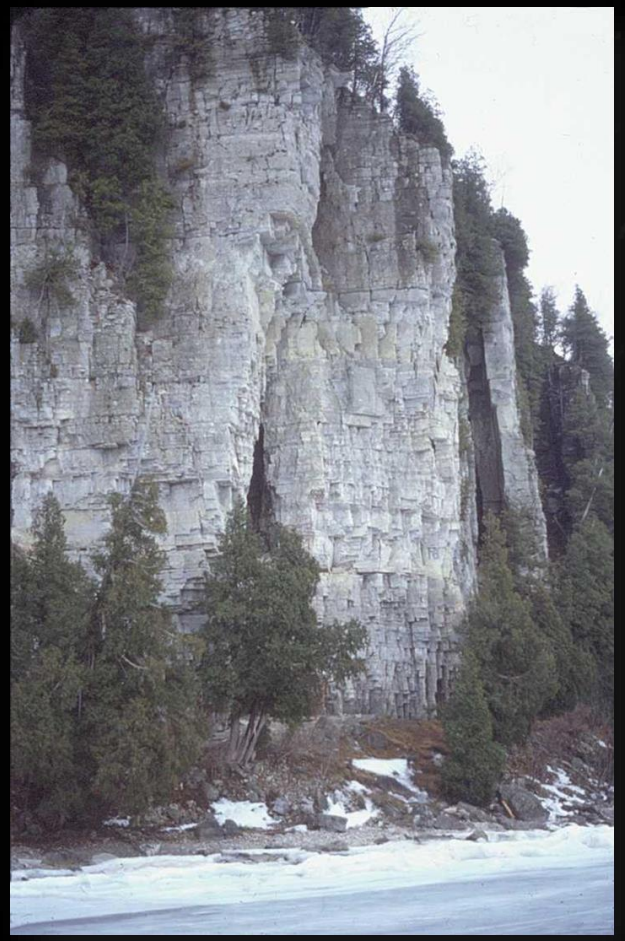
- Range: <100 to >1,000 gallons/min
- Garden hose is 5 gallons/min



Silurian dolomite (carbonate) aquifer is present in ***Eastern Wisconsin***

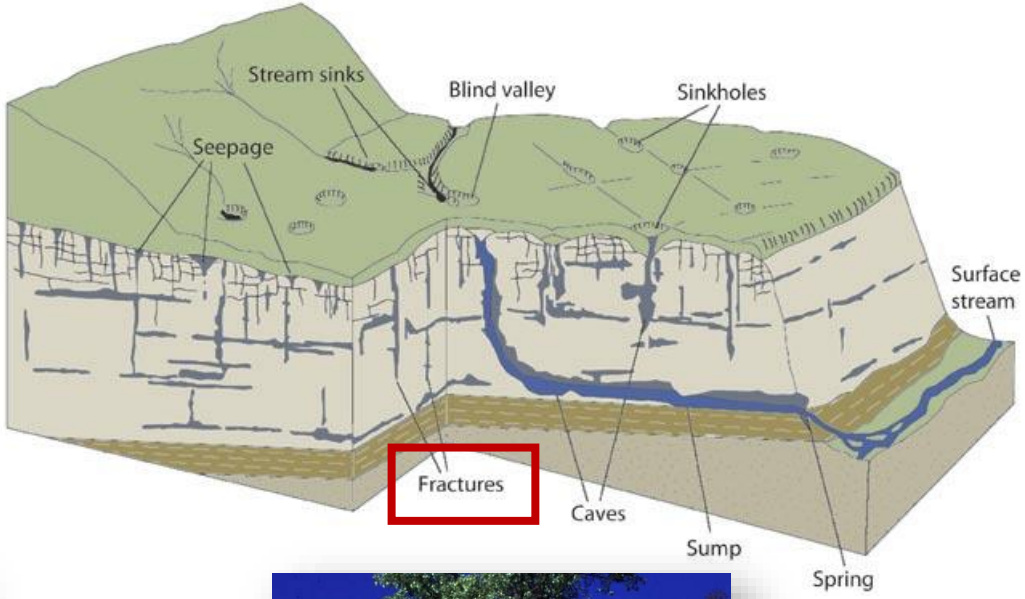
Silurian dolomite (carbonate) aquifer is present in ***Eastern Wisconsin***

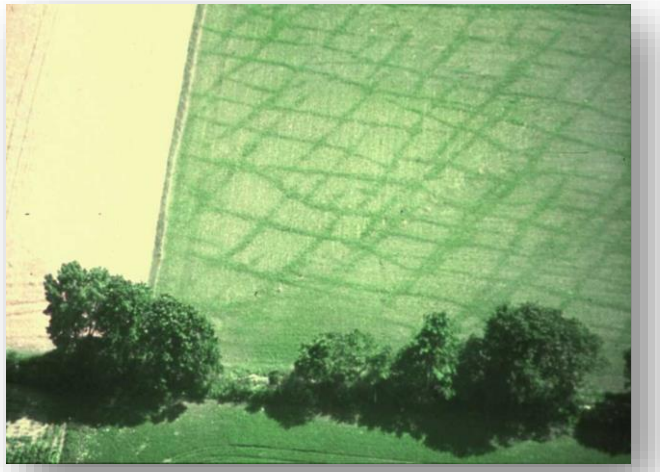
Niagara Escarpment, Peninsula State Park

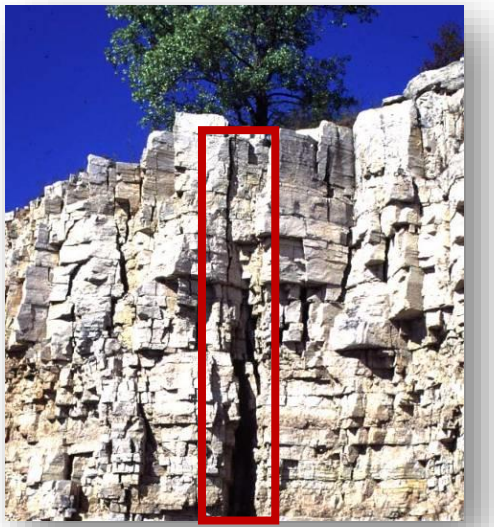


Fractures in the Silurian dolomite make groundwater ***vulnerable*** to contamination

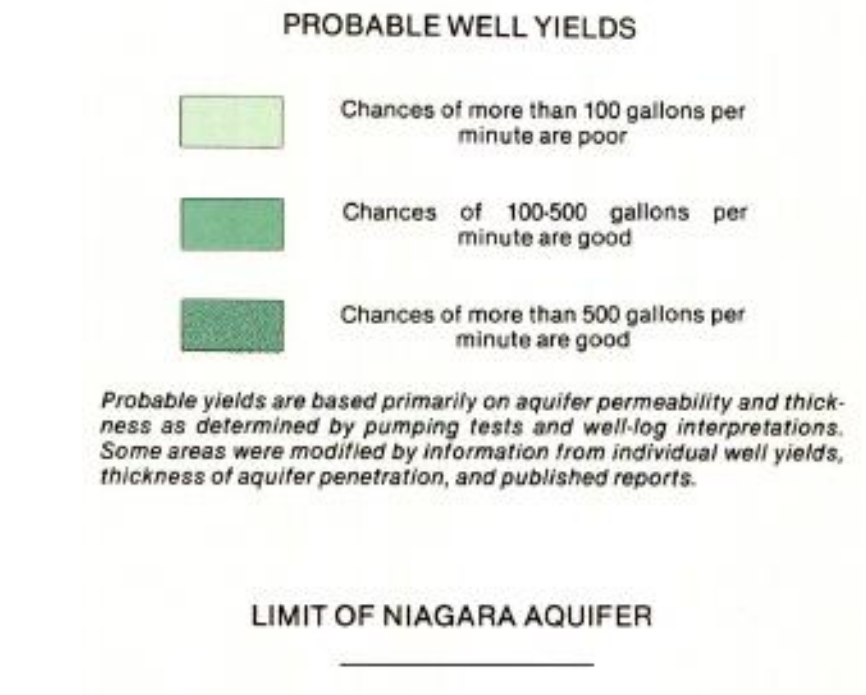
- Also referred to as the “Niagara aquifer”



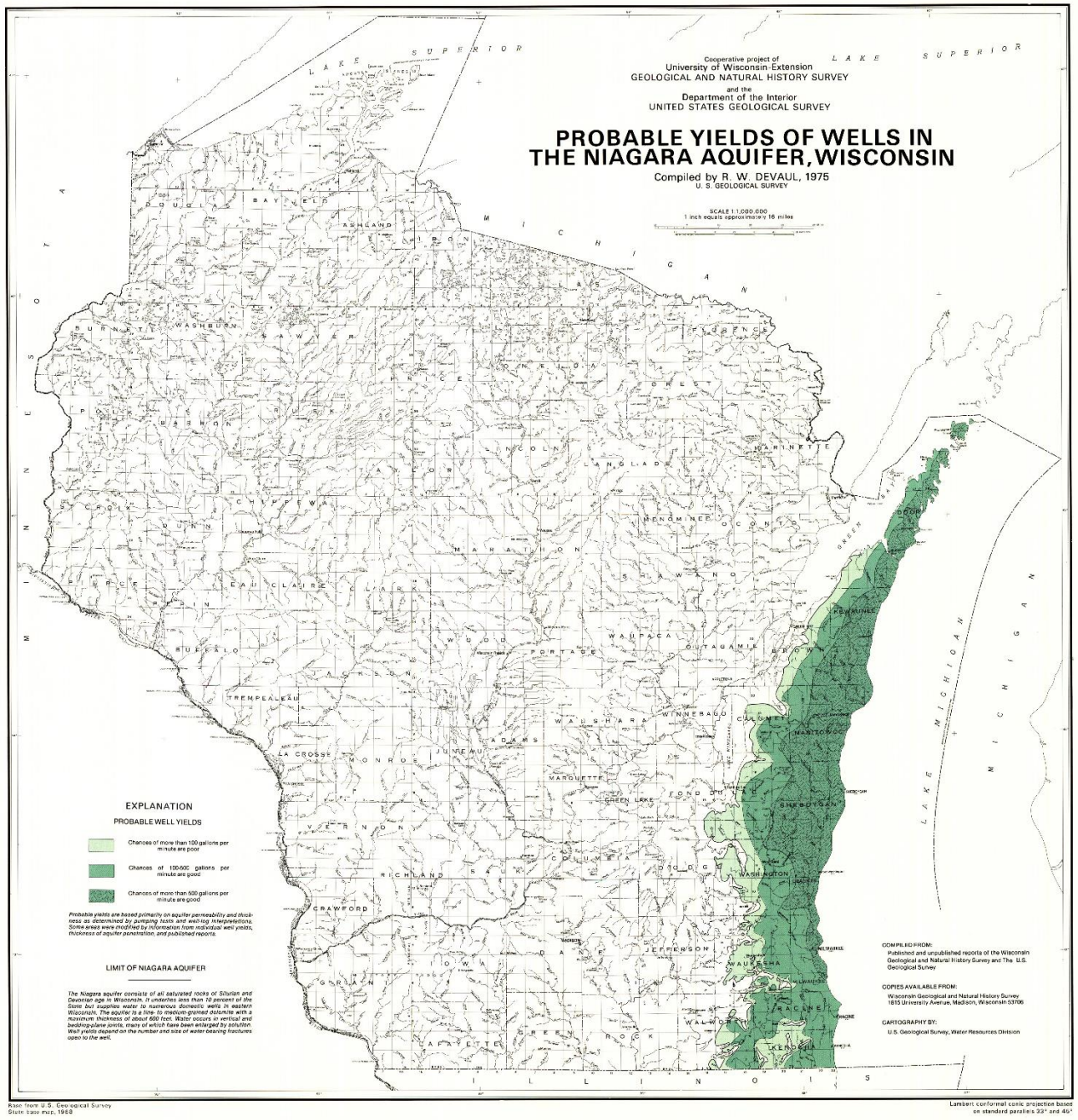




Well yields for the dolomite aquifer are also ***good***



- Range: <100 to 500 gallons/min
- Garden hose is 5 gallons/min

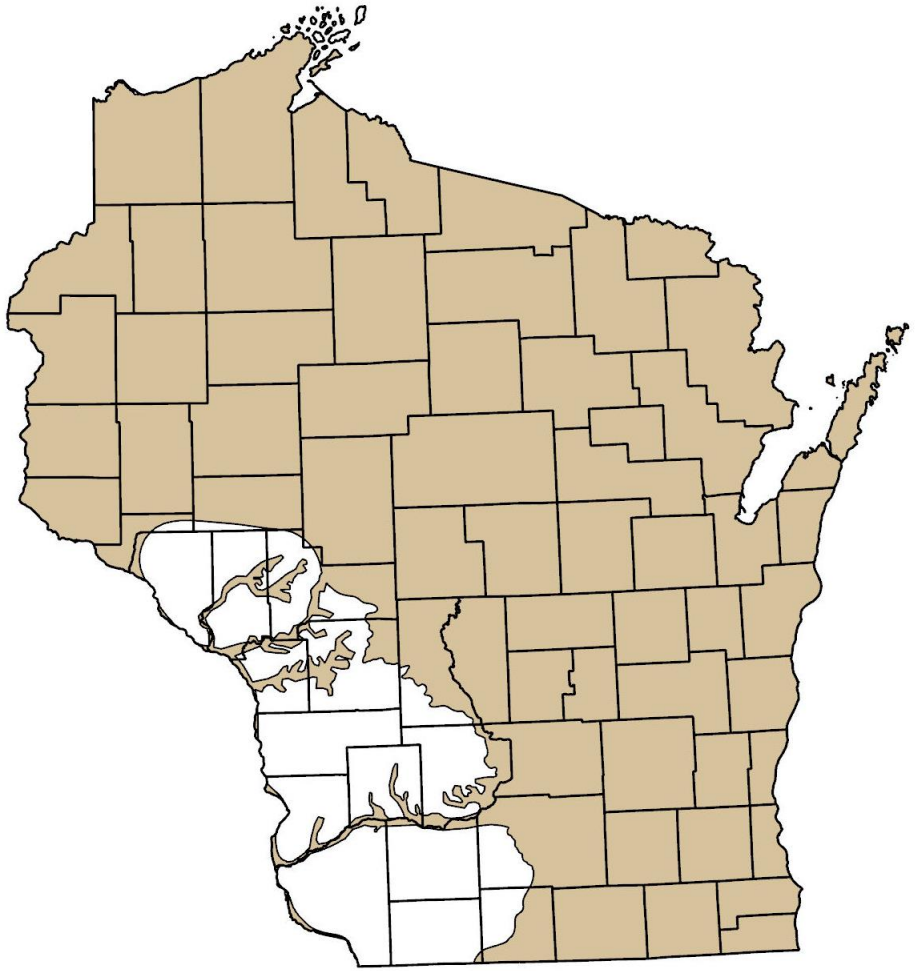


Bedrock geology impacts groundwater availability

- If you were to drill a well into bedrock, what part of the state would you choose? Avoid?

Takeaway

Wisconsin’s surficial aquifer



The surficial aquifer ***overlies*** our bedrock aquifers, except in the Driftless Area

The surficial aquifer is made up of ***glacial*** and ***modern river*** sediments

- Also referred to as the “sand and gravel aquifer” or “glacial aquifer”

Sand and gravel near West Bend

Central sands near Stevens Point

Well yields for the surficial aquifer are ***variable***

PROBABLE WELL YIELDS

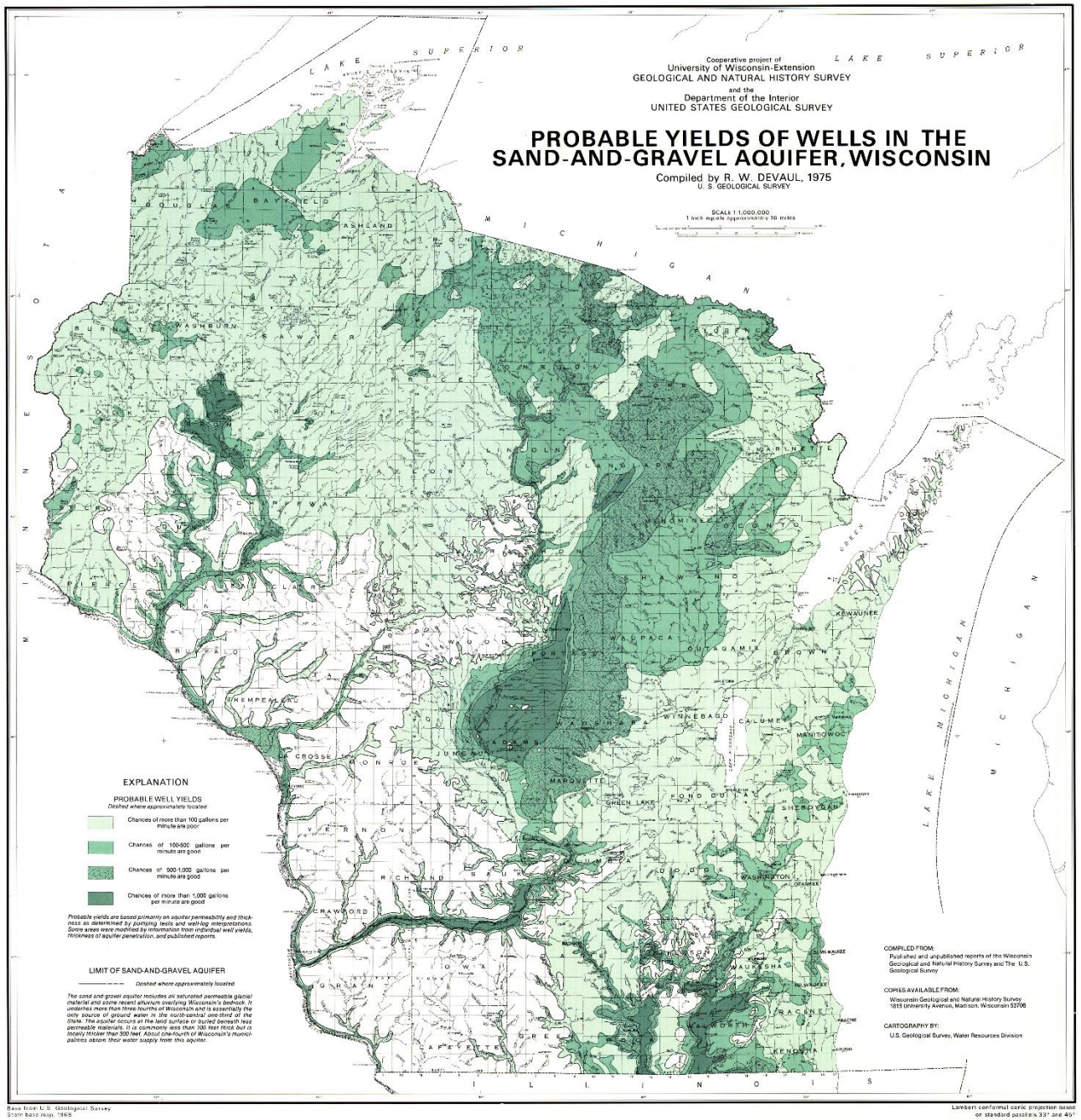
Dashed where approximately located

- Chances of more than 100 gallons per minute are poor
- Chances of 100-500 gallons per minute are good
- Chances of 500-1,000 gallons per minute are good
- Chances of more than 1,000 gallons per minute are good

Probable yields are based primarily on aquifer permeability and thickness as determined by pumping tests and well-log interpretations. Some areas were modified by information from individual well yields, thickness of aquifer penetration, and published reports.

LIMIT OF SAND-AND-GRAVEL AQUIFER

Dashed where approximately located



- Range: <100 to >1,000 gallons/min
- Garden hose is 5 gallons/min

Surficial geology impacts groundwater availability

- ***Sands and gravels*** = high well yields

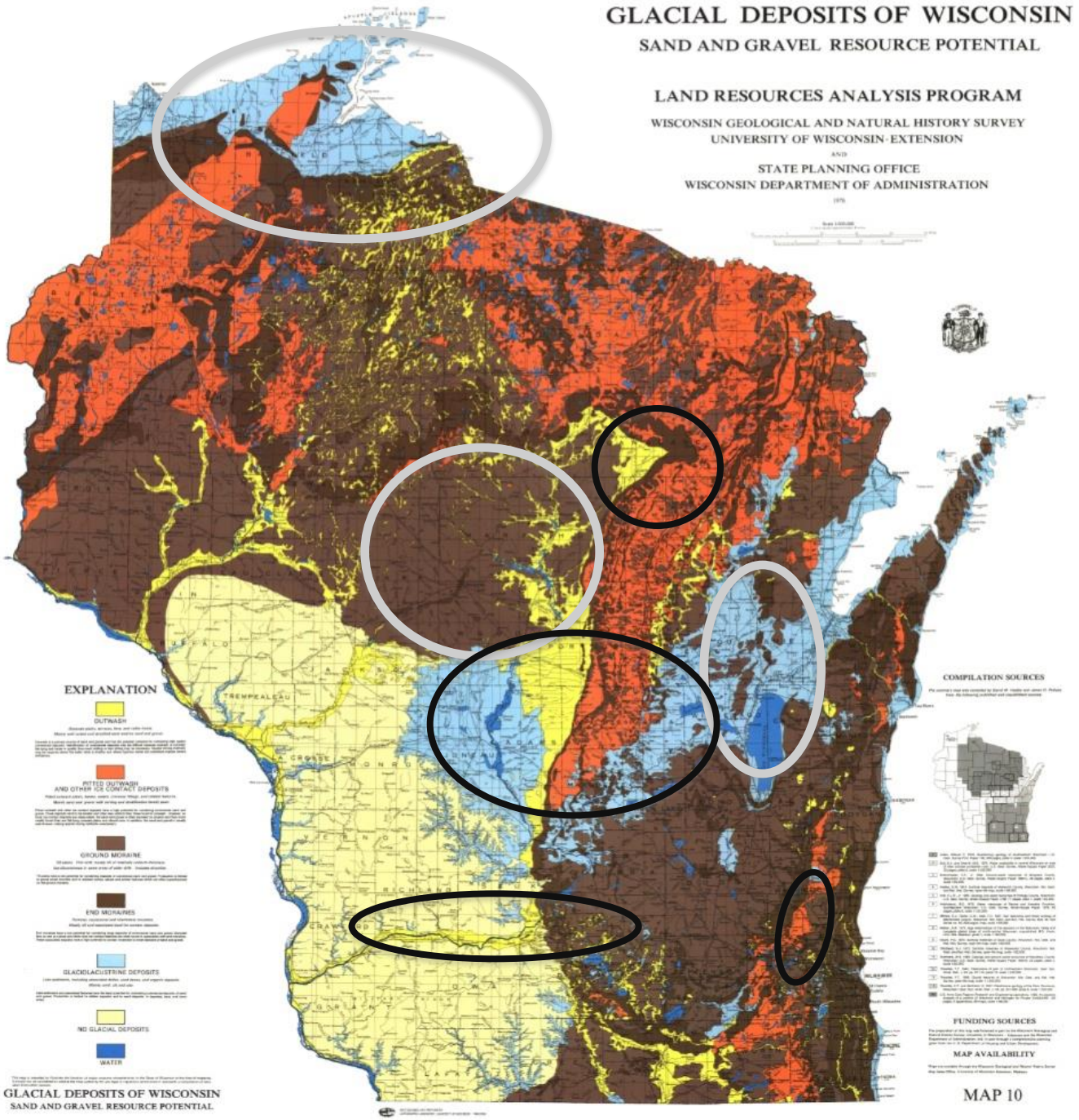
OUTWASH

PITTED OUTWASH AND OTHER ICE CONTACT DEPOSITS

- *Silts and clays* = low well yields

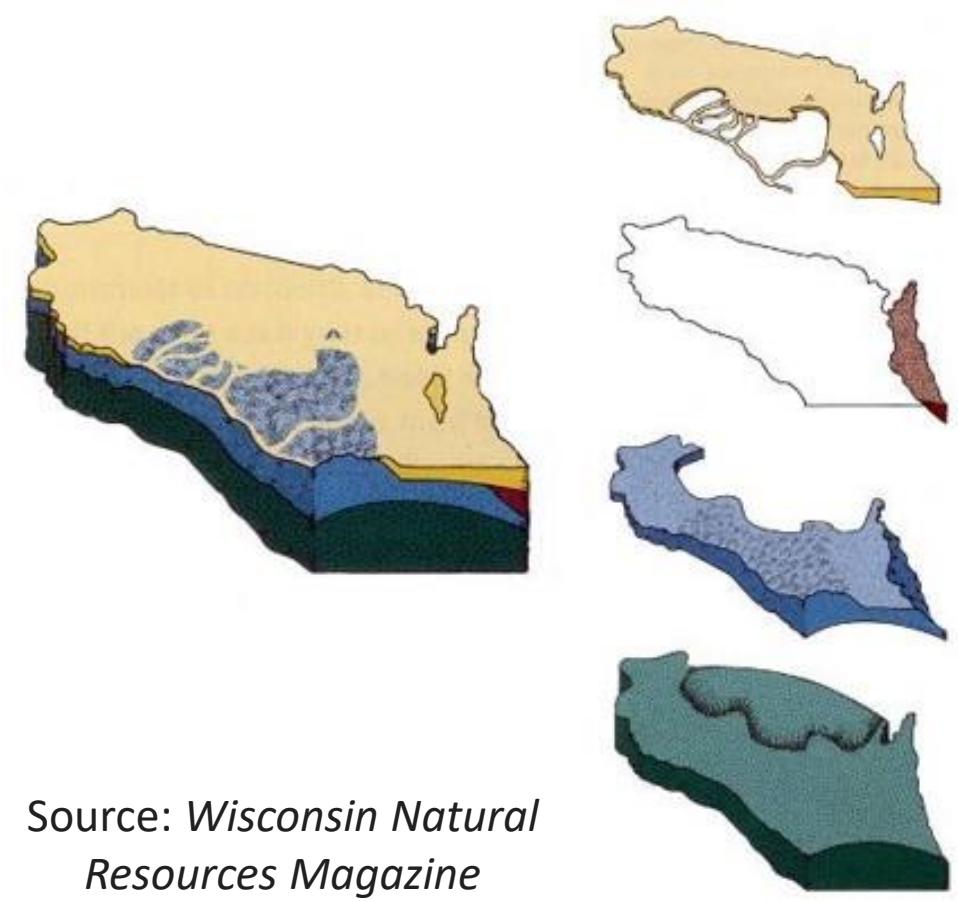
GROUND MORAINE

GLACIOLACUSTRINE DEPOSITS



Takeaway

Summary

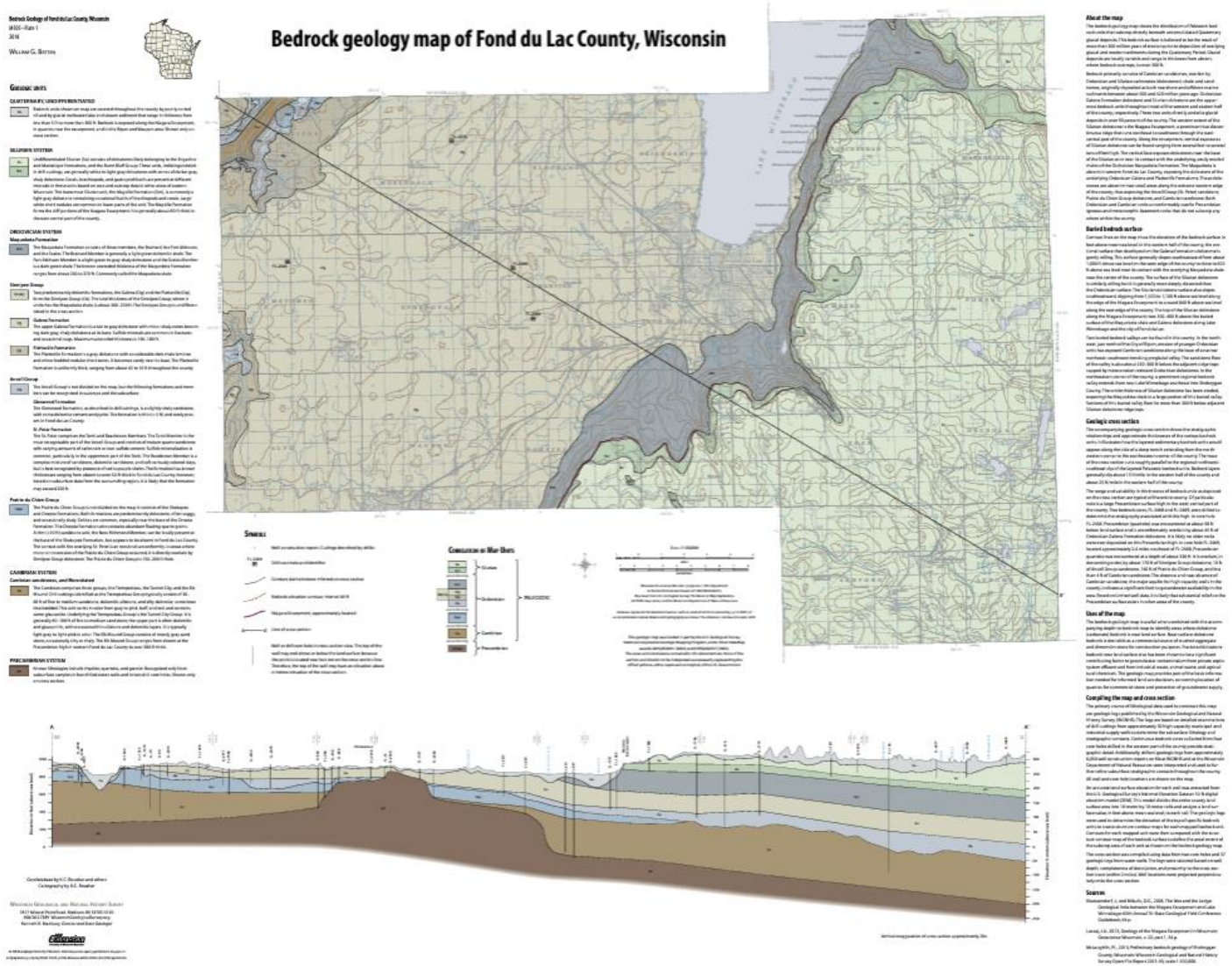


Source: *Wisconsin Natural Resources Magazine*

- What makes a rock or sediment a good aquifer?
- What are the three main stages in Wisconsin's geologic history?
- What are Wisconsin's four aquifers?

Takeaway: Wisconsin's geology controls the availability of groundwater.

What aquifers are in ***my area***?



- Maps are available for free on our website!

WGNHS Publications Catalog

Flowing well, Door County

Wisconsin Geological and Natural History Survey

DIVISION OF EXTENSION
UNIVERSITY OF WISCONSIN–MADISON

Amy Wiersma

Hydrogeologist

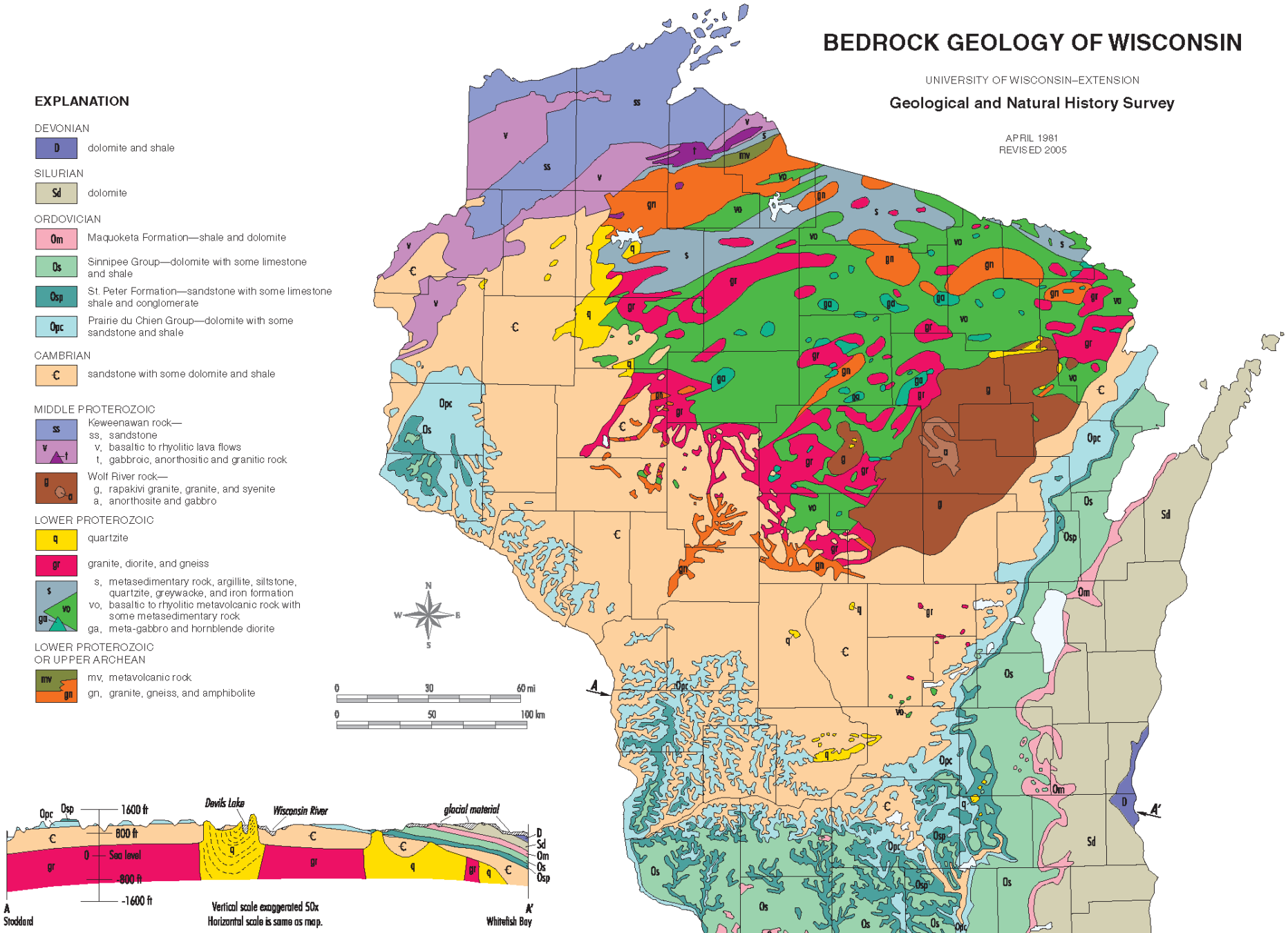
amy.wiersma@wisc.edu

Mel Reusche

Communications & Outreach Specialist

reusche@wisc.edu

State bedrock map



Bedrock geology

Hydraulic conductivity

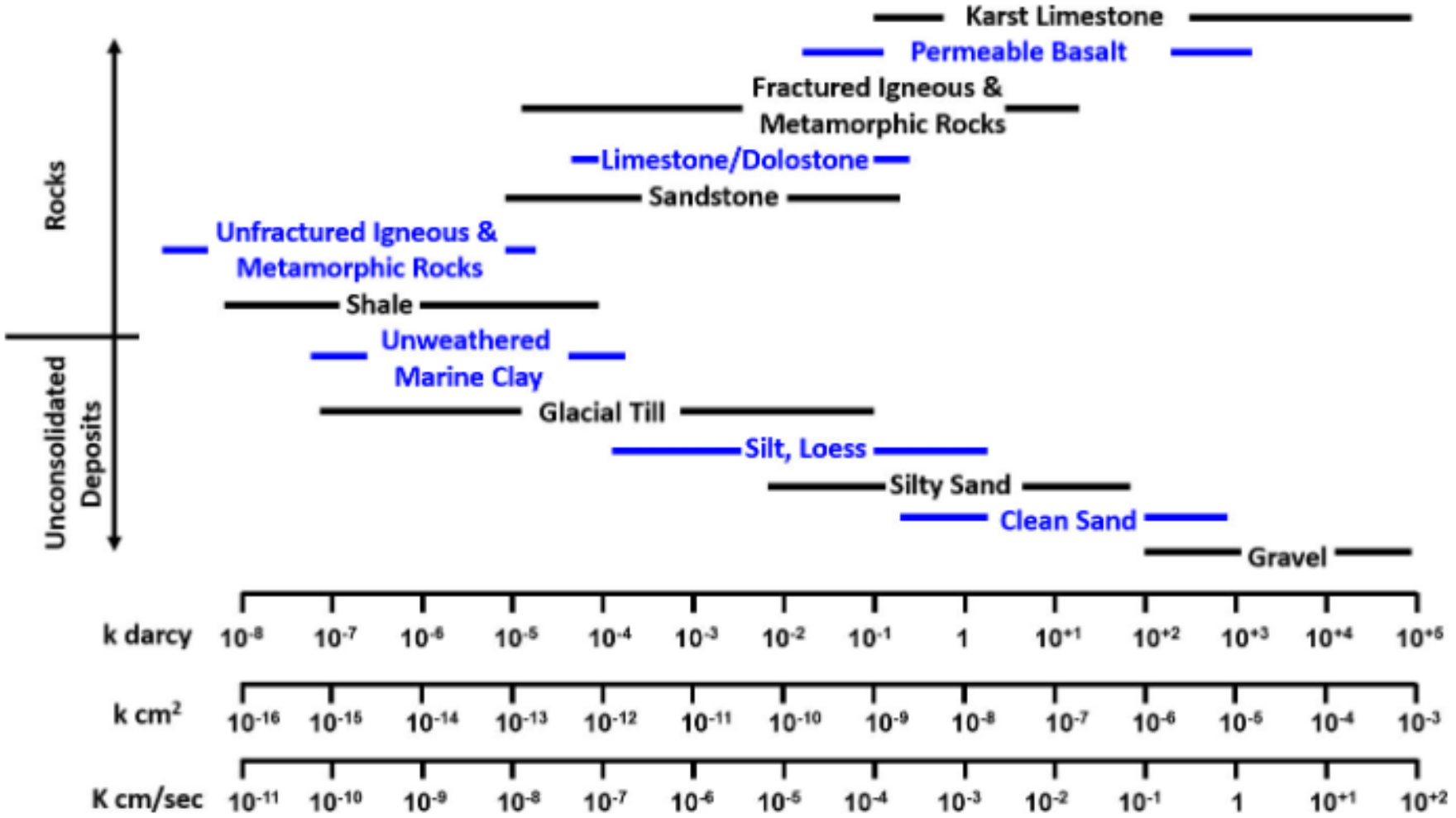
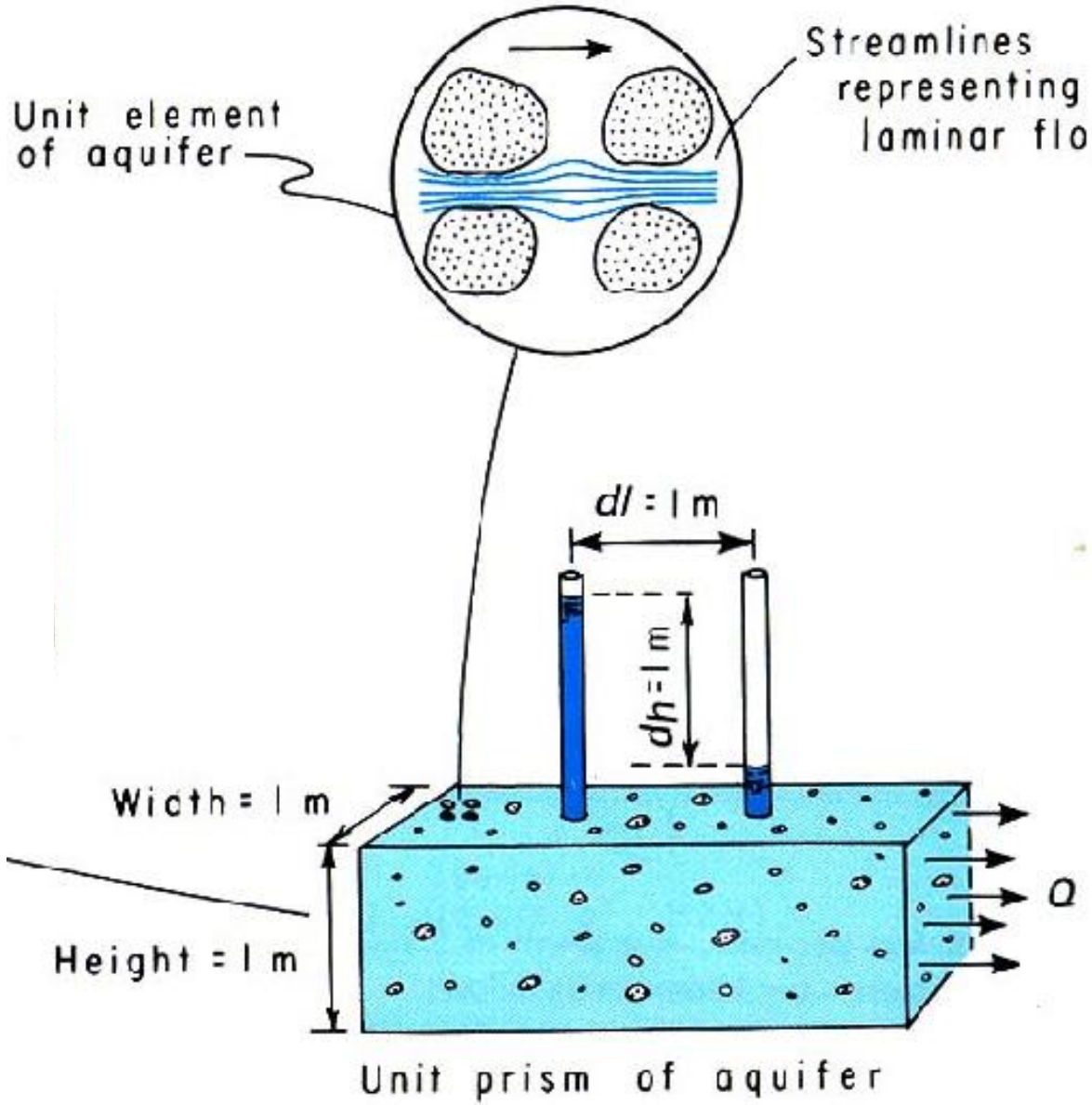


Fig. 2. Woessner, W.W. and Poeter, E.P. (2020). *Hydrogeologic Properties of Earth Materials and Principles of Groundwater Flow*. The Groundwater Project.

Darcy's Law

$$Q = -KA\frac{dh}{dl}$$

Q = Flow rate (L^3/T)
K = Hydraulic conductivity (L/T)
A = Cross-sectional area (L^2)
dh/dl = Hydraulic gradient (slope of the water table, L/L)



Groundwater susceptibility

- Major controls:
  - Depth to bedrock
  - Soils and surficial materials
  - Bedrock type
  - Depth to water table

- Used for education and general understanding; not site-specific