UW Green Bay Lifelong Learning Institute
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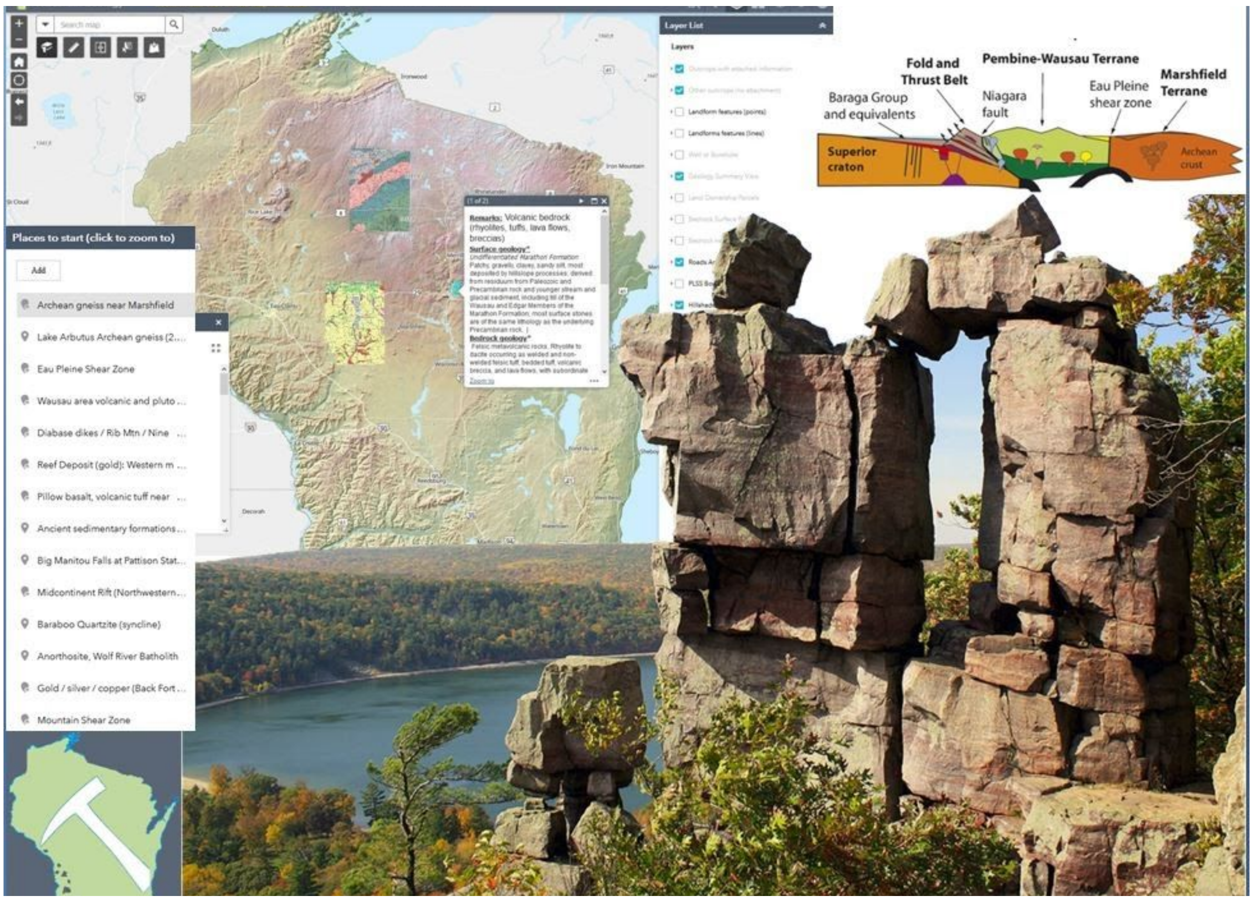
Exploring Wisconsin Geology
With GIS Mapping

Instructor: Jeff DuMez



Introduction

This course will teach you how to access and interact with a new online GIS map revealing Wisconsin's fascinating past and present geology. This online map shows off the state's famous glacial landforms in amazing detail using new datasets derived from LiDAR technology. The map breathes new life into hundreds of older geology maps that have been scanned and georeferenced as map layers in the GIS app. The GIS map also lets you find and interact with thousands of bedrock outcrop locations, many of which have attached descriptions, sketches, or photos. Tap the GIS map to view a summary of the surface and bedrock geology of the area chosen. The map integrates data from the Wisconsin Geological & Natural History Survey, the United States Geological Survey, and other sources.

How to access the online map on your computer, tablet, or smart phone

The Wisconsin Geology GIS map can be used with any internet web browser. It also works on tablets and on smartphones which makes it useful for field trips. **You do not have to install any special software or download an app**; **The map functions as a web site within your existing web browser** simply by going to this URL (click here) or if you need a website address to type in enter: **https://tinyurl.com/WiscoGeology** If you lose this web site address, go to Google or any search engine and enter a search for "Wisconsin Geology GIS Map" to find it. There are other geology maps out there, but look for the one branded as the state outline with the rock hammer inside.

Basic use instructions

The GIS map is easy to use no matter what device you choose to use it on. Once you open the map/web site, **you need just three basic skills to interact with it:**

1) **Zoom in to your area of interest**
    a) On a desktop computer, your **mouse wheel** works great to 'zoom in/out'.
    b) On a tablet or smartphone, you can **"pinch to zoom"** or **tap the GPS button** to zoom to your location.
2) **Click or tap on the map to view popup information about the geology of the area**
    a) **Tap anywhere** to view a popup summary of the bedrock and surface geology for that location.
    b) Tap specific map features such as outcrops to view information about it.
3) **Use the map layer list to turn on or off map layers** and to hone in on the geologic information that interests you the most.

That's it! The basic functions are as easy to use as a Google Map.

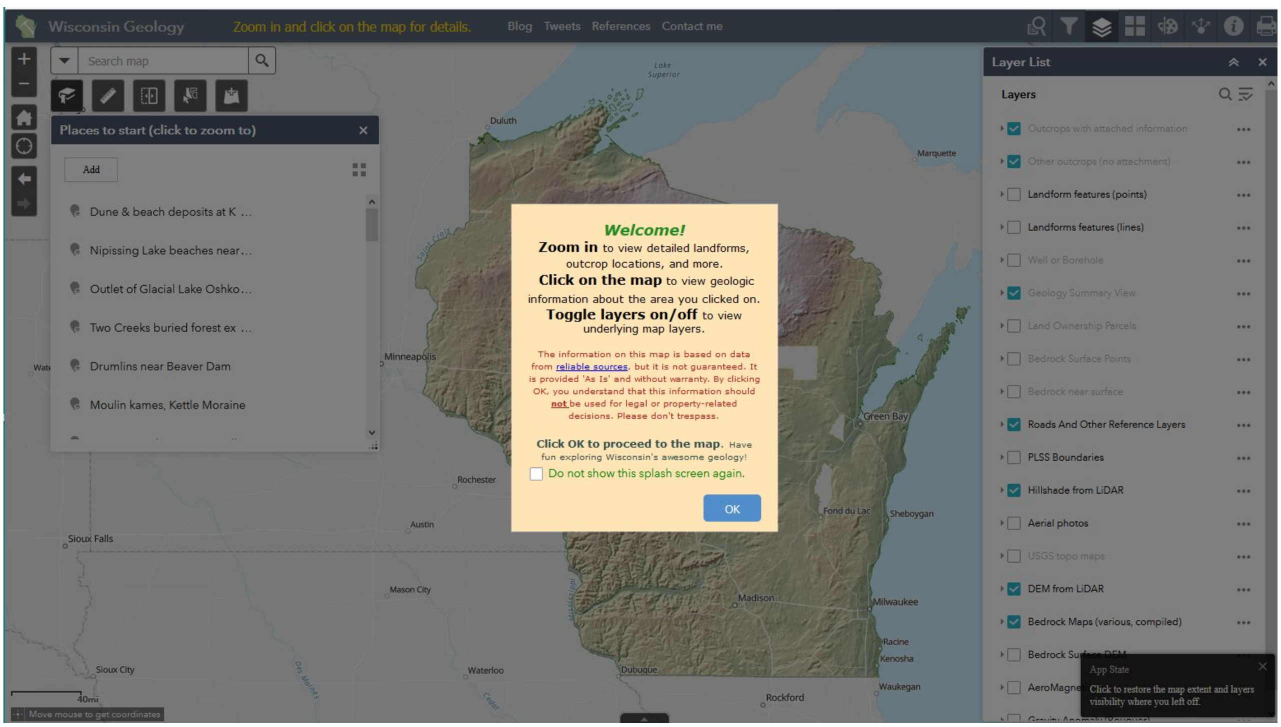
If you wish to dig deeper into the map, the Wisconsin Geology GIS map includes advanced features and tools (though none are difficult to use). Play with the buttons and see what happens, otherwise, you can read more about some of the advanced features in the appendix section of this document.

Other tips, instructions, stories and news about this app can be found at my blog:
https://wisconsingeology.blogspot.com

GIS map link:

https://tinyurl.com/WiscoGeology

When first opened, the online GIS map will appear as shown below.



Course Goal

The goal of this course is to look into the fascinating stories of Wisconsin's deep past as told by geology. The instructor will speak of these stories and show you how to use the online GIS map as a new way to illustrate them. One idea behind this online mapping app is to let you discover the "geology of your backyard". This map can serve as a field trip guide the next time you're outdoors, even in your own neighborhood. The GIS map blankets the state with all sorts of geologic information that you may find interesting. This handout includes some topics we will explore in class. **Neither this class nor this handout will cover everything there is to discover in the online GIS map** *(not even close!)* The class and this document are intended to give you a start on how you can use the online GIS map on your own to learn much more about the state's geology. The online map is a great companion to other books you might read about Wisconsin's geology, including those recommended below. The instructor will ad-lib during class and dive into some topics not included in this handout. It is strongly encouraged that you use this GIS mapping app on your own after class to see what else it has to offer to you.

Basic concepts and terminology: You may or may not have background knowledge of the geologic concepts and terms we will discuss in this course. The instructor will answer questions during class, but you are using the GIS map or reading this handout after class and you're unclear of a concept or term, I suggest you use a search engine such as Google to learn more. Some of the terms used in this class and on the GIS map are specific to Wisconsin, others are more generic geologic terminology that you can find in standard textbooks. The online GIS map includes thousands of links to external resources as well.

Some books that are beginner/intermediate level and focus on Wisconsin Geology:

Great Lakes Rocks by Stephen Kesler, published in 2019

Wisconsin Rocks by Scott Spoolman published in 2018

Roadside Geology of Wisconsin by Robert Dott and John Attig published in 2004

Geology of the Lake Superior Region by Gene LaBerge published in 1994

Journey back through time

For this course, we will start our journey in the present and work back through time, ending our journey through Wisconsin's space and time in the Archean about 3 billion years ago. These Archean-age rocks are found in central Wisconsin and are are the oldest rock exposures you can find on the surface of the state (or almost anywhere on Earth for that matter).

One reason to move in reverse order through time is because it is easier for most people to understand how the detailed landforms appear on the GIS app by comparing them to modern, familiar landscape features such as roadbeds and yard landscaping. Viewing these familiar features of the landscape first will help train your brain to see how landforms are abstracted and displayed in the GIS map. You'll then be able to see and better understand natural landforms created by glaciers and other geologic processes. Older geologic landforms are usually less conspicuous on the GIS map's LiDAR hillshade images than the new features because geological processes such as erosion had more time to erase evidence of past events. However, as you're finding out, the GIS map has lots of underlying map layers and popups that will help you interact and understand these older and more obscure geological features as well.

In this course, time is referenced using the Geologic Time Scale which is included in Appendix E of this document.

Let the journey begin!

Cenozoic Era (Present → 66 million years ago)

Quaternary Period (Present → 2.58 million years ago)

Holocene Epoch

2

Present → 11,700 years ago. *This is <u>after</u> the glaciers receded from our area.*

Many landform features visible on the LiDAR image on the Wisconsin Geology GIS map were shaped during the Holocene. This makes sense, since it is the most recent geologically-speaking. Humans have made a lot of changes to the topography. Some scientists have proposed the term Anthropocene as a new epoch which covers very recent time during which human activity has been the dominant influence on the environment (including geology and landforms).

<u>On the GIS map, we will explore the following features</u> using LiDAR Digital Elevation Model (DEM) with the hillshade effect applied. Looking at these familiar topographic features on the GIS map will give you a sense of the detail the LiDAR data can reveal.

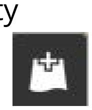
Human-made landforms we will view on the GIS map in class:

1. City streets of Green Bay and the UWGB campus area
2. Quarries, freeway and septic (mound) systems along Church Rd east of Green Bay
3. Dredge spoils from the 1800s-early 1900s along the Fox River between Berlin and Princeton
4. Because people find this interesting, we'll look at Native American effigy mounds. Use the Search function to find Koshkonong Mounds near Baraboo

Does that give you a feel for how landforms appear on the GIS map? Let's continue:

Natural landforms from the Holocene or late Quaternary Period to view in class:

5. Lake level fluctuations, elevated shorelines including the Nipissing Great Lakes lacustrine features in Brown County

    a. Click the "Add Data" button  then add the "Nipissing Shoreline in Wisconsin" map layer. Zoom and move around the map to explore the former Nipissing shoreline with the LiDAR elevation + hillshade.

6. In class we will discuss the history and formation of these and other landforms largely created during this time period, using the online GIS map as illustration.

Pleistocene Epoch

11,700 --> 2.588 million years ago. This is often referred to as the Ice Age. It is the most recent time that continental glaciers covered much of Wisconsin.

On the GIS map, many landforms from the Pleistocene really stand out. Among them we will explore:

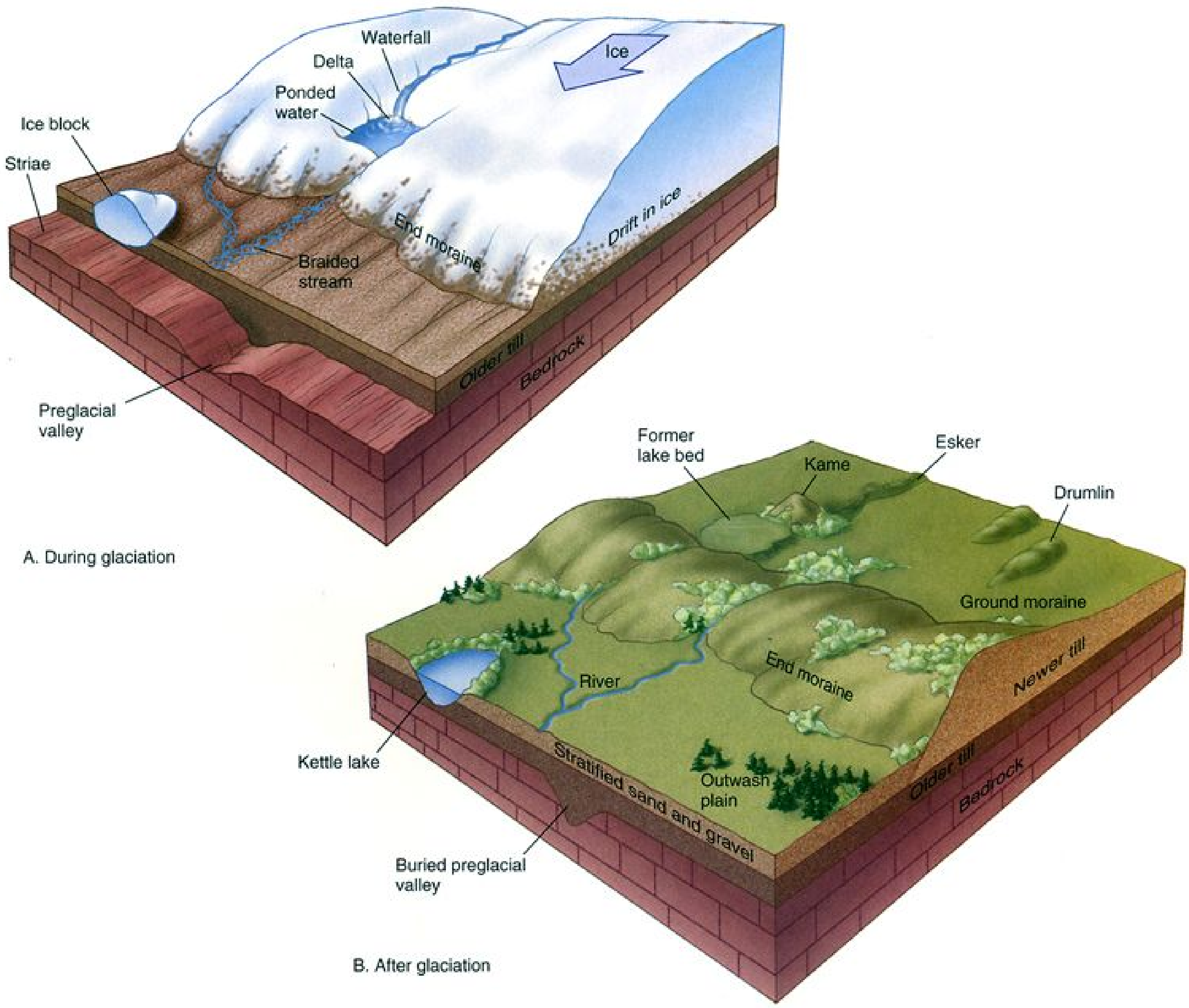
1. "Driftless Area" of southwestern Wisconsin. How did the glaciers miss this area? We will use the map to discuss this in class.
2. Ice-formed moraines including those found in Brown County
3. Drumlins including those in Brown County and the textbook drumlin fields of Dodge County
4. Eskers
5. Ice dams, glacial lakes, and outflow channels (spillways) including the Neshota valley in Brown County

Refer to the graphics below if you are unfamiliar with how these landforms were created by glaciers.

When using the GIS map, you can get help interpreting these landforms by turning on two map layers on the mapping app *(use the layer list to check on the following):*

1. Landform Features (points)
2. Landform Features (lines).
3. After you turn on these map layers, click on the landform features (symbols) on the map itself to view a popup description of each. Remember, you can click on other parts of the map to view available popups. These landform symbols, in conjunction with the LiDAR image and the interactive popups, will help you interpret many of the glacial landforms in parts of the state.

The landforms interpretation map layer is not complete across the state. The Landform layers mentioned above are more complete in the area covered by the Green Bay Lobe of the Laurentide Ice Sheet.



Neogene Period (2.58 → 23.03 million years ago)

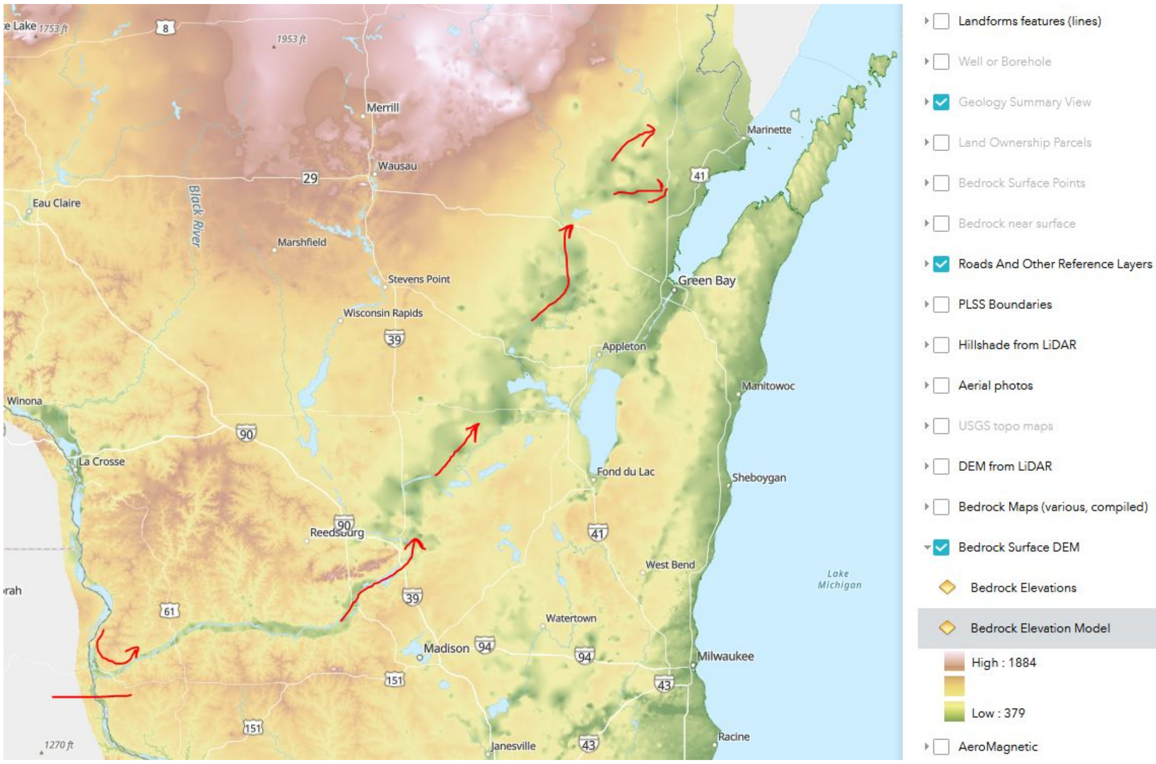
Before the great glaciers of the Pleistocene invaded the state, Wisconsin's landscape as a whole likely looked like the Driftless Region of present-day southwestern Wisconsin. Deeply-cut river valleys were the predominant landscape features. When the glaciers advanced, they greatly altered the landscape: They buried these river valleys under deep layers of glacial till and smoothed out the landscape. The glaciers also blocked the flow of water which make for some interesting stories. In class, we will explore some of these buried river valleys in northeastern Wisconsin. We will discuss a rather new discovery in Wisconsin geology: That today's major rivers including the Mississippi and Wisconsin Rivers used to flow into Green Bay!

We will use the GIS map to explore the Ancestral Wyalusing River which is described by Dr. Eric Carson and others from the Wisconsin Geological and Natural History Survey in this Geolocial Society Paper as well as this article on WisCONTEXT which includes a more user-friendly video format on PBS (go to https://www.pbs.org/video/university-place-did-ancient-wisconsin-river-once-flow-east/). I encourage you to watch the PBS video referenced above to learn more about this and view Dr Carson's multiple lines of compelling evidence of these events.

In summary, Dr Carson has convinced a lot of people (myself included) that prior to the Pleistocene glaciers, the Mississippi River took a left turn at Prairie Du Chein and flowed east, emptying into Green Bay. The glaciers of the Pleistocene drastically changed the course of the river by creating an ice dam in the Green Bay lowland, causing the ancestral Mississippi river to overtop the bedrock ridge (called Military Ridge) in southwestern Wisconsin, then start to flow toward the Gulf of Mexico as it does today. The glaciers buried the large river valley in northeastern Wisconsin with glacial sediment, nearly erasing evidence of where the Ancestral Wyalusing River would have emptied into Green Bay.

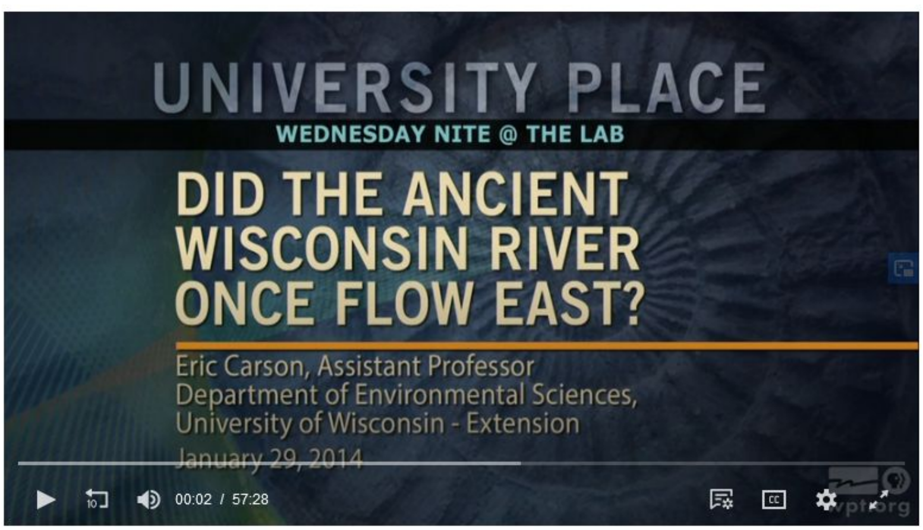
Using the Wisconsin Geology GIS app, we can explore much of the data cited by Dr. Carson including LiDAR and some of the well log data he used. One of the map layers I created using the well logs I had access to (not nearly all of them) is a bedrock surface model. This map layer can be viewed in the Wisconsin Geology GIS app.

1. In the Map Layers list, turn **off (uncheck)** the following map layers:
    a. Roads and Other Reference Layers
    b. Hillshade from LIDAR
    c. DEM from LiDAR
    d. Bedrock maps
    e. Turn off any other map layers listed above the "Bedrock Surface DEM" layer
2. Turn **ON** the layer named **Bedrock Surface DEM.** You may have to zoom in a little to see it. Again, this is a very course, low resolution dataset used here, but using this you can see the lower elevations on the bedrock surface represented by green colors. Using this, you can make out a broad valley that continues from the Baraboo HIlls to Lake Michigan (Green Bay). We will explore this in class.



Above: Screen image taken from the Wisconsin Geology GIS mapping app showing the bedrock surface elevation. Reds, oranges, yellows are higher bedrock surfaces while greens are lower elevations. With the online interactive map, you can compare this bedroc elevation surface with today's topography using layers derived from LiDAR.

Below, in this video, Dr. Carson describes further evidence.



Mesozoic Era (66 → 252 million years ago)

Where are geologic deposits in Wisconsin from the Mesozoic Era (Cretaceous, Jurassic, and Triassic Periods)? Are there any dinosaur fossils in Wisconsin? These are common questions people ask as they begin looking into the state's geology.

We will discuss upland gravels found in the Driftless Area of southwestern Wisconsin. This is river gravel preserved on some of the highest points on the landscape, indicating they were deposited before the modern river systems and drainage patterns of the area. The Wisconsin Geological & Natural History Survey initial research indicates this gravel was derived from the Wyoming-Montana-Idaho region and was likely deposited more than 55 million years ago, perhaps during the Mesozoic. For more information go to: https://gsa.confex.com/gsa/2014AM/webprogram/Paper248511.html

Geologic event of unknown date (possibly Mesozoic)

Use the GIS map to search for "Six Pak Diatreme". This is a Kimberlite pipe near Kenosha. Click on the mapped location of the Six Pak Diatreme to view a popup summary on the map. This appears to have formed sometime between the Paleozoic and Quaternary.

Kimberlites are magmatic rocks that formed deep in the Earth and brought to the surface by very focused volcanic eruptions. Sometimes, minerals such as diamonds are brought to the surface as xenoliths. Few if any large diamonds were found with the Six Pak Diatreme, but more significant diamonds have been found in glacial till in Wisconsin. These diamonds are thought to have originated in other diatremes known to exist north of Green Bay and carried south by the glaciers.

Interestingly, these kimberlite pipes may have formed as this part of the continent passed over a mantle plume (hot spot). We will discuss plate tectonics more in a bit.

Paleozoic Era (252 → 541 million years ago)

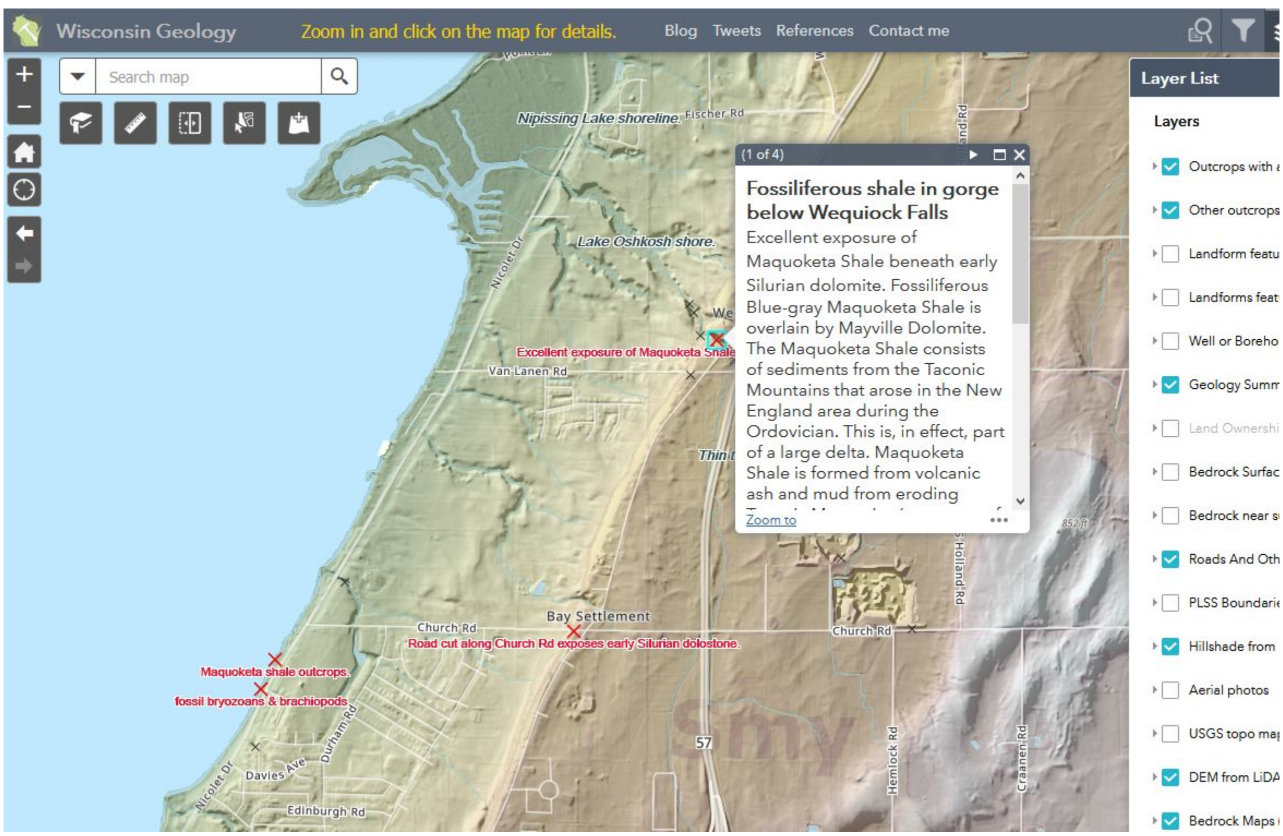
Unlike the Mesozoic, much geologic evidence of the Paleozoic Era exists in Wisconsin because so much deposition occurred as tropical seas advanced, retreated, and readvanced across much of the state during this time. These seas created many hundreds of feet of sandstone, shale, limestone and other sedimentary rocks. These rocks are visible throughout much of southern and eastern Wisconsin. The Niagara Escarpment, for example, is made up of Paleozoic-era rocks. You might have noticed I used the word "tropical" to describe the seas which deposited these rocks. In case you're wondering why:

Plate Tectonics: A brief introduction

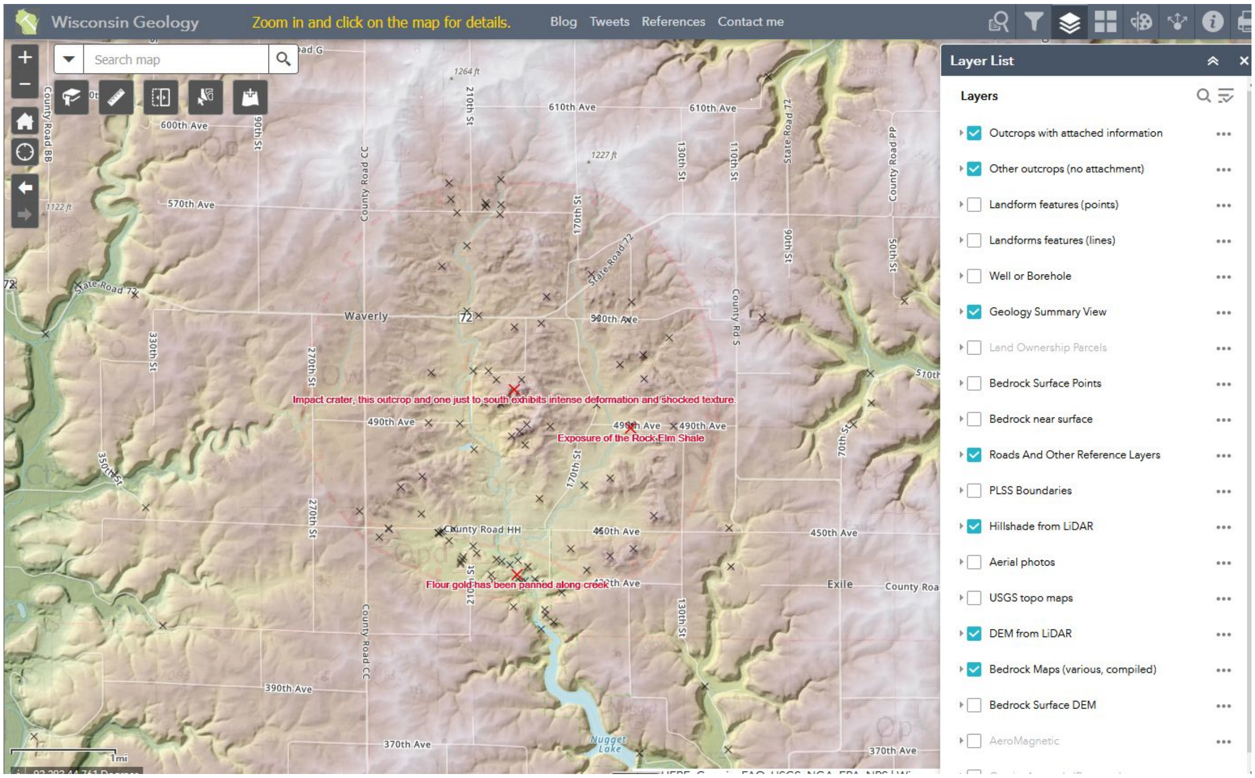
The North American plate (on which present-day Wisconsin is located) has moved across the globe considerably since the Paleozoic. What is today the "Frozen Tundra" of Wisconsin was located much closer to the equator during the Paleozoic Era. If you're unfamiliar with plate tectonics, in summary, it explains how rigid crustal continental (lithospheric) plates can slowly move across the Earth's underlying mantle. Plate tectonics were not well understood until fairly recently (the mid 1960s). In fact, most scientists dismissed (and laughed at!) the early evidence of this theory since it seemed so incredible to imagine something so large and solid as hunks of continents could move hundreds and thousands of miles across the planet. If you're unconvinced, I encourage you to read more about this fascinating topic outside of class. For now I'll ask you to consider this: Using today's accurate and precise surveying tools (GPS and other methods), we now can directly measure crustal plate movements. What do we observe? Surveyors and geodesists directly observe crustal movement averaging 1 to 3 inches each year or even more in some places! It only takes a few inches of crustal movement each year to get thousands of miles of movement if you consider a time span of millions of years. Not every plate moves at the same rate or even in the same direction. In places where plates collide or grind against each other, we have earthquakes, volcanoes and other mountains. Rift valleys form where crustal plates spread apart. Plate tectonics unlocked many geologic mysteries across the globe. Check out this animated Paleomaps **https://tinyurl.com/paleoWis** Wisconsin is near the red dot on this animated map. More on plate tectonics later as we move deeper into time. Let's get back to the Paleozoic for now.

Some of the Paleozoic era geologic features we will explore in class using the GIS mapping app include:

- Devonian rocks near Milwaukee
- Silurian rocks of the Niagara Escarpment
- Ordovician rocks with fossils near UWGB
    - Shale rock exposures in this area, such as those at Wequiock Falls, are sedimentary rocks deposited from seawater; However, interestingly the mud these rocks formed from at least partly consists of volcanic ash and other materials from far to the east: The Taconic Mountains of New England (ancestral Appalacians). We will discuss this in class.
    - Asteroid impact crater near Rock Elm (west-central Wisconsin)
- Cambrian rocks containing fossils and ripple marks in central Wisconsin

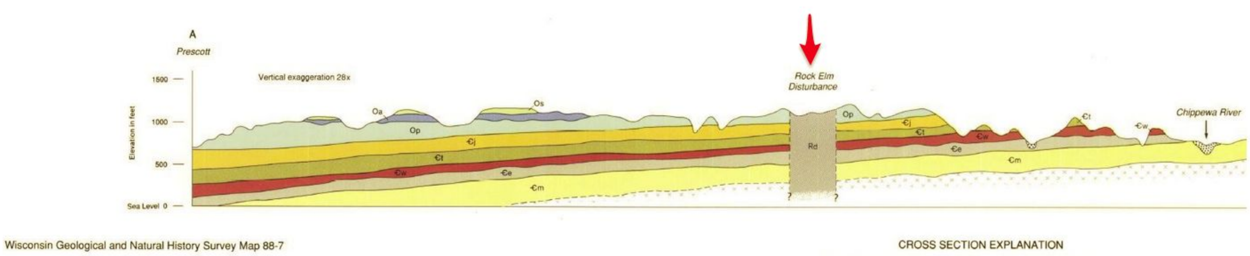


Above: Screen capture of the GIS app zoomed in to the area just north of UWGB.



Above: How the Rock Elm asteroid impact crater (which likely formed during the Ordovician) can still be seen as subtle changes in terrain and in drainage patterns on today's LiDAR+hillshade terrain image. Can you see it? View the online GIS map for a better view.

Below: A cross section of the bedrock geologic mapping of this area which is available as popup from the GIS mapping app. Click the red X near the center of the crater to view this and other information about this incredible event.



Precambrian (541 million years ago and older)

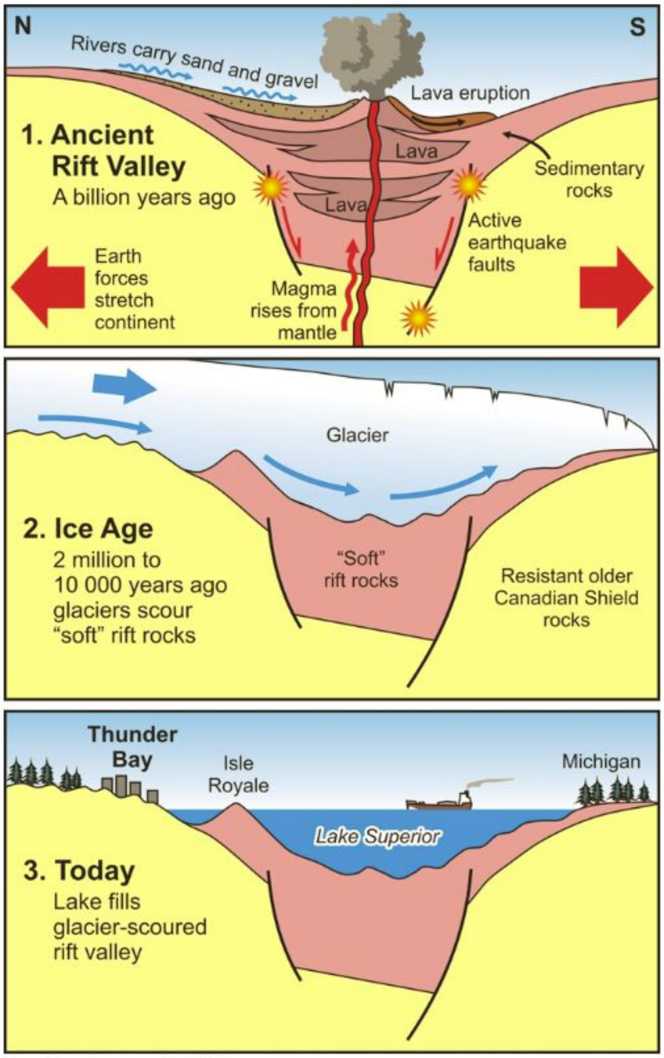
The Great Unconformity

One of the biggest mysteries in geology is a huge gap in the rock record: About 1 billion years of time is seemingly not recorded in the rocks in the time between the Paleozoic and the Precambrian. If you're not familiar with the Great Unconformity, I encourage you to research it in your favorite geology book or even by Google search.

There are several places in Wisconsin where you can view this unconformity. Use the search box or the Places to Start bookmarks to zoom to places where you can view the Great Unconformity in former quarry rock walls (note: Some locations are on private property and require permission. Tip: Use the GIS app's parcel ownership layer to look up the land owner names and mailing addresses).

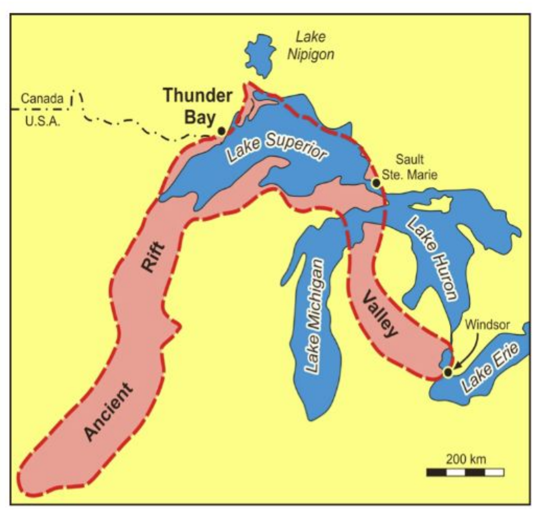
Other Precambrian stories and sites of interest. There are many more on the GIS app than what are listed here, but here are a handful that we will explore in class if there is time:

- **Mid Continent Rift.** Did you know that once upon a time, Wisconsin tried to break away from Minnesota? We will spend some time looking at two map layers (AeroMagnetic and Gravity Anomaly map layers) and discuss what the data on these map layers represent. Hint: It involves a LOT of awesome magma and lava! We'll also explore the geologic story behind the Midcontinent Rift. This is one of the awesome stories in geology that we have lots of evidence of right here in Wisconsin.
- On the GIS map, turn OFF (uncheck) all layers except for the Gravity Anomaly layer at the bottom to view the rift on the map. See also this article on my blog: https://wisconsingeology.blogspot.com/2018/10/new-to-gis-map-aeromagnetic-gravity.html



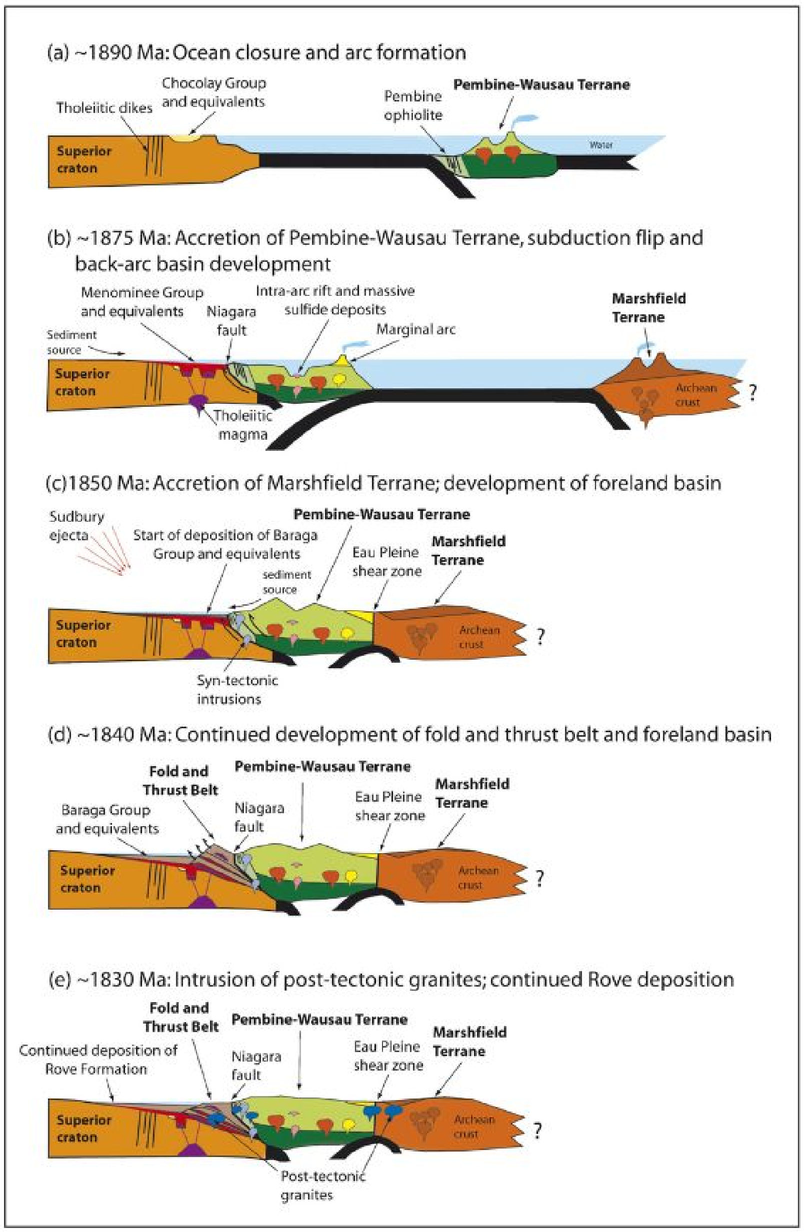
- *Deep Basin forms in a Rift Valley*

Mid Continent Rift graphics from https://lakeheadca.com/events-education/geology/mid-continent-rift



- **More evidence of plate tectonics**. In class, we will view places in Wisconsin where the Earth's crust was "sutured" together or sheared as a result of crustal plate movements. Look for the Eau Pleine Shear Zone east of Marshfield, click on the outcrop symbols to read more about these hunks of earth's crust that fused together many millions of years ago. We will discuss this sequence of events in class (from Schulz & Cannon, 2007, [The Penokean orogeny in the Lake Superior Region](#))

K.J. Schulz, W.F. Cannon / Precambrian Research 157 (2007) 4–25



- Fig. 6. Schematic cross-sections illustrating the tectonic evolution of the Penokean orogen. See text for discussion.

- **Evidence of volcanoes.** Wait, there were volcanoes in Wisconsin? Yes! Although there have been none since the Precambrian, the volcanoes that existed back then left plenty of evidence behind. In class, we will spend some time exploring extrusive volcanic rocks such as rhyolite and tuff in the Wausau area. We will also look at the remnant “footprints” of a couple of volcanoes using the LiDAR data. We will also discuss why volcanoes formed near Wausau and other parts of Wisconsin and why we no longer have active volcanoes in this state.
- **Archean-age rocks in Central Wisconsin.** These are the oldest rocks you’ll find at the surface in Wisconsin. Many, such as those near Black River Falls, Stevens Point, and Marshfield are around 2.8 billion (2,800 million) years old according to radiometric age dating.
  - Zoom to Lake Arbutus and click the outcrop symbols near the dam on the south end. There are some fairly easy-to-read geologic papers describing these very remarkable old rocks.

During class, the instructor encourages questions about the geology of other areas in the state. If there is sufficient time, the class will use the GIS map to look into the class participant’s areas of interest.

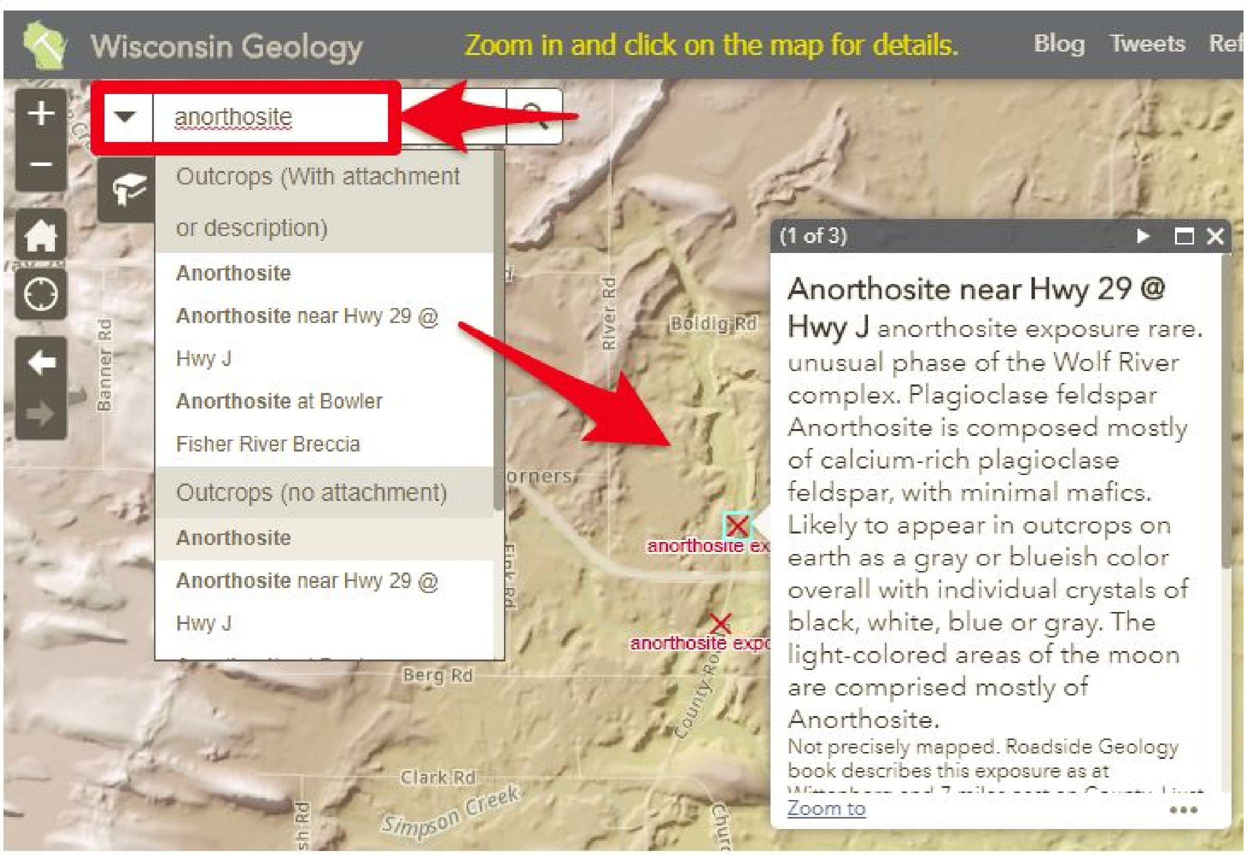
Use the “Places to Start” list to zoom to various other geologic areas of interest on the map. Be sure to click to view popup descriptions, photos, etc for outcrops and other sites.

We may run out of time in class to look at the many other awesome geologic features included in the Wisconsin Geology GIS map. I encourage you to keep exploring on your own. Better yet, use the map to plan your field trips and go outdoors to view these features in person.

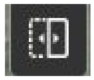
Appendix A: A few more advanced features (yet still very easy to use!) features of the GIS mapping site:

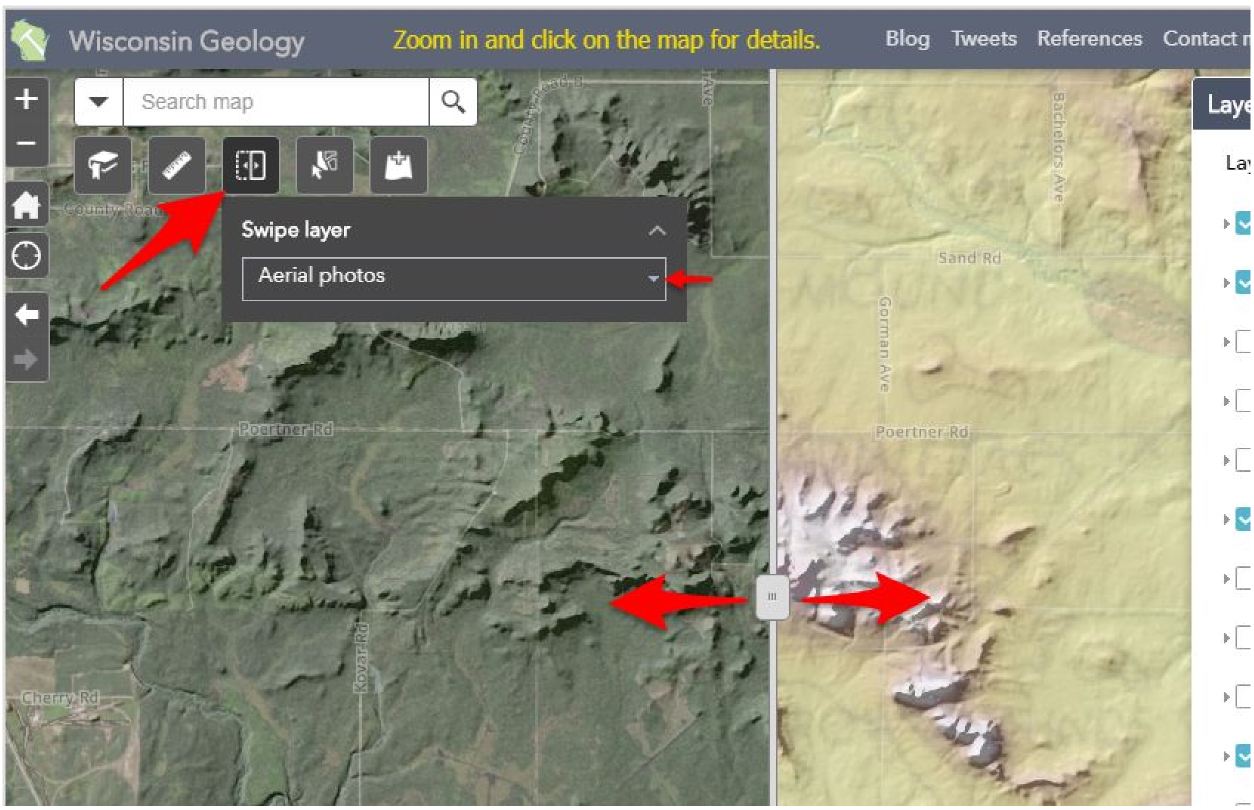
Search the map for locations and other cool geology features in Wisconsin! Like a Google map search but way better. As geologic locations are being mapped into this app, they are being tagged with key words that make this seach possible. Here are just a handful of examples of things you might search for using the Search map function, then just pick from the results to zoom to that feature on the map.

- Gold
- Impact crater
- Athelstane
- Moulin kame
- Try out your own keyword searches!



Swipe Tool

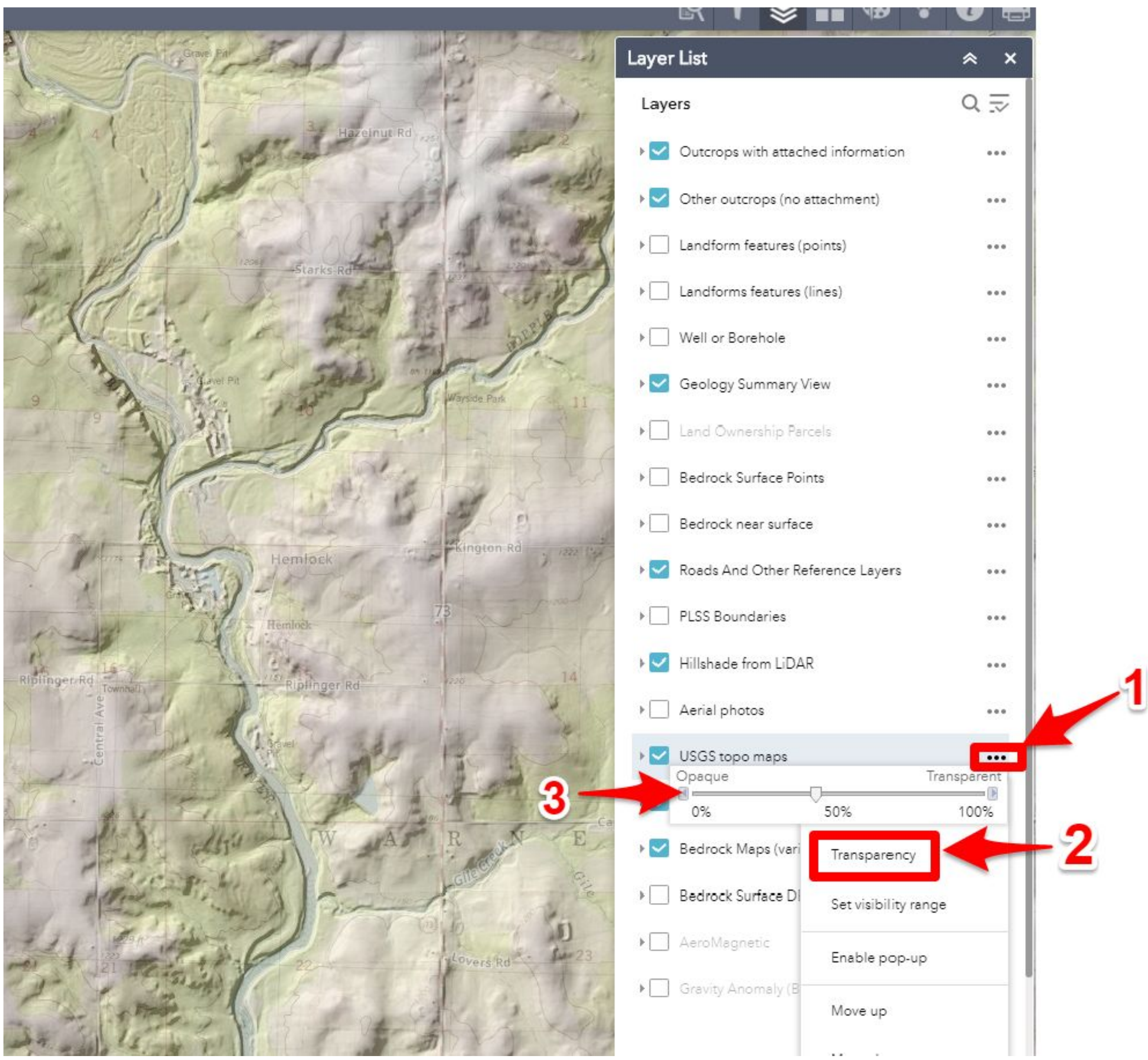
Use the **“Swipe”** tool  to peel back an overlay map layer of your choice. This lets you explore map features in an interactive way. Move the slider back and forth as a useful data visualization tool.



Adjust Layer Transparency for some really cool map combinations and visual effects

View maps in your own unique way by customizing the map layers. One awesome way to do this is to play with the layer transparency settings. Follow the steps below for any of the map layers. In the example below, the USGS topographic map transparency adjusted so that it can be used along with the Hillshade layer for some great visual effects.

1. Click the ellipses (...) to the right of any of the layer names, a popup will appear
2. Click the Transparency option from the popup
3. Use the slider to adjust layer transparency. Move it back and forth with other map layers as overlays to see how the map changes.

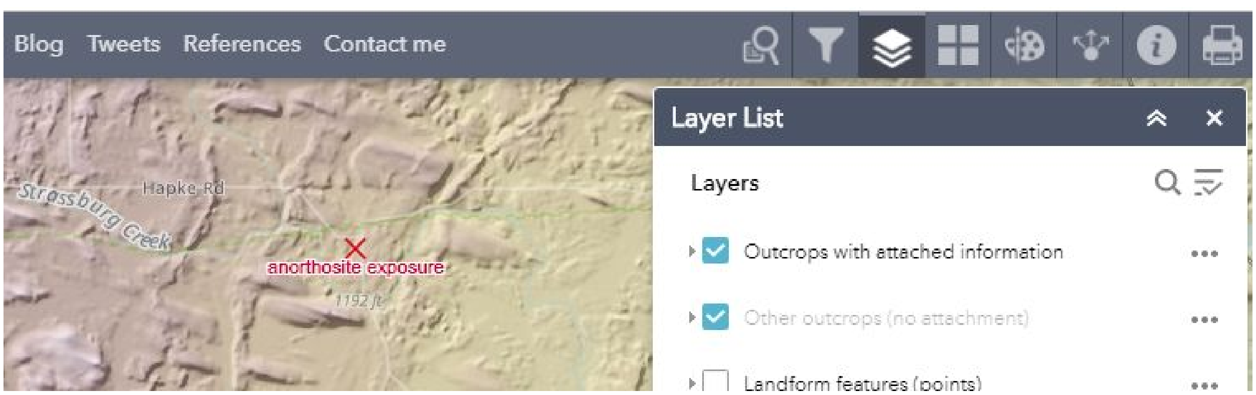


Click the ellipses next to the Outcrops with Attached Information layer and choose "View Attribute Table". This will open a list of interesting outcrops. Click the list to zoom to each.

Play with some of the other buttons in the toolbars along the top and left side of the map. Most are intuitive and include some instructional tips as you hover your cursor over them.

These tools do things like enable the GPS on your phone to locate yourself on the map, zoom in/out, save locations, measure length and area, pull up coordinates, add more map layers, filter or query data layers, draw your own text, share the map, and of course make printouts.

The blog includes news as well as some instructional articles on how to use the mapping app.



Appendix B: Landscapes of Wisconsin

Landscapes of Wisconsin

Landscapes of Wisconsin depicts the terrain of Wisconsin, stripped of vegetation and human influences.

The diverse landscapes of the state can be divided into the following major regions on the basis of their geologic heritage (fig. 1):

- The *northern and eastern parts of the state* were most recently glaciated by six lobes of the Laurentide Ice Sheet during the Wisconsin Glaciation. Myriad hills, ridges, plains, and lakes characterize this region.
- The *central to western and south-central parts of the state* were glaciated during advances of early ice sheets. This region has subdued, rolling topography.
- The *Driftless Area, in southwestern Wisconsin,* appears never to have been overrun by glaciers and represents one of the most rugged landscapes in the state. This region contains a drainage network of stream valleys and ridges that form branching, tree-like patterns on the map.

Between about 26,000 and 10,000 years ago, the lobes of the Laurentide Ice Sheet left their imprint: They scoured and flattened the land, changed the courses of rivers, built up ridges and hills, and created numerous meltwater lakes.

For example, the northern highlands area (**1**) is widely known for its forests, lakes, and wetlands. Most of these lakes and wetlands occupy *kettles,* poorly drained, bowl-shaped holes. Kettles form after blocks of ice that have become detached from a glacier are buried by sediment; the subsequent melting of the ice blocks results in the sinking of the sediment and the formation of the kettles. In the northern highlands, kettles developed in broad plains that were formed by meltwater streams from the Langlade, Wisconsin Valley, and Chippewa Lobes of the Laurentide Ice Sheet (fig. 1) as it receded from its maximum extent about 18,000 years ago.

The Baraboo Hills (**2**), an elongated, discontinuous ring in Sauk and Columbia Counties, straddles the boundary between the Driftless Area and the glaciated part of the state. These hills rise 700 feet above the surrounding terrain and are composed of ancient-river and nearshore ocean sediment, approximately 1.7 billion years old, which has been metamorphosed and folded. The resulting rock, called quartzite, is distinctively purple-gray, extremely hard, and resistant to erosion.

Figure 1. *Major landscape regions and extent of glaciation in Wisconsin. Numbered areas are approximate locations of the features described in text.*

Although the Driftless Area was probably not covered by ice, the glaciers and accompanying climate did leave their mark. For example, immediately north of the Baraboo Hills is the broad, flat sand plain of central Wisconsin (**3**). This sand plain was once the floor of a large glacial lake that formed adjacent to the Green Bay Lobe as it advanced onto the eastern edge of the Baraboo Hills, damming the upper Wisconsin River. As the Green Bay Lobe began to recede, the lake drained, probably very rapidly, around the east end of the Baraboo Hills and down the lower Wisconsin River. The torrent of water cut through the soft sandstone, carving out the Wisconsin Dells. This water also transported large amounts of sand and gravel that contributed to the formation of the broad valley that contains the lower Wisconsin River (**4**).

More detailed information can be found on the full-size version of the *Landscapes of Wisconsin* map (size 42 x 42 inches; scale 1:500,000; available from the Wisconsin Geological and Natural History Survey).

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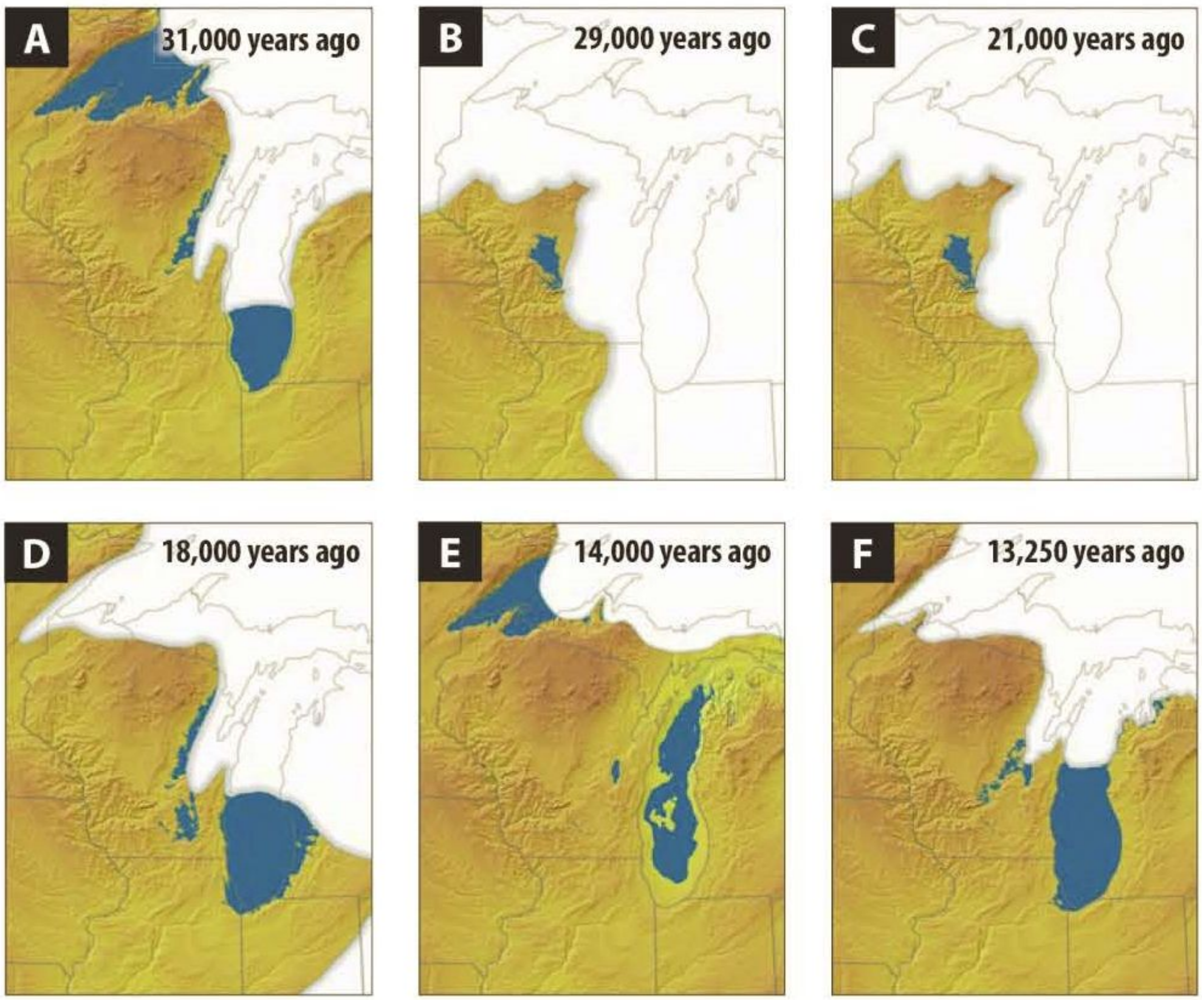
Appendix C:

Tracking the glacier

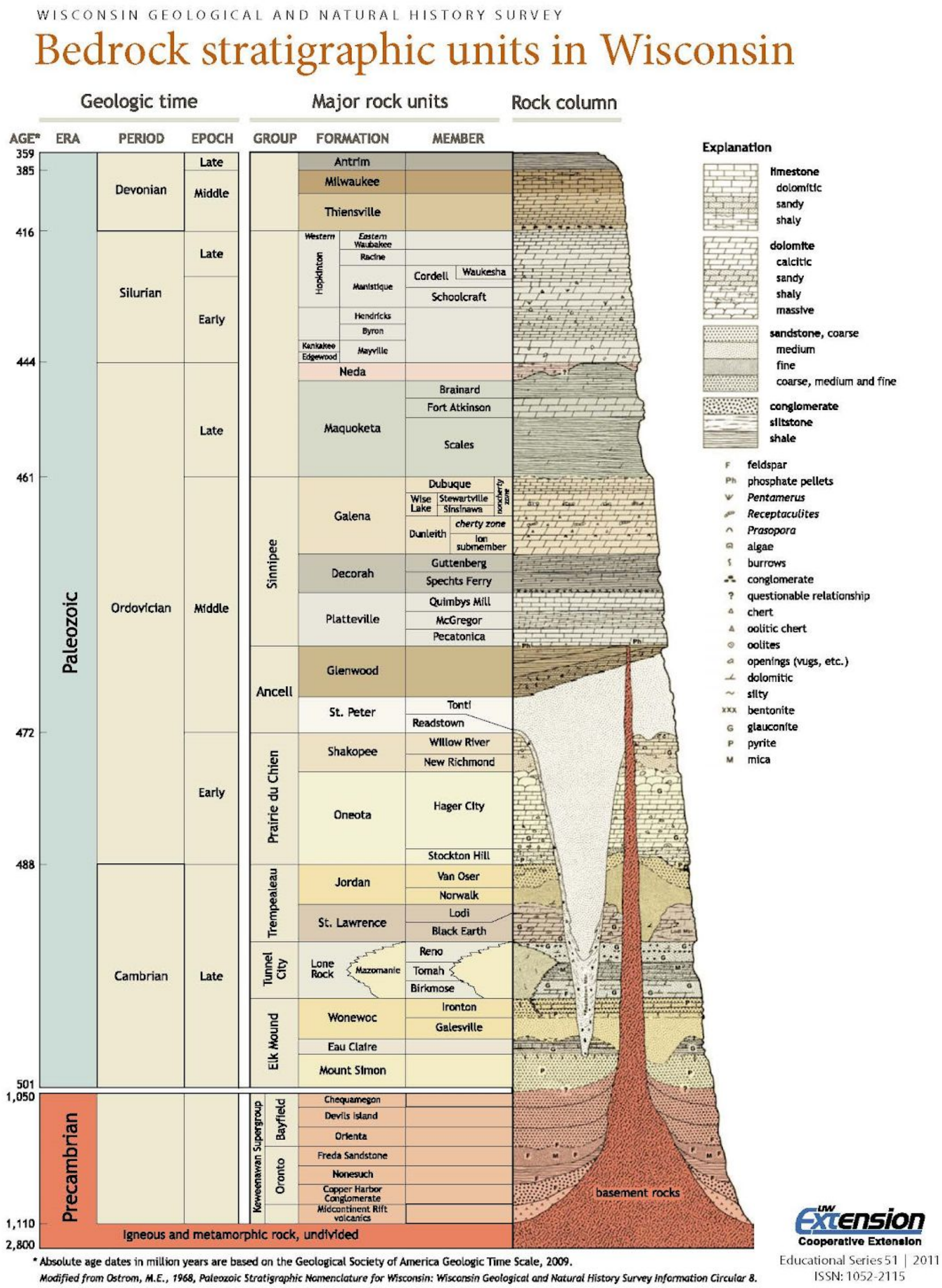
Maps showing the extent of the Laurentide Ice Sheet and changes to glacial lakes at several times. This set of maps, keyed to the graph below, shows when ice first began its advance into Wisconsin (A), ice near its maximum extent (B and C), the initial retreat (D), when ice left Wisconsin (E), and the final major readvance (F).



From: https://wgnhs.wisc.edu/wisconsin-geology/ice-age/

Appendix D: Bedrock Stratigraphic Units in Wisconsin

https://wgnhs.wisc.edu/pubs/ES051/ Wisconsin Geological & Natural History Survey



Appendix E: Geologic Time Scale

https://www.geosociety.org/documents/gsa/timescale/timescl.pdf