Les Cheneaux Geology Tour

From the Past through the Present: Reefs, Glaciers, Lakes, and Quarries

2021 Aldo Leopold Festival
June 3 - June 6, 2021
Les Cheneaux Islands, Michigan

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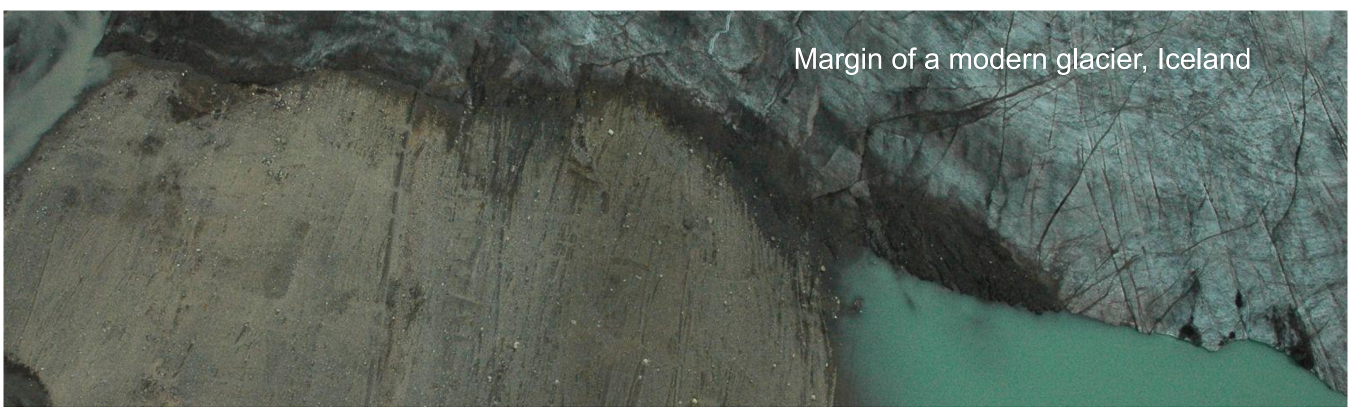
This field trip guide is available for download at <> or you may email Libby at libby.r.w.ives@gmail.com for a copy.



Margin of a modern glacier, Iceland

Reconstruction of a Silurian Reef

Image from Virtual Silurian Reef Project (https://silurian-reef.fieldmuseum.org)

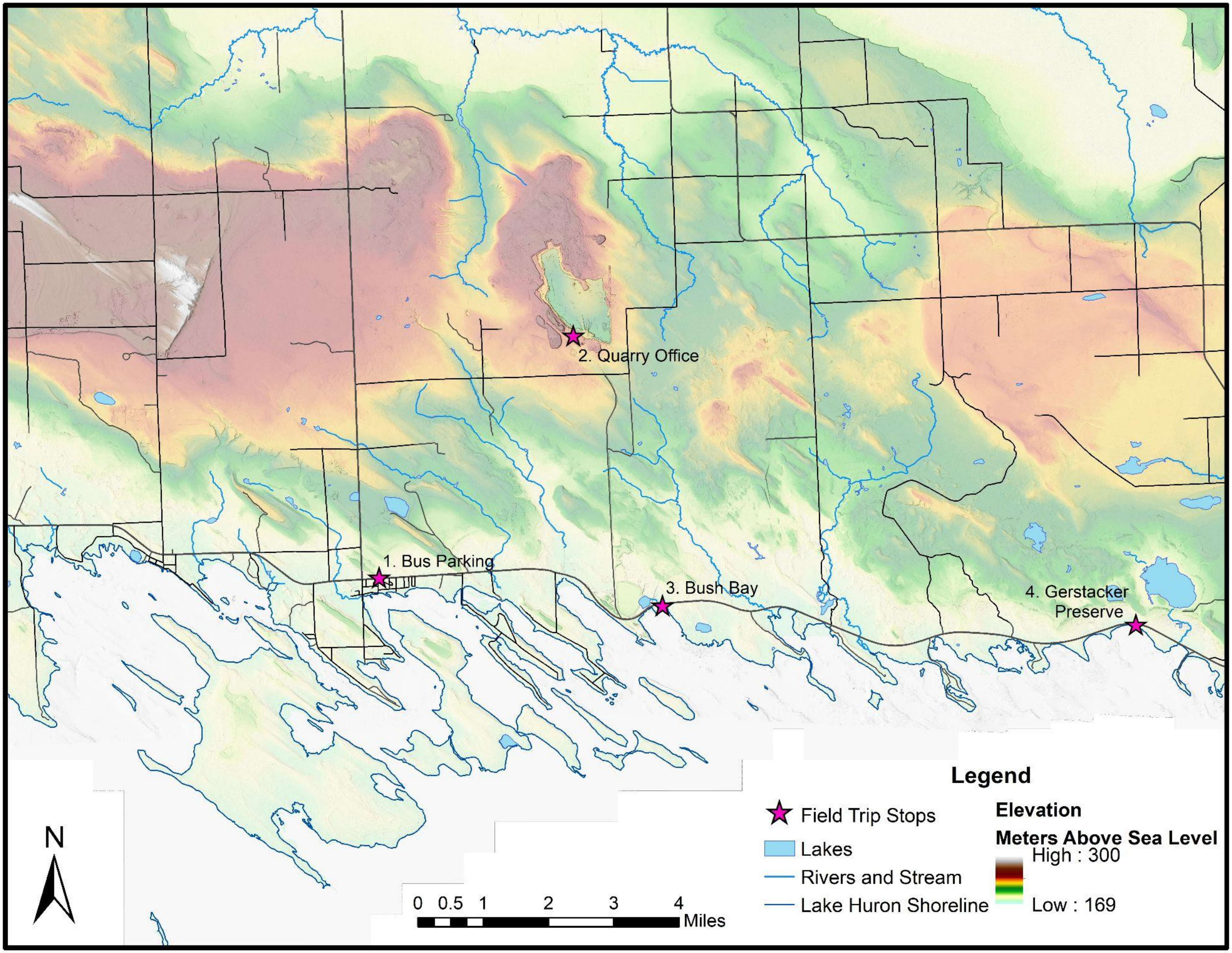
Schedule

Begin and End Tour: Bus parking lot across the street from Les Cheneaux Community Schools
298 M-134, Cedarville

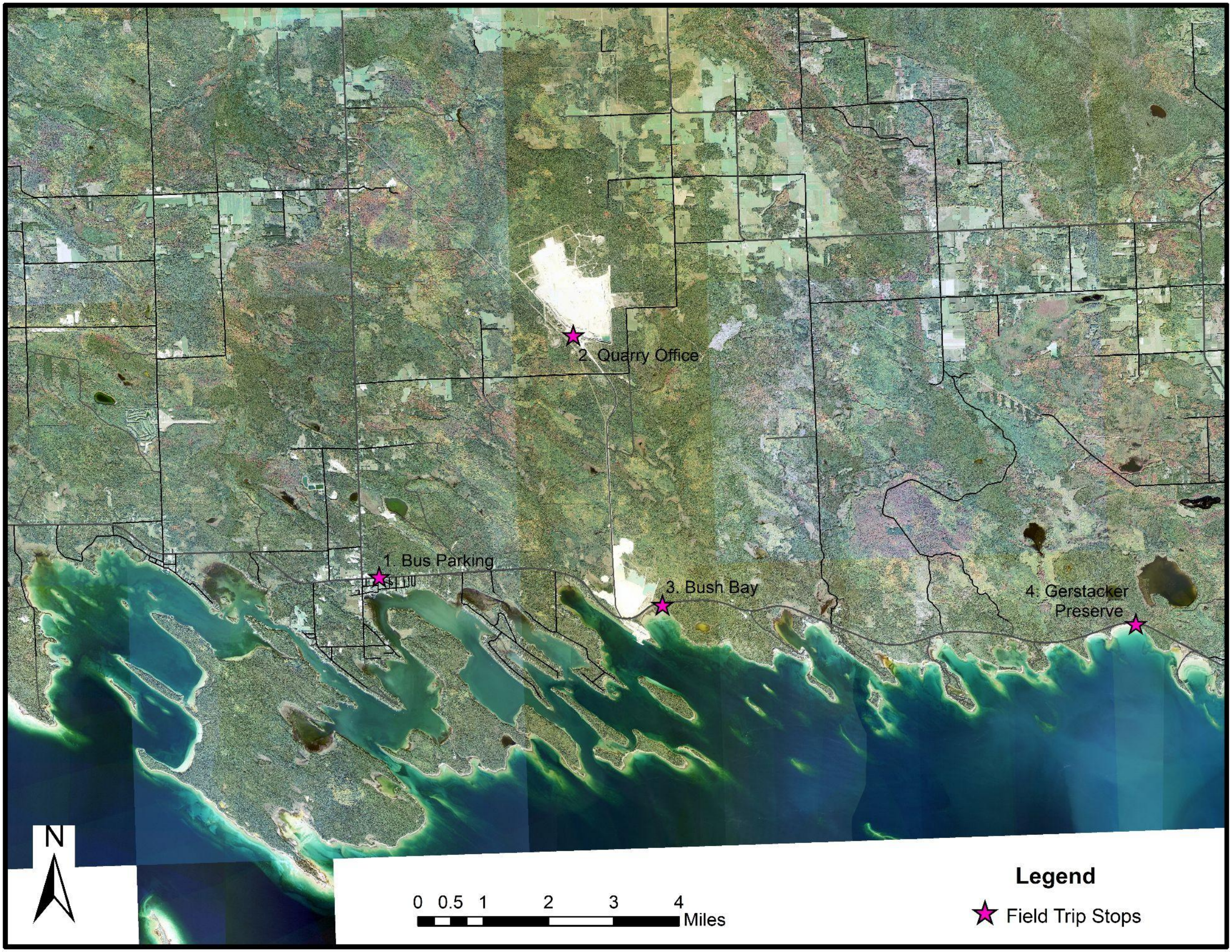
Schedule times are approximate. Will do our best to get you back on time!

	Friday, June 4 Morning 9:15 am - 12:00 pm		**Friday, June 4** Afternoon 1:00 pm - 4:00 pm		**Saturday, June 5** Afternoon 2:00 pm - 5:00 pm
9:15	- Meet at Bus Parking - Trip Introduction	1:00	- Meet at Bus Parking - Trip Introduction	2:00	- Meet at Bus Parking - Trip Introduction
9:20	- Depart Bus Parking	1:10	- Depart Bus Parking	2:10	- Depart Bus Parking
9:30	- Arrive at Mine Office - Safety Video	1:20	- Arrive at Mine Office - Safety Video	2:20	- Arrive at Mine Office - Safety Video
9:45	- The Silurian in Michigan (Libby) - The working quarry (Melissa)	1:35	- The Silurian in Michigan (Libby) - The working quarry (Melissa)	2:35	- The Silurian in Michigan (Libby) - The working quarry (Melissa)
10:00	- Driving quarry tour	1:50	- Driving quarry tour	2:50	- Driving quarry tour
10:30	- Depart quarry	2:20	- Depart quarry	3:20	- Depart quarry
10:40	- Arrive at Bush Bay Scenic Overlook - Glacial history and movement (Libby)	2:30	- Arrive at Bush Bay Scenic Overlook - Glacial history and movement (Libby)	3:30	- Arrive at Bush Bay Scenic Overlook - Glacial history and movement (Libby)
11:00	- Depart Bush Bay	3:00	- Depart Bush Bay	4:00	- Depart Bush Bay
11:10	- Arrive at Gerstacker Preserve - Postglacial Lake Levels (Libby)	3:10	- Arrive at Gerstacker Preserver - Postglacial Lake Levels (Libby)	4:10	- Arrive at Gerstacker Preserver - Postglacial Lake Levels (Libby)
11:45	- Depart Gerstacker Preserve	3:45	- Depart Gerstacker Preserve	4:45	- Depart Gerstacker Preserve
12:00	- Arrive at Bus Parking	4:00	- Arrive at Bus Parking	5:00	- Arrive at Bus Parking

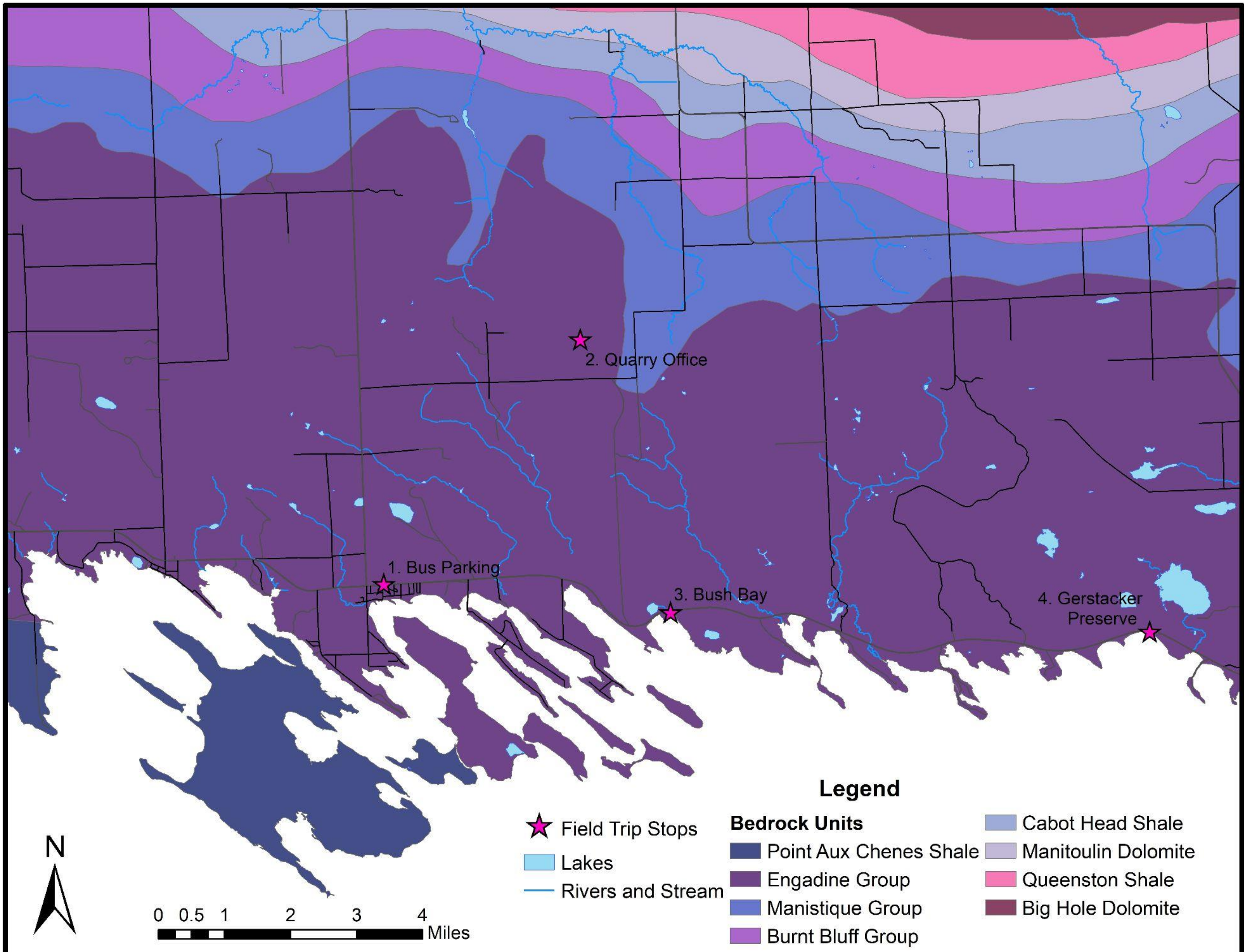
Digital Elevation Model of Field Trip Area

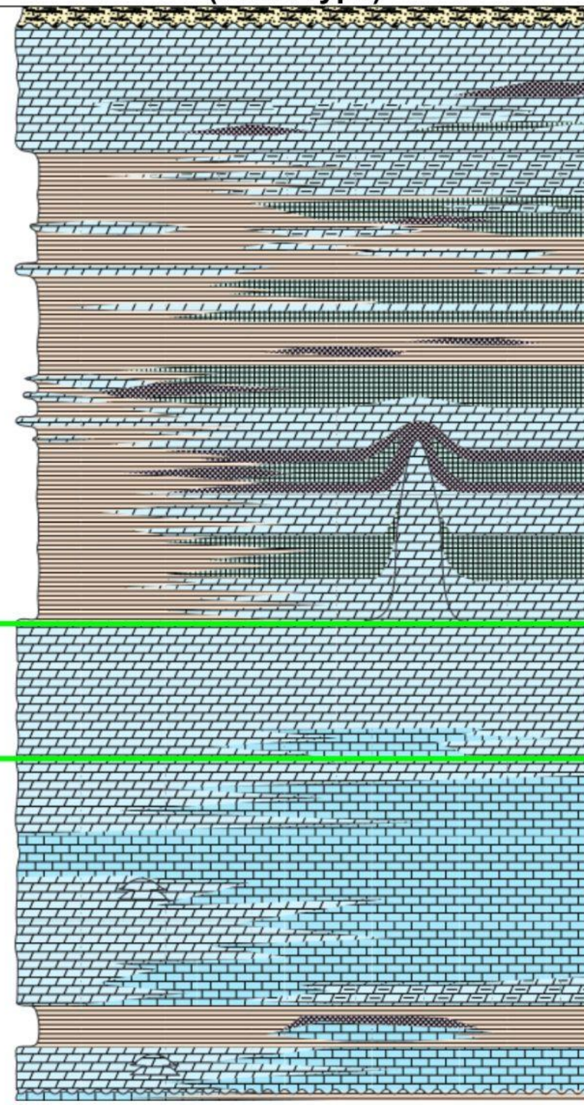


Aerial Imagery (Nov. 2014) of Field Trip Area



Bedrock Geology of Field Trip Area



Geologic Time: Period	Epoch	North American Stage	Rock Unit Names: Group	Formation	Member	Dominant Lithology (Rock Type)
	Early			Garden Island Fm		
Silurian	Late	Cayugan	Bass Islands Gr	Rasin River Dol	Macki	
				Put-in-Bay Dol		
				St. Ignace Dol		
			Salina Gr	Pte. aux Chenes Fm		
			Engadine Gr	Bush Bay Fm		
				Rapson Creek Fm		
				Rockview Fm		
	Middle	Niagaran	Manistique Gr	Cordell Fm		
				Schoolcraft Fm		
			Burnt Bluff Gr	Hendricks Fm	Fiborn Ls Mbr	
				Byron Fm		
				Lime Island Fm		
	Early	Alexandrian	Cataract Gr	Cabot Head Sh		
				Manitoulin Dol		

Copied From:

STRATIGRAPHIC NOMENCLATURE FOR MICHIGAN

Michigan Dept. of Environmental Quality
Geological Survey Division
Harold Fitch, State Geologist
and
Michigan Basin Geological Society

Stratigraphic Nomenclature Project Committee:
Dr. Paul A. Catacosinos, Co-chairman
Mr. Mark S. Wollensak, Co-chairman

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Mr. Mark S. Wollensak

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Acknowledgements

This work is the product of the combined efforts of the geological communities of Michigan and the surrounding states and provinces. Below are given just a representative few of the contributors:

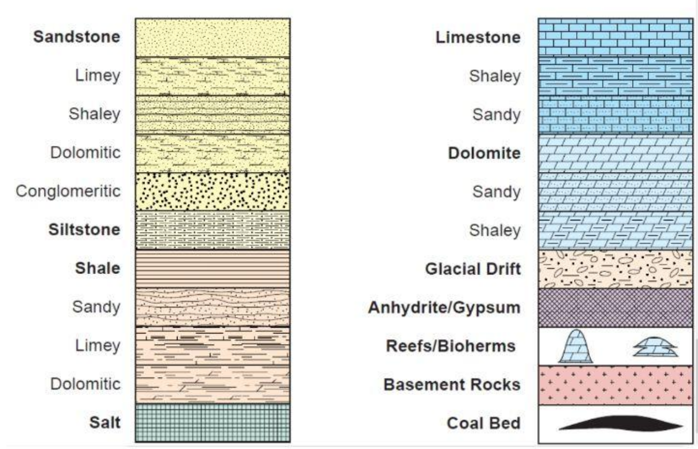
Academia: Dr. Aureal T. Cross, Michigan State University; Dr. Robert H. Dott, Jr., University of Wisconsin; Mr. William D. Everham, Ph.D. Candidate, Michigan Technological University.

Government: Dr. Terry R. Carter, Ontario Ministry of Natural Resources; Mr. John M. Esch, Michigan Department of Environmental Quality; Dr. Brian D. Keith, Indiana Geological Survey; Mr. Lawrence H Wickstrom, Ohio Geological Survey.

Industry: Mr. Donald J. Bailey, Consultant; Mr. Jimmy R. Myles, Scot Energy; Mr. Dan E. Pfeiffer, Pfeiffer Exploration Services.

A complete listing of all contributors will be found in the Stratigraphic Lexicon for Michigan, of which this column is an integral part.

LEGEND



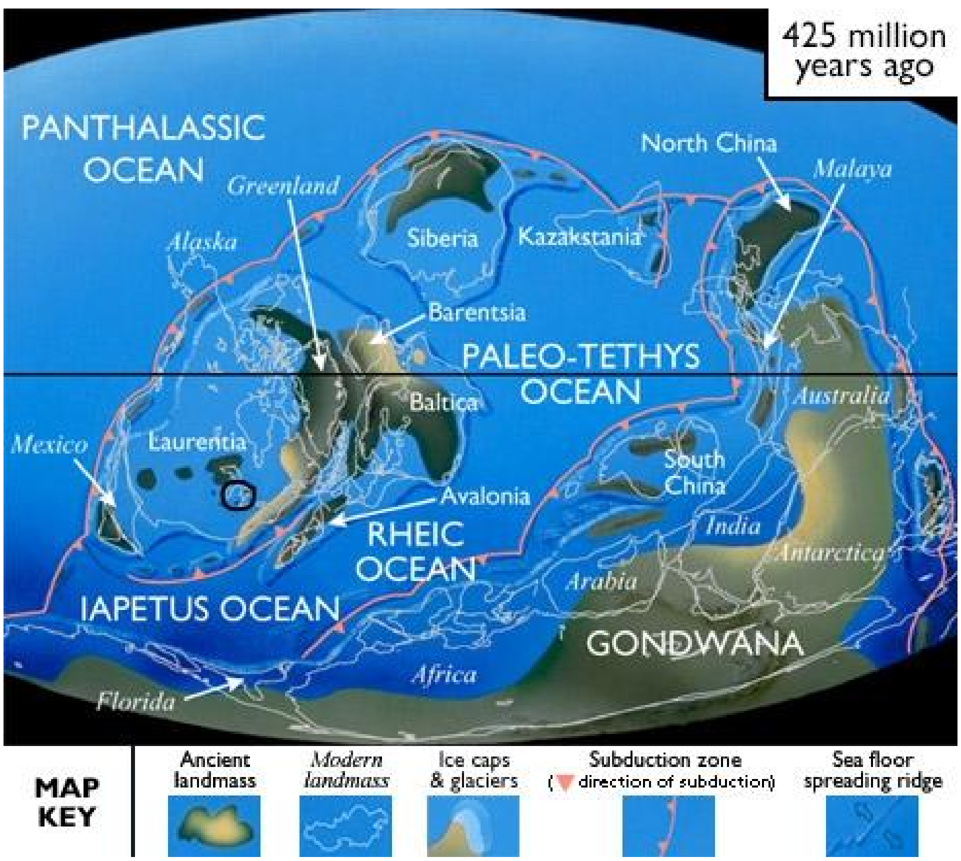
Stop 1: **Quarry**

Quarry Geology

Age of Rock: Silurian

The Engadine Group was deposited during the late Silurian Period, which is a period of time ~427 to 419 million years ago (Ma). For reference, the first records of multicellular life first occur at ~600 Ma and the dinosaurs went extinct around 68 Ma.

Major evolutionary events of the Silurian Period include: wide distribution of jawless and primitive-jawed fish, first terrestrial fungi, and beginning of land colonization by vascular plants.



Paleogeographic reconstruction of the late Silurian Period. Michigan is circled in black. Image from Paleoportal.org.

Type of Rock: Dolomite

The rocks in this quarry are dolomite (or dolostone). The rock is part of a unit called the **Engadine Group**. Dolomite is the name of both the rock and the mineral that comprises the rock. The rock and mineral are named after the Dolomite Mountains in Italy. The dolomite rocks in the Dolomite Mountains formed during the Triassic Period (~250 Ma).

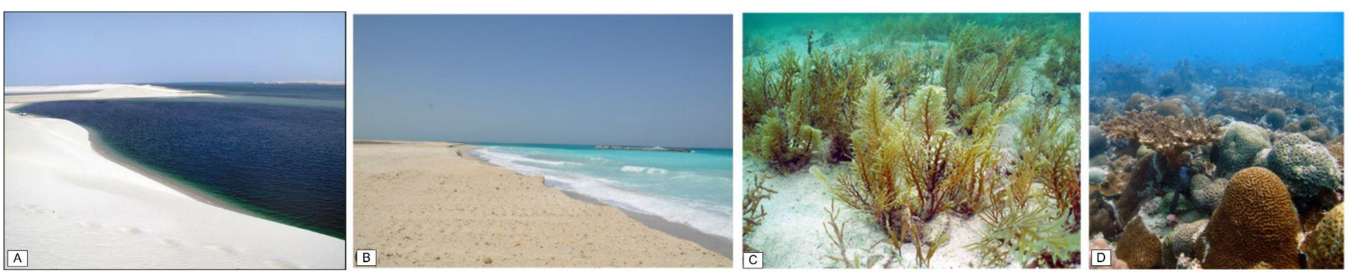
Dolomite is a sedimentary rock, which means it is created through the accumulation (deposition) of organic and inorganic (mineral) particles on the surface of the Earth, most often in bodies of water. Dolomite (made of the mineral dolomite) and Limestone (made up of the mineral calcite) are both carbonate sedimentary rocks. Carbonate sedimentary rocks are a special class of rocks that are created through biological, chemical, and physical processes. Unlike rocks like clastic sedimentary rocks (sandstones, siltstone, and shale), living organisms play a big role in the creation of carbonate rocks.

Dolomite rock is usually limestone that has been transformed so that all of its original calcite ($CaCO_3$) to dolomite ($CaMg(CO_3)_2$) in the distant past. THis replacement process is known as dolotomitization. **How and why dolomitization occurs is still one of the big, unanswered questions in geology.** We know that it was very common in the past, but have not found any modern analogs for the process.

As the calcite minerals are replaced during the dolomitization process, the original structure of the rock (layers, fossils, reefs, etc.) are often disrupted or obscured.. This is true in many parts of the Engadine Group, giving this rock a fairly homogenous appearance.

Paleogeography: Tropical

During the Silurian Period, Michigan was covered by shallow sea (~200 m maximum depth) and located at hot, dry tropical latitudes. A modern analog to this environment is the Persian/Arabian Gulf.

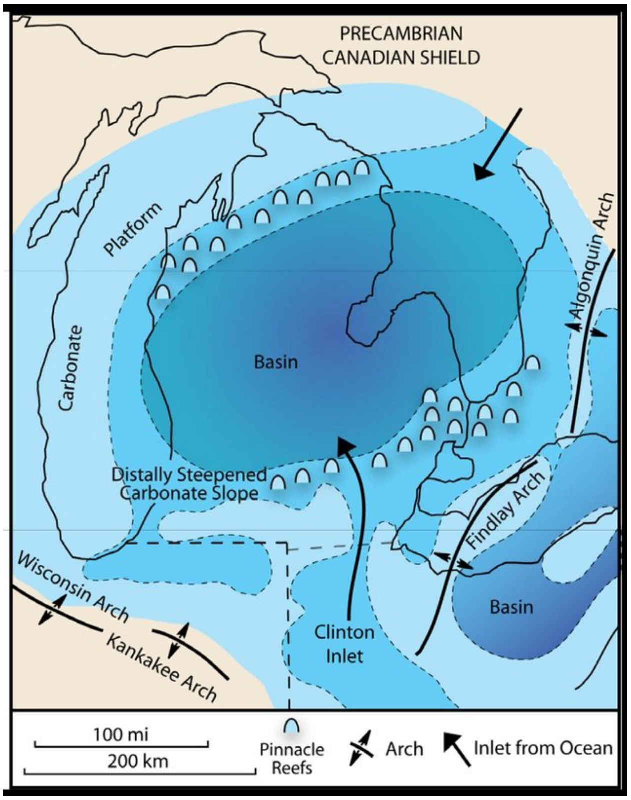


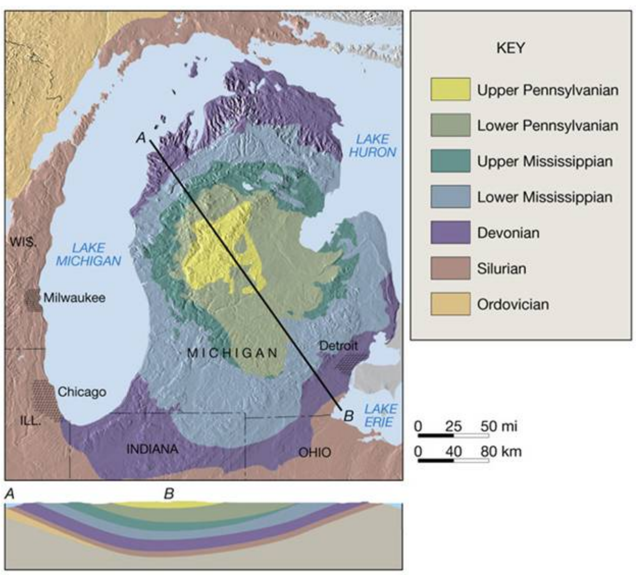
Habitats in the modern Persian Gulf that are likely similar to the Michigan Basin during the SIlurian. **A.** super-tidal dunes, **B.** inter-tidal beach, **C.** algae beds, and **D.** coral reefs. Images from Vaughan, Grace O., Noura Al-Mansoori, and John A. Burt. "The arabian gulf." World seas: An environmental evaluation. Academic Press, 2019. 1-23.

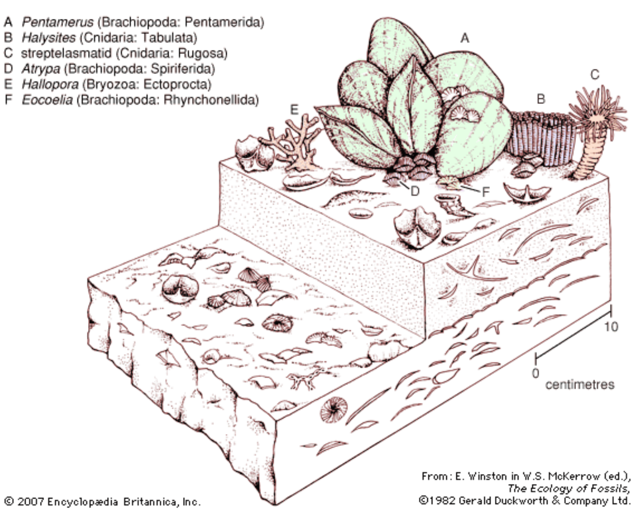
Environment of Deposition

During the late Silurian, the southern Upper Peninsula was located on the “northern” edge of the shallow sea over Michigan, which we call the “Michigan Basin”. The Michigan Basin persisted as an ocean basin for 250 million years from ~550 Ma (Cambrian Period) to ~ 300 Ma (Pennsylvanian Period).

Because the Michigan Basin was relatively shallow and had limited connections to the larger ocean, changes in sea level resulted in drastic changes to the Basin’s environments. During the Silurian Period, sea levels in the Michigan Basin fluctuated on the scale of 10’s of meters (10 - 60 m; 33 - 195







ft.) over million-year cycles. During intervals of high sea levels, the south-eastern UP was covered with ocean water and the Michigan Basin has a good connection to the rest of the ocean. This is the environment the Engadine Group was deposited in. During intervals of low sea levels, the Michigan Basin was isolated from the rest of the ocean, and the south-eastern UP was in a zone that was sometimes under water and other times exposed to the hot, dry air. This is the environment the Point Aux Chenes Shale (the unit overlying the Engadine Group) was deposited in.

The Point Aux Chenes Shale includes thin beds of gypsum, which is formed as an evaporite, meaning that the sea water evaporated and became more concentrated to the point where gypsum came out of solution. There are many evaporite units in the Michigan Basin that formed during low sea level intervals, including the salt underlying Detroit.

Fossils

Most fossils in the Engadine Group have been obscured by the dolomitization process. During this process, the original calcite and aragonite minerals in the animal shells and biofilms are replaced by dolomite. In other parts of the Engadine group, fossils were literally dissolved and removed, leaving behind holes or “vugs” in the rock. Fossils are best preserved in the lower portion of the Engadine Group, where the dolomitization is less “intense”.

Fossils that have been identified in the Engadine group in crinoids (*Echinodermata*;sea lilies), brachiopods (*Brachiopoda*), algal mats, trilobites (*Arthropoda*), corals (*Cnidaria*), bivalves, and stromatoporoids.

Reef mounds (also called bioherms and pinnacle reefs) are common in Silurian-aged carbonate rocks, like the Engadine Group. From the Virtual Silurian Reef Project:

> “A reef is a structure built by organisms that rises above the surrounding seafloor...Reefs are built in

warm shallow seawater in the tropics and subtropics. Reefs occur only in waters that are relatively free of suspended, land-derived sediment, which allows sunlight to penetrate to the reef surface, permitting photosynthetic organisms to live. Reefs are characterized by high biodiversity…”

In our modern Landscape: The Niagara Escarpment

The highly dolomitized nature of the Engadine Group and its correlate rocks across the Michigan Basin make it much more resistant to erosion than the adjacent shales and limestones. This has allowed these rocks to form a high ridge, the Niagara Escarpment, or Niagara Cuesta, that rings the Michigan Basin. The Escarpment is named after the famous Niagara Falls, where the Niagara Rivers famously falls over the Escarpment. In Ontario and New York these units are known as the Lockport Dolomite.

The Niagara Escarpment creates unique environmental conditions that support distinct assemblages of plants and animals. Perhaps most notably, the Escarpment is home to very small, rare land snails as well as some endangered, threatened, and rare plant species.

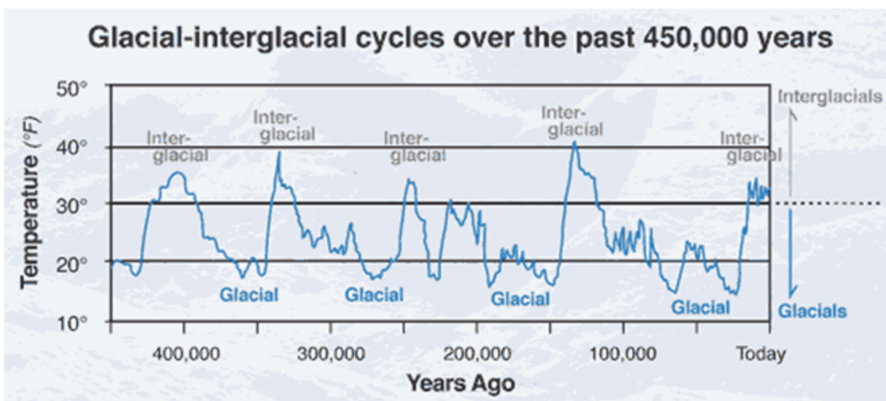
Map of the Niagara Escarpment, shown in red. From Wikipedia Commons. (commons.wikimedia.org/wiki/File:Niagara_Escarpment_map.png)

Stop 2: Bush Bay

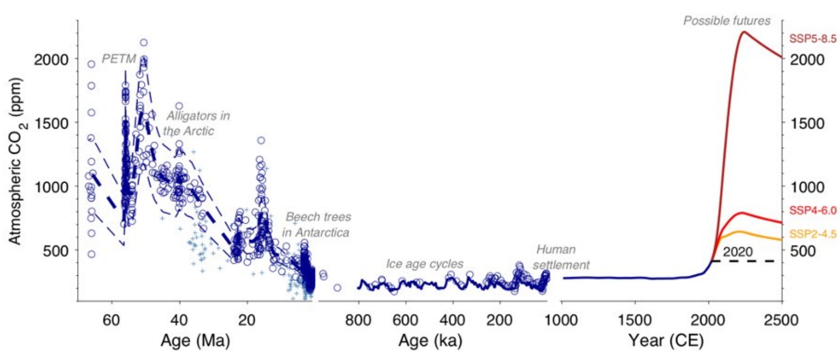
Glacial History and Striations

On this stop, we fast forward by 425 million years, from the Silurian Period to the Ice Age. The Earth has been in a global cold snap since about ~2.58 Ma (that's 2,580,000 years), when we have the first record of large ice sheets (glaciers) in both Antarctica and Greenland. The Antarctic ice sheet has been around since ~34 Ma, the Greenland Ice Sheet is much younger.

Within this ice age, there have been colder "glacial" periods where the ice sheets were more extensive, and warmer "interglacial" periods where the ice sheets were smaller (retreated to the poles). The most recent "glacial" period began around 71,000 years ago, and is known as "The Last Glacial Period" or the "Wisconsinan Glaciation" in North America. We have been in an "interglacial" period since the large ice sheets began to retreat ~ 18,000 years ago, and fully left areas like Michigan only ~11,000 years ago. This coincides with the advent of agriculture, and is known as the Holocene Epoch.



Global average air temperature for the last 500,000 years (0.5 Ma). Image from:
https://geology.utah.gov/map-pub/survey-notes/glad-you-asked/ice-ages-what-are-they-and-what-causes-them/

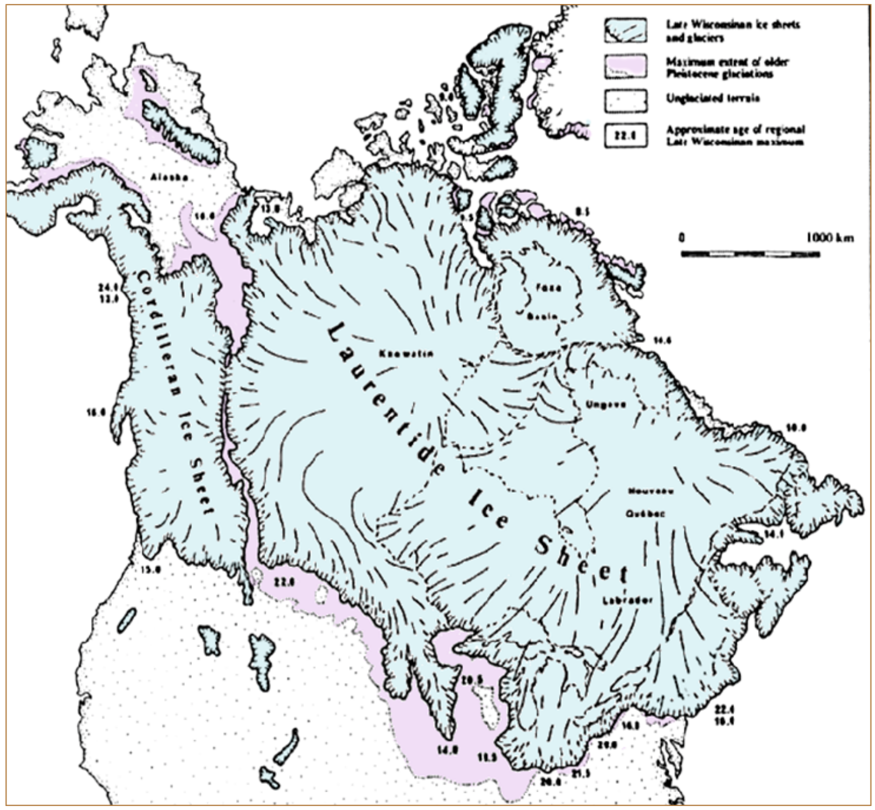


Atmospheric CO_2 since the Dinosaur extinction. Note that the time scale changes along the x-axis. Atmospheric CO_2 is now present in our atmosphere at higher levels than it has been since the beginning of the ice age 2.58 million years ago. From Rae et al., (2021) Through their repeated advances and retreats, glaciers completely reshaped the landscapes of North America, Europe, and high mountains like the Andes, Alps, and Himalaya during this time. **Since glaciers are so efficient at eroding, most of the glacial features we see at the surface are from the Wisconsinan Glaciation.**

Glaciers are constantly in motion, and slowly flow across the landscape. Ice is a viscous fluid, like honey or tar.

Glaciers leave behind distinct landforms and signatures that tell us about how they flowed across the landscape and in what direction. Drumlins, for example, are elongate, tear-drop shaped hills that form beneath glaciers and point in the direction of glacier flow. Drumlins are what give the Les Cheneaux islands their unique shape.

The features we're going to see at Bush's Bay are concentric gouges on bedrock that are formed when glaciers drag rocks locked into the ice across the bedrock.



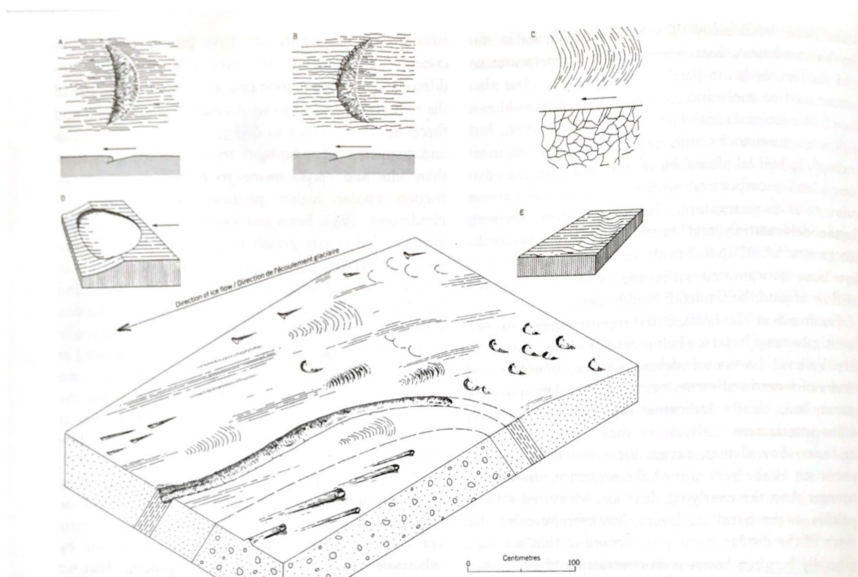
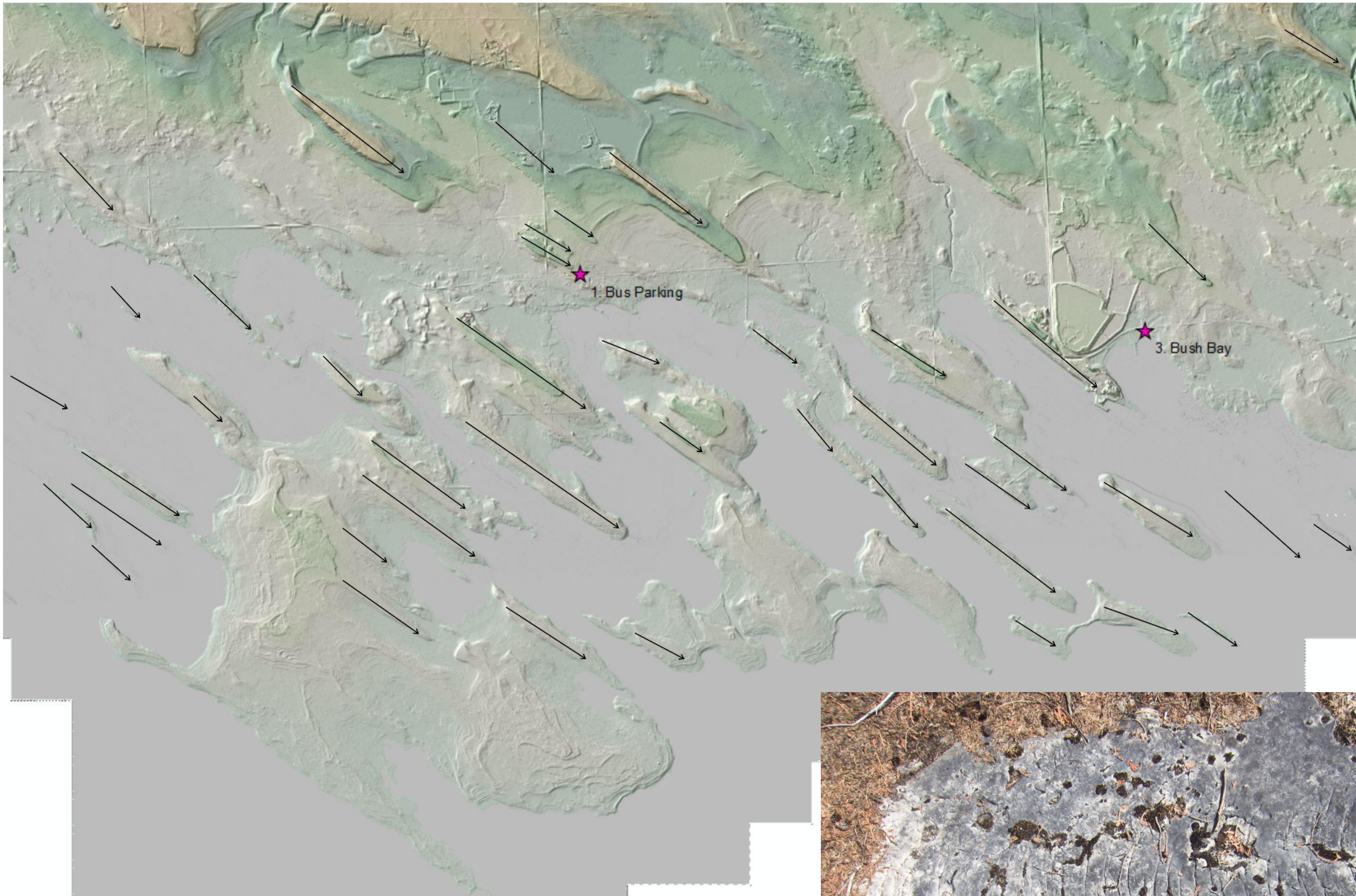


Figure 8.11 Small-scale forms of glacial erosion. (A) Lunate fracture (plan and section). (B) Crescentic gouge (plan and section). (C) Crescentic fractures (plan and section). (D) Conchoidal fracture. (E) Sichelwanne. Main diagram: striae, fractures, grooves and associated features and their relationships to bedrock lithology (After Prest 1983; Embleton and King, 1975)

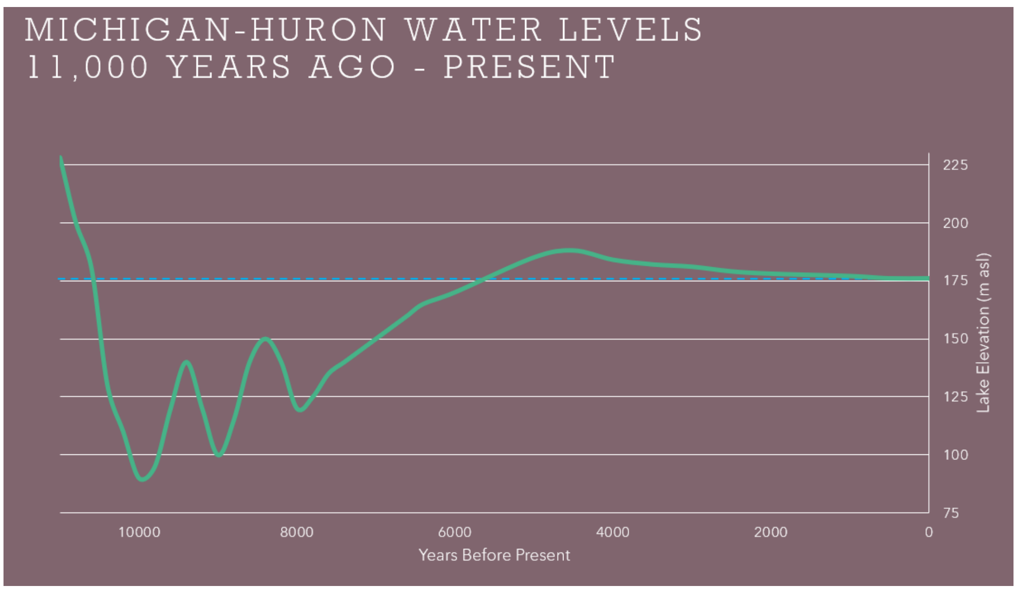


[above] Digital elevation model and hillshade of the Les Cheneaux Islands with drumlin long axes indicated by black arrows (I probably missed a few! [right] Glacier made concentric gouges on the Engadine Group dolomite at Bush Bay. Photo by Ken Drenth.

Stop 3: Gerstacker Preserver

Post-Glacial Lake Level Change

After the glaciers retreated out of the Michigan-Huron Lake Basin 11,000 years ago, the region went through a lot of drastic changes that were indirectly caused by the glaciers. Some of these changes were due to climate - a boreal, permafrost landscape likely persisted in the northern Great Lakes until ~10,000 years ago. People appeared to have moved into the region almost as soon as the glaciers retreated.



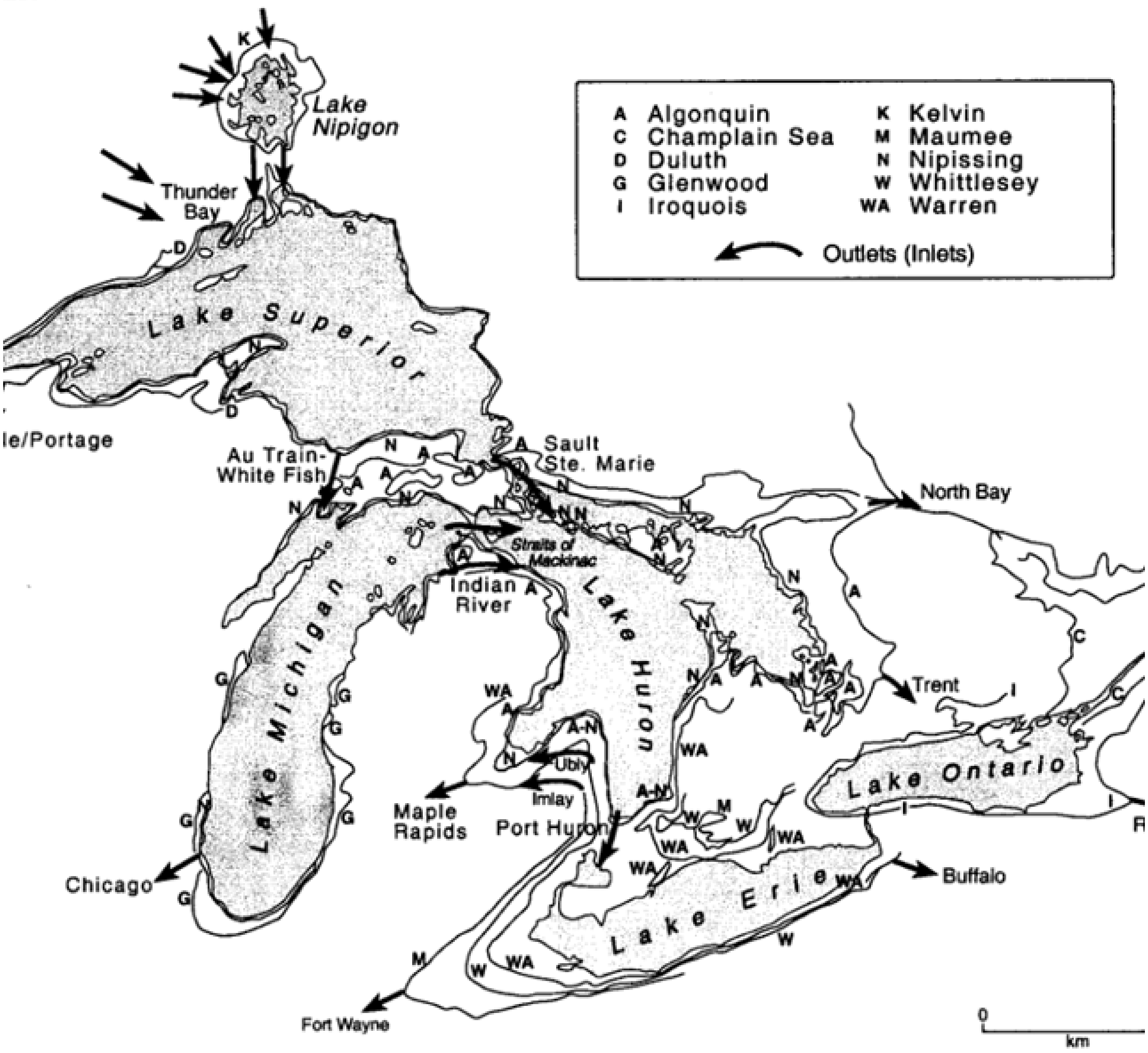
The green line indicates pproximate lake level elevation in the Michigan-Huron Basin since the retreat of the last large glacier to the present. The blue dashed line in the modern lake level average.

Besides changes in climate, and the accompanying changes in the distribution of animals, plants, and people, the most striking transition that the Great Lakes region went through during this time was the change in Great Lakes levels.

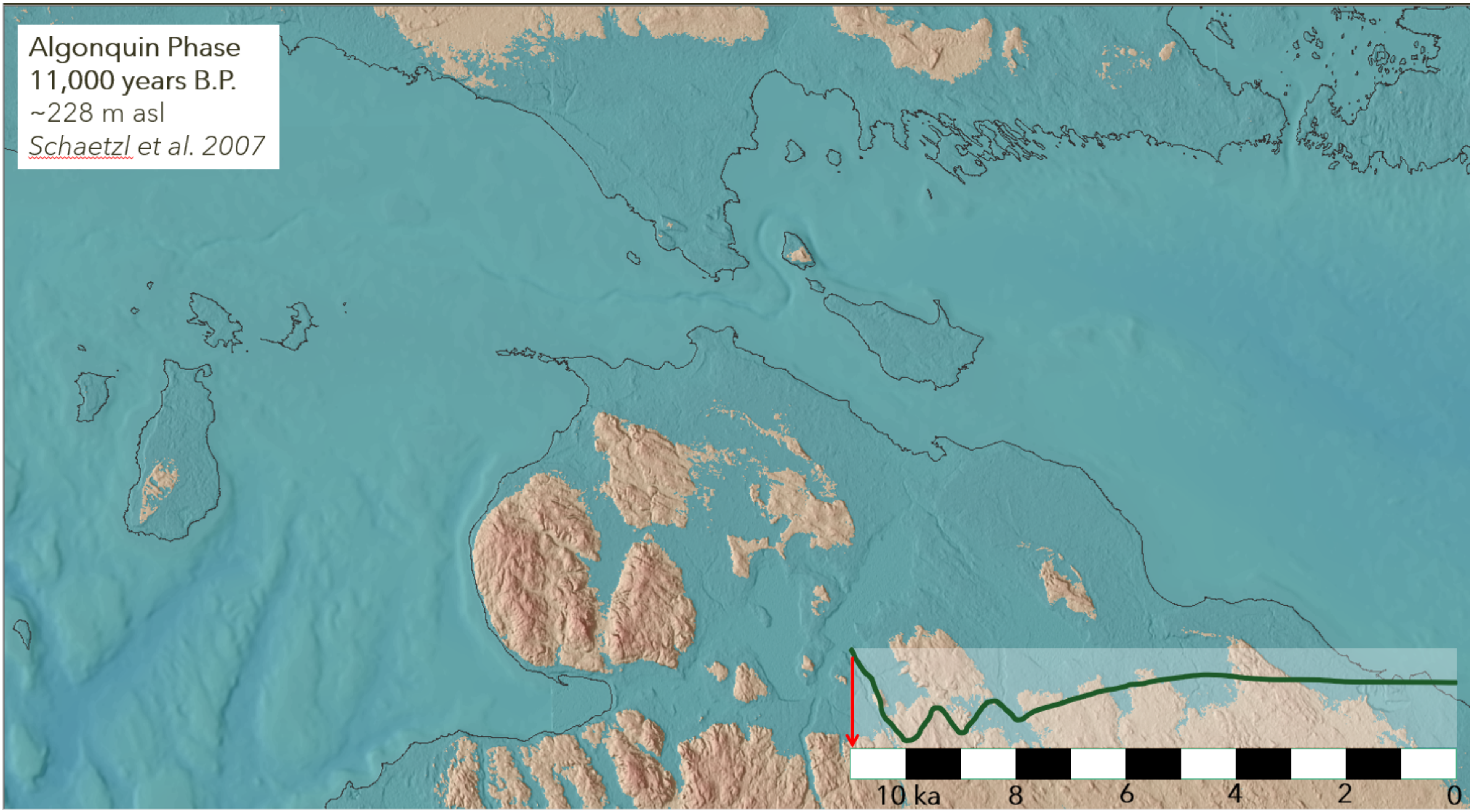
There lake levels changed due to four driving factors:

1. **Decrease input of meltwater from glaciers -** lake levels were really high 11,000 years ago because the ice sheet was dumping a bunch of water into them
2. **Isostatic Rebound** - the glaciers were extremely heavy, and weighted down the earth's surface. Once the glaciers were removed, the ground began to rebound (move back towards an equilibrium with the weight of ice). Since the glacier melted back over thousands of years, different parts of the Great Lakes Region rebounded at different times and at different rates, **changing the elevation of lake outlets.**

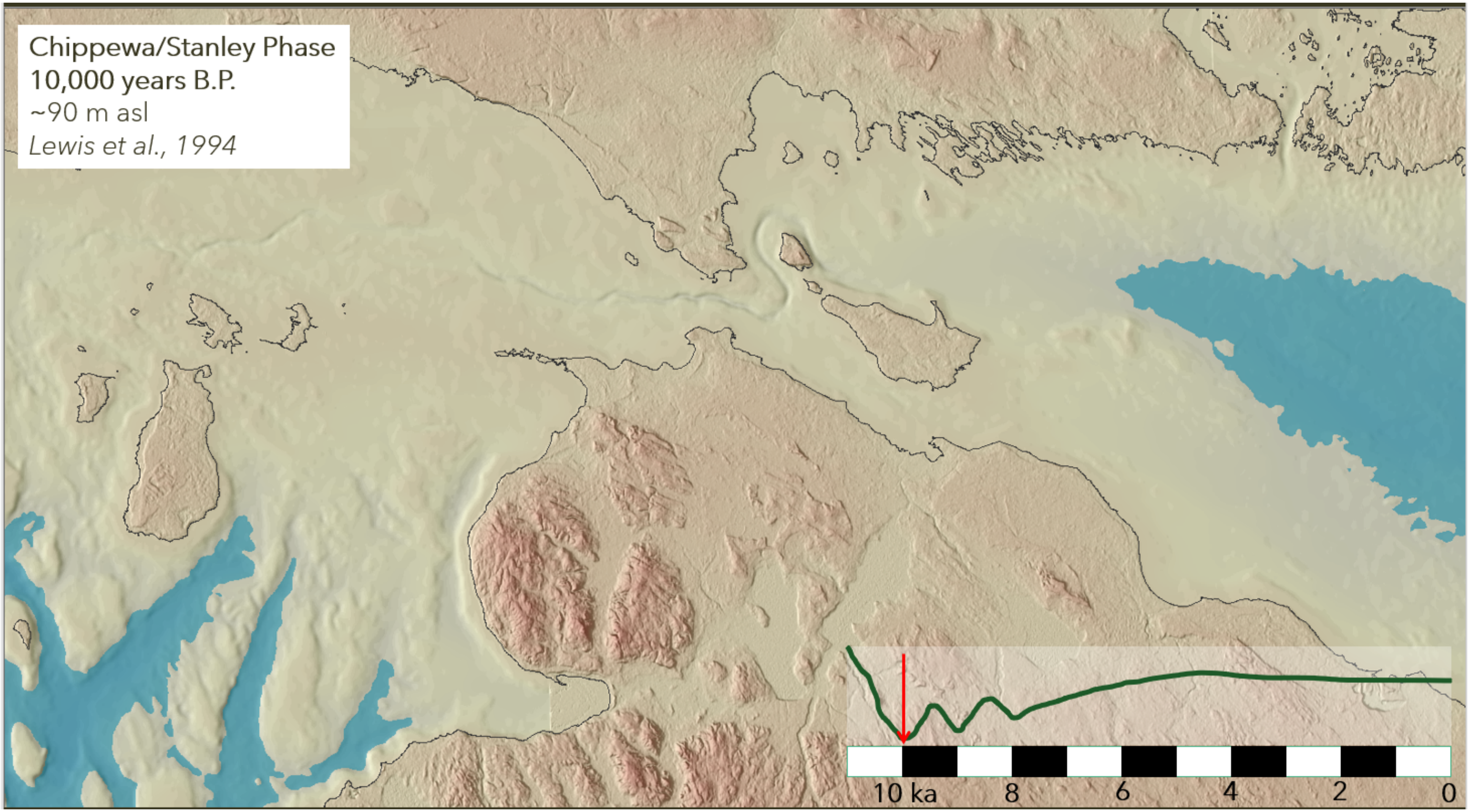
3. **Climate** - changes in precipitation between relatively wet and relatively dry periods also influenced lake levels

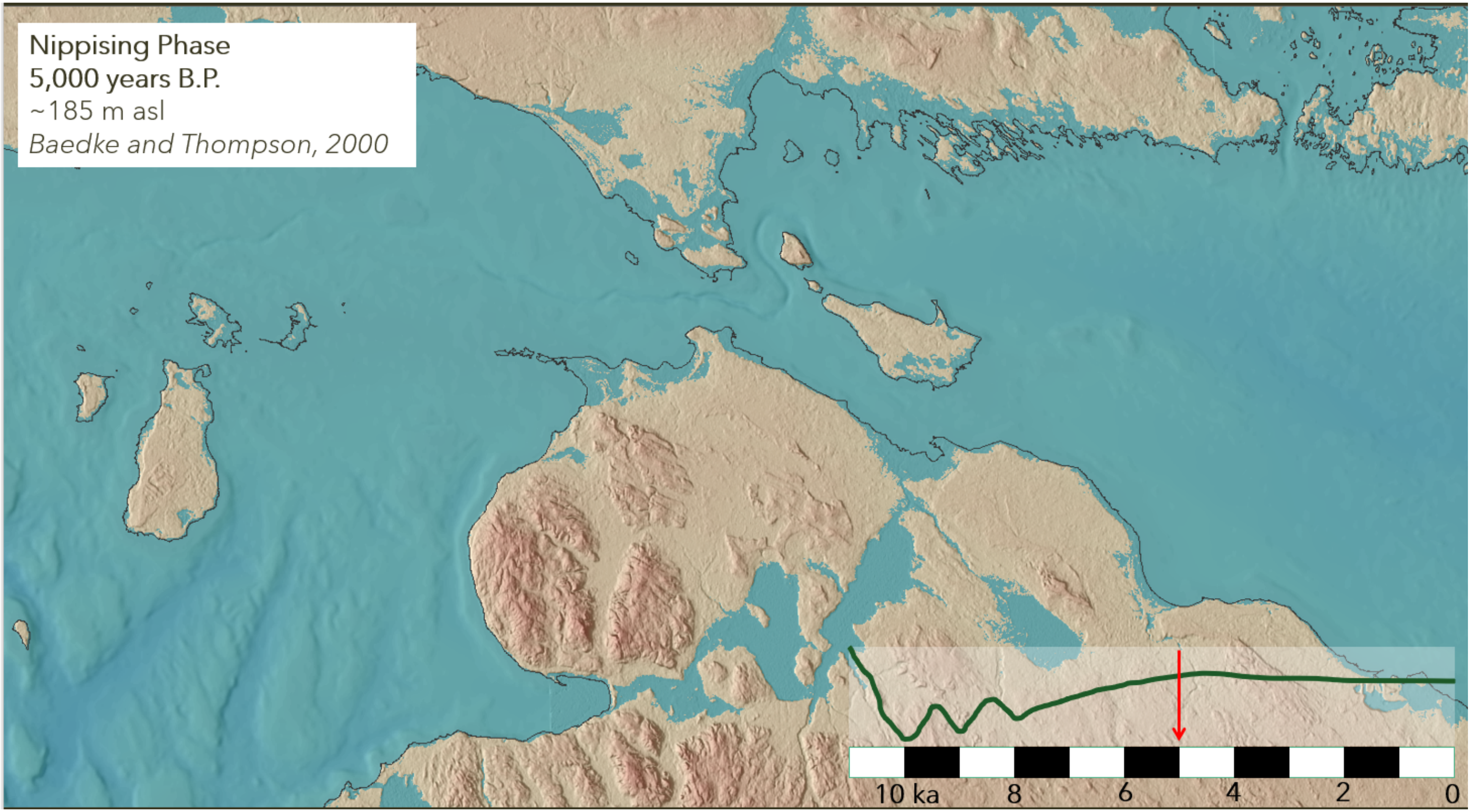


Various outlets for the Great Lakes Basins after glacier retreat. From Larson and Schaetzl (2001).



Algonquin Phase
11,000 years B.P.
~228 m asl
Schaetzl et al. 2007
10 ka
8
6
4
2
0

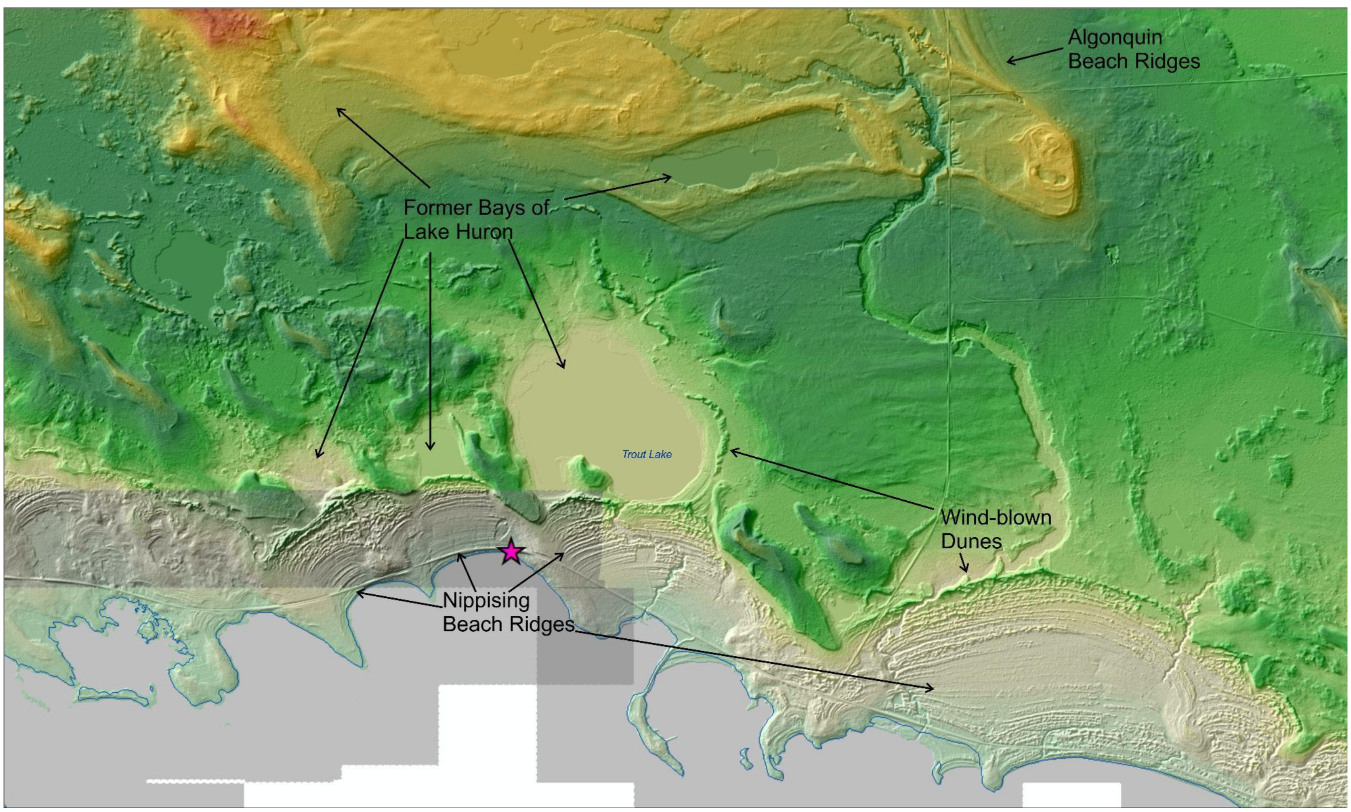

Chippewa/Stanley Phase
10,000 years B.P.
~90 m asl
Lewis et al., 1994
10 ka
8
6
4
2
0


Nippising Phase
5,000 years B.P.
~185 m asl
Baedke and Thompson, 2000
10 ka
8
6
4
2
0

Dune and Swale Complexes

Dune and swale landscapes are relatively common around the Great Lakes, but rare globally. These systems are home to a number of endangered and threatened species, including Pitcher's thistle, Houghton's goldenrod, and piping plover. The landscape consists of a sequence of beach ridges that are between 0.5 - 4 m high separated by lows that are often wetlands. An acquaintance once described these areas as looking like a cat had left long scratches along the lake shore.

These beach ridges formed gradually as lake levels dropped following the Algonquin (~11,000 years ago) and Nippising (~5,000 years ago) high stands (see figures). The upper elevation limit of the beach ridges is generally marks each high stand. Before they were vegetated, these vast expanses of sand were often blown up into large dunes. The dunes and beach ridges work together to impound water in lakes trapped behind them.



Digital Elevation Model of area near our final stop. Major features are marked on the landscape. Can you find any drumlins??

Resources/Additional Reading

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Michigan Tech Earth Science Education: http://www.geo.mtu.edu/MiTEP/EarthCache/BlueRidgeEsker/

PaleoPortal: http://paleoportal.org

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Vaughan, G. O., Al-Mansoori, N., & Burt, J. A. (2019). The arabian gulf. In *World seas: An environmental evaluation* (pp. 1-23). Academic Press.

Virtual Silurian Reef (collaboration between the Field Museum and Milwaukee Public Museum): https://silurian-reef.fieldmuseum.org