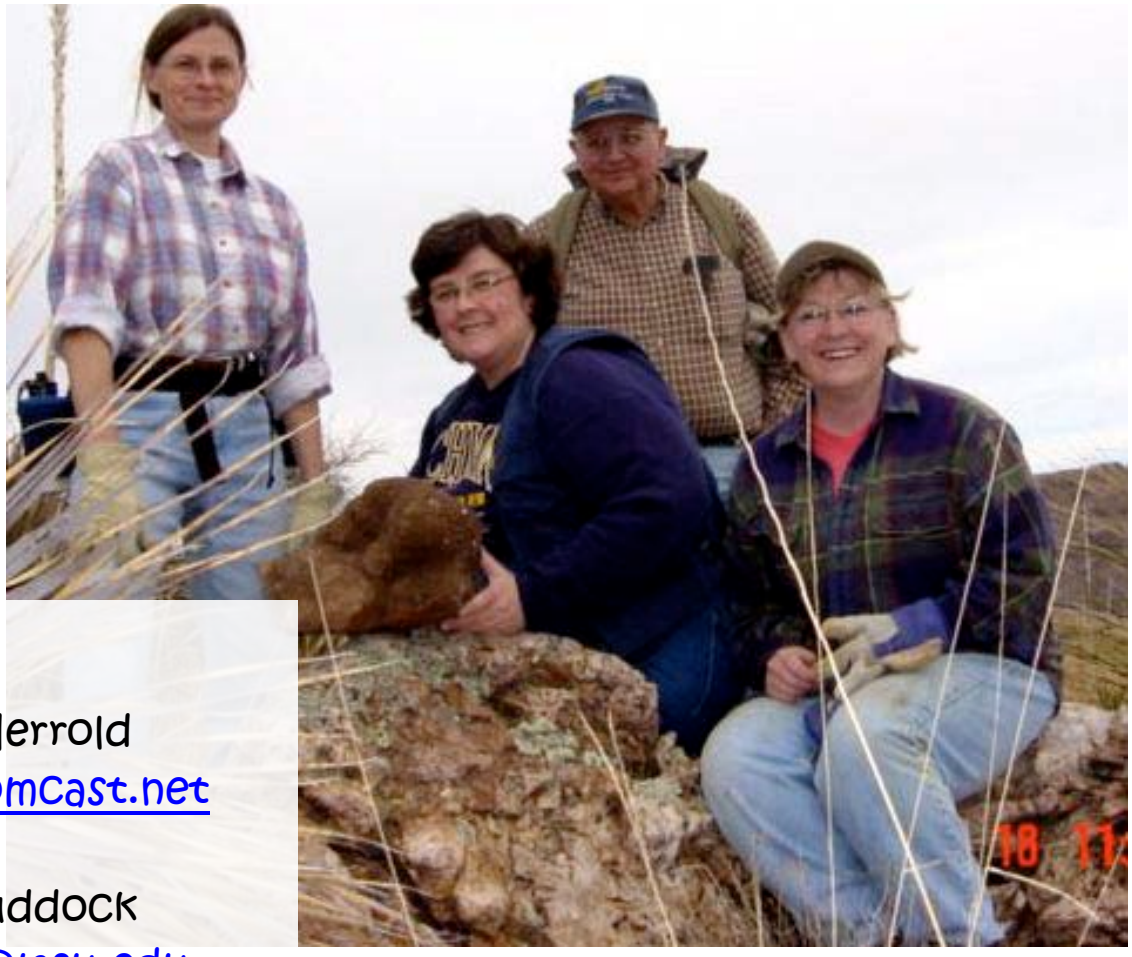
# A Walk Through Time:

## *Michigan Geology in 460 Steps*

www.mestarocks.org

The activities and ideas in this kit cover these content expectations in the Michigan Merit Curriculum for high school science: E2.1C, E2.3a & b, E3.p1, E3.p2, E3.p3, E3.3A, E3.r3f, E3.4e, E4.p3a & c, E4.2B, E5.3C & g, E5.4B & f, E5.r4i

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**A Walk Through Time – Michigan Geology in 460 Steps  Student Activities**

**Activity 1 – A Walk Through Time**

*Teacher Instructions: In this activity, students will walk 460 steps, stopping along the way to learn about significant events in Michigan's geologic history. This activity can be combined with Activity 2 or 3.*

Before the Walk

1. Find an area around your school where you can pace off 460 steps. It is helpful if you have a designated starting and ending location, such as a fence or building that allows students to visually relate geologic time and events with the distance.
2. Mark the beginning and walk off the 460 steps, marking each of the stops you will be making with your students.
3. Prepare envelopes with the narrative and materials for each stop.
4. Introduce students to the activity and assign a stop to each student or student group, depending on number of stops you are using and class size.

During the Walk

1. Take students and materials out to the walk area. Explain to students that we will now walk forward through time from the creation of the Earth towards the present day. Point out for students a visual clue for where the walk will end.
2. Explain that each step we take represents 10 million years of Michigan's history.

After the Walk

Summarize using the questions from Activity 2 or 3

**A Walk Through Time – Michigan Geology in 460 Steps - Student Activities (cont.)**

**Activity 2 – Measuring Tape Timeline**

*Teacher Instructions: In this activity, students will make a half-meter mini timeline, then use it along with the Geologic Time Chart and the simple color Michigan Bedrock map. It concludes with some simple summary questions.*

Before the Walk

1. Measure out 0.5 meters of adding machine tape. (Alternatively, you can use graph paper with 1 cm grids, cut and taped together to form 0.5 meters.)
2. Mark the left end of the tape "Earth Forms".
3. Using a ruler or meter stick, place tick marks along the tape every 5 cm from where "Earth Forms" to the end of the paper. Number each, starting at 0 cm.
4. Draw lines across the tape for the divisions between geologic eras at these places:
   - 41.6 (42) cm = 544 Ma - the end of the PreCambrian Eon
   - 43.5 (44) cm = 245 Ma - the end of the Paleozoic Era
   - 45.4 (45) cm = 65 Ma – the end of the Mesozoic Era
5. Label each segment of the tape with its eon or era: PreCambrian, Paleozoic, Mesozoic and Cenozoic.

During the Walk

1. Write a key word or phrase for each stop at the appropriate place along the tape. Label it with the stop number (1-20).
2. Write the time in Ga (billion years ago) or Ma (million years ago) for each stop, including the Present Time (today).

After the Walk

1. Using the Geologic Time Chart, write where each stop (number and key words) of the timeline is located.
2. Using the color map of Michigan bedrock, write a number on the correct rock layer for where rocks from stops 3-17 might be found.
3. (optional) Illustrate each stop with a symbol or picture.

Questions

1. What was your favorite station during the walk? Explain.
2. What surprised you the most about the timing or spacing of the events on the walk? Explain.

Use the bedrock map and Geologic Time Chart to answer the next questions:

3. Where are the oldest rocks in Michigan? Where are the youngest rocks?
4. Name two metals that could be mined in the Upper Peninsula.
5. Name two materials that could be mined in the Lower Peninsula.

**A Walk Through Time – Michigan Geology in 460 Steps Student Activities (cont.)**
**Activity 3 – Questions from the Walk**

*Teacher Instructions: In this activity, students will make notes on the Geologic Time Chart during the walk, then use it with the simple color Michigan Bedrock map. It concludes with some simple summary questions.*

Before the Walk
Read the questions below before you begin the walk.

During the Walk
Write where each stop (number and key words) is located on the Geologic Time Chart. You may also use the back of the chart to make notes about the answers to any of the questions.

After the Walk
On the color map of Michigan bedrock, write a number on the correct rock layer for where rocks from stops 3-17 might be found, then answer the questions below.

Questions

1. What gases were in the early atmosphere of Earth?
2. The greenstone rock found in Michigan gives evidence that many years ago that place in Michigan used to be a _____ _____.
3. Did Michigan have just one Ice Age, or were there more than one?
4. What is the oldest Michigan fossil that you saw on the walk?
5. What three "spheres" were involved in the formation of banded iron?
6. Where in Michigan did the Earth's crust begin to rift, forming volcanoes?
7. Which metal formed along the rift zone?
8. What may have caused the "Explosion of Life"?
9. Which Michigan Peninsula contains most of the Michigan Basin?
10. How can you explain the presence of coral reefs in Michigan?
11. Explain why Michigan has large salt deposits.
12. What is the State Stone of Michigan?
13. What formed Michigan's oil and gas?
14. What is the rock gypsum used to make?
15. Describe the type of environment that formed Michigan's coal deposits.
16. Have dinosaur fossils ever been found in Michigan?
17. What is Michigan's State Fossil?
18. Do we have evidence that humans were living in Michigan before the last Ice Age ended?
19. What was your favorite station during the walk? Explain.
20. What surprised you the most about the timing or spacing of the events on the walk? Explain.

Use the bedrock map and Geologic Time Chart to answer the next questions:

21. Where are the oldest rocks in Michigan? Where are the youngest rocks?
22. Name two metals that could be mined in the Upper Peninsula.
23. Name two materials that could be mined in the Lower Peninsula.

***Teacher Answer Key for Activity 2***

*1. possible answers: water vapor, carbon dioxide*
*2. subduction zone or mountain range*
*3. no, there were probably multiple Ice Ages, as indicated by Stop 5*
*4. Kona stromatolites. (The rock is a dolostone)*
*5. biosphere, atmosphere, hydrosphere, (geosphere also contiributes)*
*6. the western Upper Peninsula*
*7. copper*
*8. possible development of the ozone layer, larger amounts of oxygen in atmosphere*
*9. Lower*
*10. there was a tropical climate and a warm shallow sea covering the Basin*
*11. the shallow sea evaporated*
*12. Petoskey Stone*
*13. microscopic plants and animals in the ocean*
*14. wallboard, Plaster of Paris, Portland cement*
*15. swampy*
*16. no- dinosaurs roamed the Earth during Michigan's Lost Interval*
*17. the mastodon*
*18 and 19. – student answers will vary*

*20. no*
*21. the western Upper Peninsula*
*22. iron and copper (silver, gold and nickel are also correct, if you mentioned these)*
*23. oil, natural gas, salt, gypsum, limestone are the most common. Coal was mined for a time but the deposits were not extensive. It would also be accurate to include aggregates such as glacial gravels.*

**A Walk Through Time – Michigan Geology in 460 Steps  Student Answer Sheet**

*Instructions: Based on what you learn as we walk through time, answer these questions about Michigan's past.*  Name: _____

1. What gases were in the early atmosphere of Earth? _____

2. The greenstone rock found in Michigan gives evidence that many years ago that place in Michigan used to be a _____ _____.

3. Did Michigan have just one Ice Age, or were there more than one? _____

4. What is the oldest Michigan fossil that you saw on the walk? _____

5. What 3 "spheres" were involved in the formation of banded iron? _____

6. Where in Michigan did the Earth's crust begin to rift, forming volcanoes? _____

7. Which metal formed along the rift zone? _____

8. What may have caused the "Explosion of Life"? _____

9. Which Michigan Peninsula contains most of the Michigan Basin? _____

10. How can you explain the presence of coral reefs in Michigan? _____

11. Explain why Michigan has large salt deposits. _____

12. What is the State Stone of Michigan?_____

13. What formed Michigan's oil and gas? _____

14. What is the rock gypsum used to make? _____

15. Describe the type of environment that formed Michigan's coal deposits. _____

16. Have dinosaur fossils ever been found in Michigan? _____

17. What is Michigan's State Fossil? _____

18. Do we have evidence that humans were living in Michigan before the last Ice Age ended? _____

19. What was your favorite station during the walk? Explain.

20. What surprised you the most about the timing or spacing of the events on the walk? Explain.

**Use the bedrock map and Geologic Time Chart to answer the next questions:**

21. Where are the oldest rocks in Michigan? _____
    Where are the youngest rocks? _____

22. Name two metals that could be mined in the Upper Peninsula. _____

23. Name two materials that could be mined in the Lower Peninsula. _____

# Geologic Time Chart

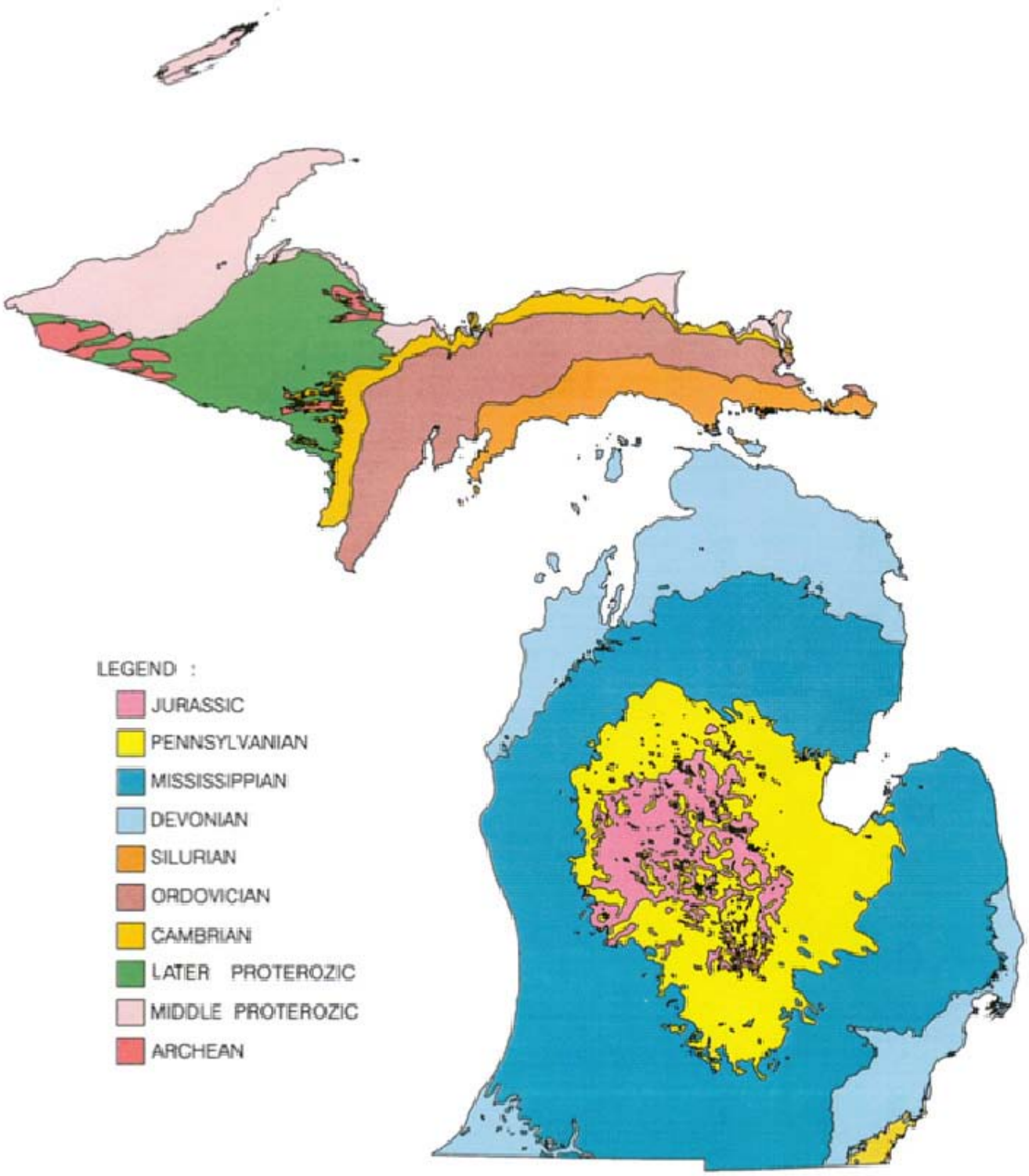
| | | | | from | to |
|---|---|---|---|---|---|
| Phanerozoic Eon | Cenozoic Era | Quaternary Period | Holocene Epoch | 0.01 | 0.00 |
| | | | Pleistocene Epoch | 1.8 | 0.01 |
| | | Tertiary Period | Pliocene Epoch | 5 | 1.8 |
| | | | Miocene Epoch | 23 | 5 |
| | | | Oligocene Epoch | 38 | 23 |
| | | | Eocene Epoch | 54 | 38 |
| | | | Paleocene Epoch | 65 | 54 |
| | Mesozoic Era | Cretaceous Period | | 146 | 65 |
| | | Jurassic Period | | 208 | 146 |
| | | Triassic Period | | 245 | 208 |
| | Paleozoic Era | Permian Period | | 286 | 245 |
| | | Pennsylvanian Period ① | | 325 | 286 |
| | | Mississippian Period ① | | 360 | 325 |
| | | Devonian Period | | 410 | 360 |
| | | Silurian Period | | 440 | 410 |
| | | Ordovician Period | | 505 | 440 |
| | | Cambrian Period | | 544 | 505 |
| Precambrian Eon | Proterozoic Era | | | 2,500 | 544 |
| | Archaean Era | | | 3,800 | 2,500 |
| | Hadean Era | | | 4,500 | 3800 |

Chart is not to scale. **Dates** are in millions of years. Dates vary from source to source

For more information go to http://www.ucmp.berkeley.edu/help/timeform.html

① Some authors refer to the Mississippian and Pennsylvanian as Carboniferous

**Michigan Bedrock Map**



# A Walk Through Time – Narratives

**Stop 1 Creation of Earth - 4.6 billion years before present** Step 0 (YOUR meteorite)

We are here together at the formation of the Earth. Although the oldest Earth rocks ever found have been dated at 4.0 billion years, geologists assume that the age of the Earth is about the same as the age of meteorites. These rocks have an average age of 4.6 billion years. It is estimated that all the planets in our solar system began to form at the same time, and took about 50 to 100 million years to grow to their final sizes. At this time the Earth was a sphere of very hot rocks, perhaps still molten. It had begun to differentiate into layers inside, but the crust was still not fully formed.

We will now walk forward through time towards the present day. Each step we take will represent 10 million years of history.

Next stop: 40 steps

**Stop 2 Hydrosphere forms - 4.2 billion years before present** Step 40 (4cm) **WATER CYCLE DIAGRAM**

400 million years after Earth formed, volcanoes and cooling rocks had degassed, releasing large amounts of water vapor and carbon dioxide into the early atmosphere. The water cycle and familiar weather patterns began as surface water, oceans, and lakes were heated and then evaporated water into the atmosphere. Erosion of rocks had begun.

The atmosphere of Earth was not made of the same gases as the ones it has today. It most likely was first dominated by water vapor. Then, when much of the water rained out to fill shallow seas, the composition shifted to primarily carbon dioxide. There was at this time no free oxygen and no ozone layer.

Next stop: 60 steps.

**Stop 3 Michigan's oldest rocks - 3.6 billion years before present** Step 100 (10cm)

The oldest rocks found in Michigan are granites and gneisses. They are located near Watersmeet in the western Upper Peninsula. These rocks are from part of an earlier micro-continent. At that time (3.6 billion years ago), most of what we call Michigan had not yet been formed into one piece. Because much of the rock is metamorphic, it is not the original rock of the Earth's crust, but instead was changed by intense heat and pressure. What caused this event is lost to time.

Next stop: 90 steps

**Stop 4 Great Lakes Tectonic Zone - 2.7 billion years before present** Step 190 (19cm)
**GLTZ Diagram & GREENSTONE**

About 2.7 billion years ago, the little granite and gneiss micro-continent was dragged northward by a subducting plate until it crashed into a larger piece of continent called the Superior Craton. As it still happens today, the collision stopped the volcanism along the subduction zone and metamorphosed the lavas and sediments there. These rocks can still be viewed today in and around Marquette. MI. The common name of these rocks is greenstone.

Mountains formed to seal the plate boundary. These early mountains have been worn away and are no longer visible in Michigan, but if you could still see them they would form a line that runs from west to east across the Upper Peninsula. Much of Lower Michigan has not yet come into view- to the South is an ocean.

Next stop: 40 steps

**Stop 5 Snowball Earth - 2.4 billion years before present** Step 230 (23cm)

**GOWGANDA TILLITE PHOTO**

Is it possible that the Earth has experienced a global ice age? Scientists are debating this very question and are looking for evidence that the Earth was almost completely covered with ice and snow, in effect a snowball at various times in the past. We don't know if it was a snowball event, but we do know that at this time, an ice age was ending here in Michigan. What is the evidence? Today, in Ontario, just to our north, we find a rock called Gowganda tillite. It is recognized as glacial material turned to rock and evidence of a past glaciation during this time period. At this time, as the ice age was ending and the oceanic ice was melting, some scientists think this could be related to the development of life on Earth.

Next stop: 10 steps

**Stop 6 Kona Stromatolites - 2.2 billion years before present** Step 240 (24cm)

**KONA DOLOMITE**

During the last half-billion years covered in our most recent walk, the little continent has been eroding and some of its rocks have been deposited in the nearby shallow sea. But the sea contains another surprise- life! The earliest life forms preserved in Michigan's rocks are found in the Kona Dolomite. This rock contains the fossilized remains of mats of stromatolites, also known as cyanobacteria. These primitive forms of blue-green algae floated in mats and built reefs in shallow seas 2.2 billion years ago.

Stromatolites and the other life forms at that time began to modify the Earth's atmosphere. They removed carbon dioxide and produced oxygen. This is an example of interaction between what three "spheres" in the Earth system?

**Next stop: 20 steps**

**Stop 7 Banded Iron Formation - 2.0 billion years before present** Step 260 (26cm)
**JASPILITE**

When stromatolites were active, they removed carbon dioxide from the water and added oxygen to it. This caused dissolved iron to precipitate and form layers of sediment on the seafloor. When stromatolites became dormant, the level of carbon dioxide in the water increased, while the level of oxygen decreased. This caused dissolved iron to remain in solution and chert (a silica rich sediment) would precipitate instead to form layers of red sediment on the seafloor. This process went on for about 400 million years, from 2.2 to 1.8 billion years before present.

Many years later, these banded sediments would become rock, then get metamorphosed into what is now called the Banded Iron Formation (BIF). Another name for this rock is jaspilite, because it contains layers of red chert (jasper) between the iron-rich bands. What three "spheres" are involved in this?

Next stop: 90 steps

**Stop 8 Mid-Continent Rift - 1.1 billion years before present** Step 350 (35cm)
**MID-CONTINENTAL RIFT ZONE DIAGRAM & AMYGDALOIDAL BASALT**

About 1.1 billion years ago, a dramatic change happened in what is now the western Upper Peninsula. Earth's crust began to tear apart and a spreading center started, forming a large rift zone that extended along the Keweenaw Peninsula and through the present position of Lake Superior. It also split down towards the Lower Peninsula, crossing from the Traverse City area all the way to Detroit. This spreading center was much like the current day example of the Great African Rift Valley and the Red Sea. There were volcanoes and hydrothermal areas, and sediments that filled the rift as it formed. The edges of this rift area are now marked by two major faults that run parallel to each other: the Keweenaw Fault and the Isle Royale fault.

For reasons not well understood, the rifting failed, and after a short period of millions of years, it stopped spreading. If it had been successful, much of Michigan would have been prime oceanfront property!

Next stop: 4 steps

**Stop 9 Copper Forms - 1.06 billion years before present** Step 354 (35.5cm)
**NATIVE COPPER**

Late in the rifting event, hot water solutions bearing copper, silver, and other metals rose through cracks and porous rocks and filled them with solid metal. The most abundant of the metals was copper. Native copper occurs in three forms in Michigan's "Copper Country", the area along the Mid-Continent Rift. It is found filling holes in lava (amygdaloidal), filling cracks or zones of weakness in rock (veins), or in the cementing material of sedimentary rocks (the Copper Harbor Conglomerate). What type of copper is this sample?

Next stop: 56 steps

**Stop 10 Explosion of Life - 500 million years before present** Step 410 (41cm)
**CAMBRIAN PALEOMAP & FOSSIL ILLUSTRATIONS**

About 510 million years ago, Michigan was barren rocks and sediments with little signs of life, but as we step forward in time, gradually the sea level begins to rise until all of Michigan is covered with a shallow sea. What caused this rise in sea level? If the rate of sea floor spreading is great, then more heat is involved and the sea floor rises, causing sea level to rise. Maybe global worming was involved. Earth is in a warming period, especially here in Michigan. Michigan is now located just south of the equator, making it a tropical climate.

Then all of a sudden (so to speak) the oceans are teeming with life; the event known as the Cambrian Explosion has just taken place. It is during this relatively short period of time that all of the animal phyla (categories of animal life characterized by unique body plans) either evolved or first appeared. In the eastern Upper Peninsula, sands are washing into the sea. These sands will eventually form the cliffs of Pictured Rocks found on the shores of present day Lake Superior. If you look closely you can see the evidence of the Cambrian Explosion in the fossil remains of trilobites and brachiopods. What caused this explosion? One possible explanation is that oxygen in the atmosphere reached a critical level, allowing an ozone layer to form and animals to construct hard skeletons and shells. There are many other ideas. What do you think?

Next stop: 6 steps

**Stop 11 Michigan Basin Forms - 444 million years before present** Step 416 (41.5cm)
**MICHIGAN BASIN AND CROSS SECTION MAPS**

We seem to be sinking! Remember all that rifting that took place, and those dense basalt flows that are under foot. Could that be dragging us down? And then there was that collision of the plates, when the Proto-Atlantic Ocean floor was subducting under North America, creating mountains to the east. While this is still being debated, we are going under water. The Michigan Basin is forming as sediments flow in over lower Michigan, in time forming sedimentary rocks. This feature can be clearly seen on a geologic map of Michigan's bedrock. The basin might be described as a bull's-eye or a nested set of mixing bowls. Looking at the cross-section, we can see that the layers of sediment get thicker toward the center of the basin, indicating that as sediments filled the basin, it continued to subside.

Next stop: 1 step

**Stop 12 Coral Reefs and Salt - 430 million years before present** Step 417 (42 cm)
**HALITE & PINNACLE REEF DIAGRAM**

Wow, it seems pretty warm, you might even say tropical. That might be because Michigan is still just south of the Equator, and during this warm period, covered by a shallow sea. This is the perfect environment for the formation of coral reefs. They are not only forming around the margin of the basin, but toward the center we find pinnacle reefs. In the deeper water, as the basin subsides, the corals grow taller, keeping pace with sea level. These towers of coral will become limestone and important reservoirs for oil and gas—but that is another story for later.

Right now, let's turn our attention to those reefs that form the margin of the basin. As they continue to flourish, they are cutting off the flow of water from the open ocean. With the warm temperatures, evaporation occurs and our shallow inland sea becomes very salty! Halite precipitates. As the water evaporates, it is replaced by small amounts of ocean water. For a long period of time, this cycle of new ocean water entering the basin, evaporation, and precipitation of salt continued, creating a huge deposit that is mined today from under Detroit. All the while this is happening, the basin continued to sink.

Next stop: 4 steps

**Stop 13 Michigan fossils - 390 million years before present** Step 421 (42cm)
**PETOSKEY STONE, DEVONIAN PALEOMAP, & PETOSKEY PHOTO**

You shouldn't think that we were always under water. Sea level in fact fluctuated and at times, we were high and dry, subject to erosion, with the rock record being worn away, creating unconformities. This had just happened in Michigan, when once again a shallow sea covered the land. With the return of the sea, came an abundance of marine life. An example is the Petoskey Stone, our official State Rock.

Let's take a closer look at the Petoskey stone, which is not a stone but, instead, a fossil colonial coral called hexagonaria. It is called that because of the six-sided shape of the limestone cups. These hexagonal chambers are sometimes referred to as the 'eyes' and they are actually the coral's mouth. When the coral was living, tentacles radiated from its mouth and brought in food. These tentacles are the lines coming out from the edge of the eye of the stone.

Next stop: 3 steps

**Stop 14 Oil and Gas Formation - 360 million years before present** Step 424 (42.5cm)
**OIL AND GAS WELLS IN MICHIGAN MAPS**

We are covered in mud! Silt and clay eroding off the Acadian Mountains in the New England area is settling in a shallow sea that is rich in microscopic plants and animals. There is so much organic material that there is little oxygen, causing the microscopic critters to die off. Mud and organic material plus heat and pressure, and we have a source rock for oil and natural gas. In this case, it is the Antrim shale. All we need now is a reservoir rock and a trap rock. Here in Michigan we have some unique reservoir rocks. What are they? Do you remember the pinnacle reefs? After the oil or gas forms from the organic material, it migrates upward, filling pore space in the rocks. If it is stopped or trapped by a non-porous rock, such as rock salt, then a reservoir forms, just waiting to be discovered by some geologist. Michigan's hydrocarbon resources have provided over a billion barrels of oil and even more natural gas.

Next stop: 4 steps

**Stop 15 Gypsum Forms - 320 million years before present** Step 428 (43cm)
**GYPSUM & EARLY PENNSYLVANIAN PALEOMAP**

On our journey, one theme that should be apparent is change. It is slow, like watching our fingernails grow, but unrelenting change is always taking place. We see the interconnectedness of the Earth systems. A change in one sphere propels change in another sphere. For example, plates continuously move over the surface of the Earth, colliding or rifting with related volcanic activity. This increases the amount of carbon dioxide in the atmosphere and as a result the temperature increases. Glaciers melt and the sea level rises. Once again, Michigan is underwater. These seas are teeming with marine organisms that produce carbonate material, and limestone (calcium carbonate) forms, locking up tons of carbon from the Earth systems. What happens next? Can you think of other examples of interconnected changes taking place?

While it appears that we are experiencing cycles of change, those cycles change. Michigan is underwater, limestone has been forming, but this time as the sea level lowers and evaporation takes place, the chemistry is different. Before we had rock salt forming, but now it is gypsum. Thick deposits of gypsum, that will be mined and used to make wallboard, Portland cement, and Plaster of Paris, are forming in the center of the basin.

Next stop: 2 steps

**Stop 16 Coal Forms - 300 million years before present** Step 430 (43cm)
(YOUR Coal sample) **Michigan Coal Basin Map**

If we look back ten steps, we would be able to see the first forests that were established on land. Remember the Antrim shale that is a source rock for oil and gas. It also contains fossils of callixylon, a primitive tree that looked more like a fern than our modern trees. Stepping forward, plants continue to evolve and during this time flourish. The global climate was cooling and glaciers were forming on Gondwana, down near the South Pole. So what do you think this did to sea level and what happened in Michigan? That's right, the seas recede, and we are left with just a small inland sea in the center of the basin. Though the Earth is cooling, we are still on the Equator and enjoying a tropical climate. These are perfect conditions for the development of swamps filled with giant ferns, club mosses and scouring rushes. These swamps were packed with life, including huge dragonflies and cockroaches. Now imagine what happens as all this woody debris builds up on the floor of the swamp. As time passes and it is compressed, we end up with coal. And that is just what you can find at Grand Ledge, near Lansing, or around Saginaw.

Next stop: 10 steps

**Stop 17 The Lost Interval - 200 million years before present** Step 440 (44cm)

**EARLY JURASSIC PALEOMAP**

All of the continents on Earth are now joined together in one super-continent called Pangaea, and we are right in the middle of it. When Pangaea formed, we were uplifted and are now high and dry, without much chance of adding more layers to the Basin.

We have been traveling through time, "reading" the sedimentary rocks of the Michigan basin, learning from them the stories of Michigan's past—but no more. We can't seem to find any bedrock. It is either missing or buried under glacial till. By studying the drill cores from gas and oil exploration, we learn there are some red beds, (sandstones stained red by iron oxides) which formed in the middle of the basin. They formed as streams flowing over the landscape dropped their sediments. The rest of the rock record is missing. The mountains have long ago eroded away and we are experiencing desert-like conditions. No rocks or dinosaur fossils for us. It is the Lost Interval!

Next stop: 18 steps

**Stop 18 Mastodon Ancestors - 18 million years before present** Step 458 (46cm)

**MASTODON PICTURE**

Ancestors of the mastodon (Michigan's state fossil) first reached North America from Eurasia by crossing the Bering Land Bridge. The American mastodon evolved to not only survive, but thrive in cold climates, where they dominated the ice age landscape in Michigan. This was short lived; they roamed Michigan from around 14,500 years ago until 6,000 years ago when they became extinct.

Next stop: 1 step

**Stop 19 The last BIG Step - 10 million years before present** Step 459 (46cm) (YOUR ruler)

Here we are just one step from the present. Before we continue…turn around and look back in time. Think about the long geologic history of Michigan, and realize that we (*Homo sapiens*) have not appeared on the scene yet. Each step we have taken on this journey equals 10 million years and has been approximately 40 centimeters. So to help us understand this very crowded last step, let's use a ruler and our scale. To review:
One step or 40 cm = 10 million years 4 cm = 1 million years 1 cm = 250,000 years 1 mm = 25,000 years

*A. Last Glacial Advances 3.6 cm from present 900 000 years before present*
Some scant evidence (remember the Lost Interval) indicates we have been experiencing a dry, open prairie-like environment. All that is about to change. If you take a look around Michigan, you will see that the glaciers are advancing. We are not sure just how many times they have advanced, and then retreated, only to advance again, but this happened about every 100,000 years during this time period.

*B. First Homo sapiens 4 mm from present 100 000 years ago*
*Palo Indians in Michigan .48 mm from present 12 000 years ago*
The first Homo sapiens appeared in Europe 100 000 years ago. That puts these humans on Earth at 4 mm from the present. However, the first Palo Indians didn't show up in Michigan until about 12,000 years ago, or .48 mm from the present.

*C. Glaciers leave Michigan .4 mm from present 10 000 years ago*
The glaciers leave Michigan, at least for now. And what was their gift to us… the Great Lakes!

Next stop: 1 step

**Stop 20 Today - Present Time** Step 460 (46cm)

We have now arrived at today. If you were a geologist of the future, how would you describe the state of the Earth today? What will be the next notable step in Michigan's history, and when will it happen? The story continues…

**Stop 4** **Great Lakes Tectonic Zone-2.7 billion years before present**

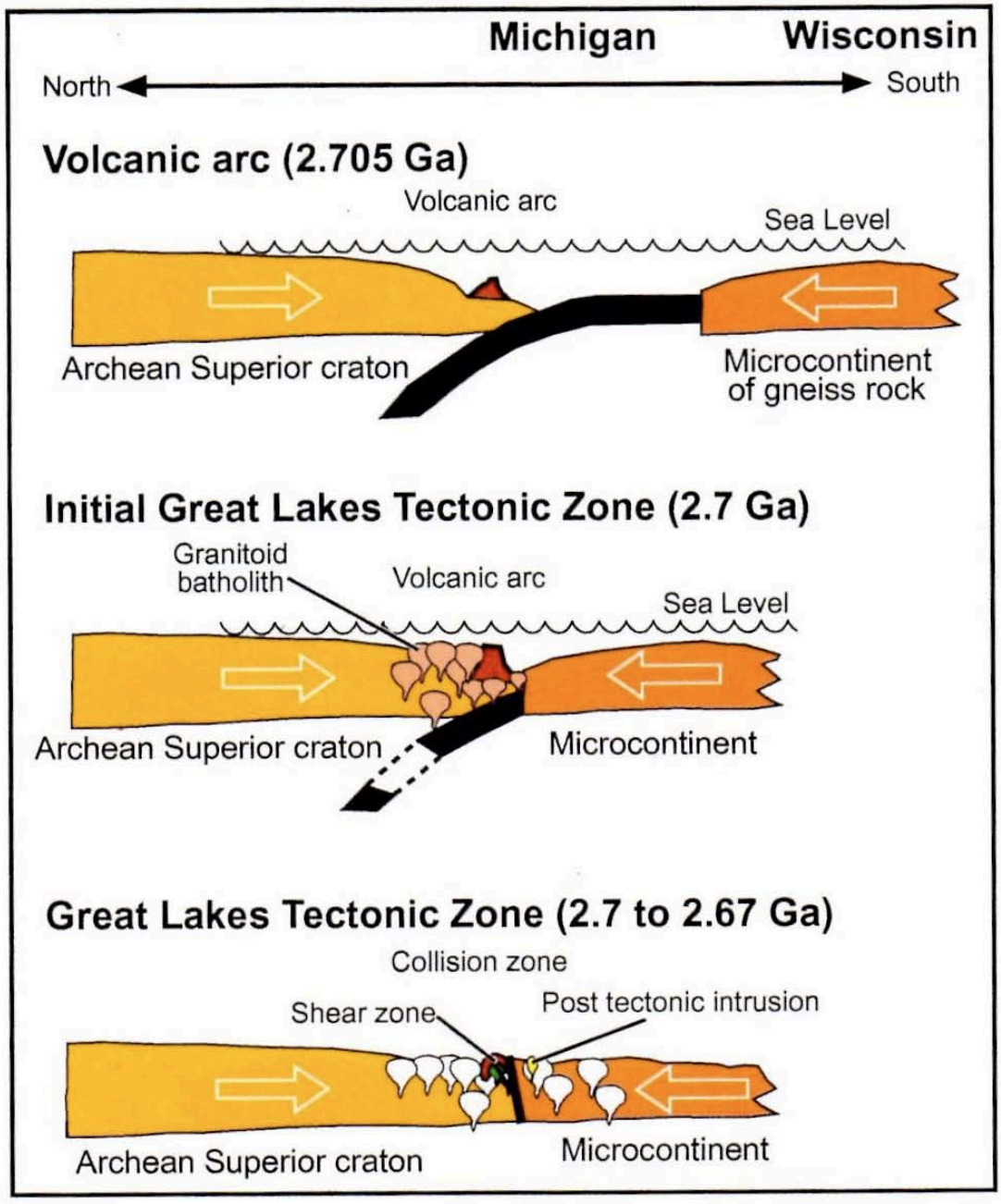



**FIGURE 3.7** Generalized diagrams depicting the succession of events that formed the Archean rocks exposed in the western Upper Peninsula of Michigan.

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Schaetzl, Randall J., Joe T. Darden, and Danita S. Brandt. *Michigan Geography and Geology*. New York: Custom, 2009, p. 31.

## Stop 5 Snowball Earth -2.4 billion years before present

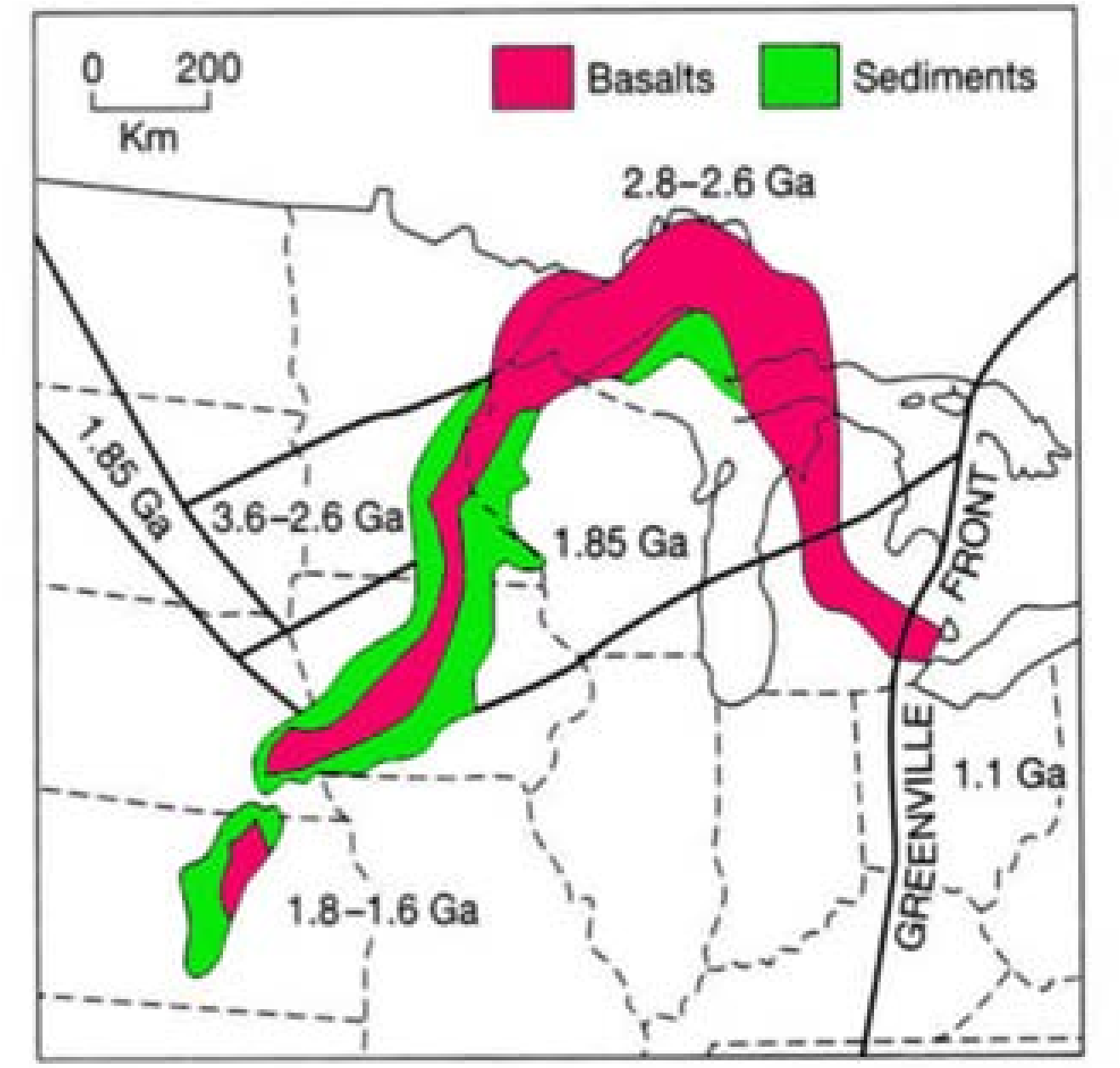
Photograph by Judy Ruddock

An Outcrop of Gowganda Tillite at Elliot Lake, Ontario, Canada

The rock contains large fragments of igneous and metamorphic rocks embedded in a very fine grained clay matrix. The entire rock has been metamorphosed, so that the rock breaks *though* the fragments as easily as it does through the matrix. The unsorted character is evidence that it formed from glacial sediments (till) during a *very old* (Precambrian) ice age!

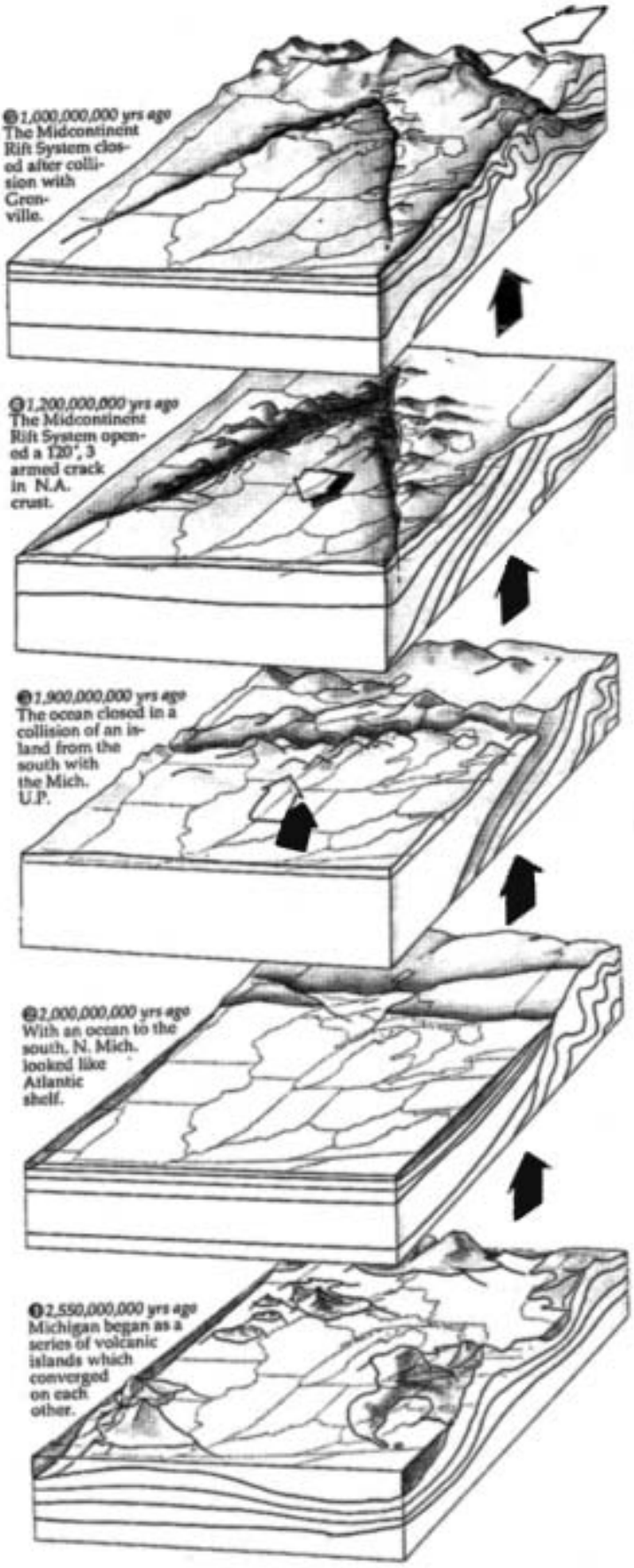
**Stop 8** Mid-Continent Rift-1.1 billion years before present

# The Mid-Continent Rift Zone




Reprinted with permission From: Dr. Randall J. Schaetzl's website, Geography of Michigan and the Great Lakes Region http://www.geo.msu.edu/geogmich/

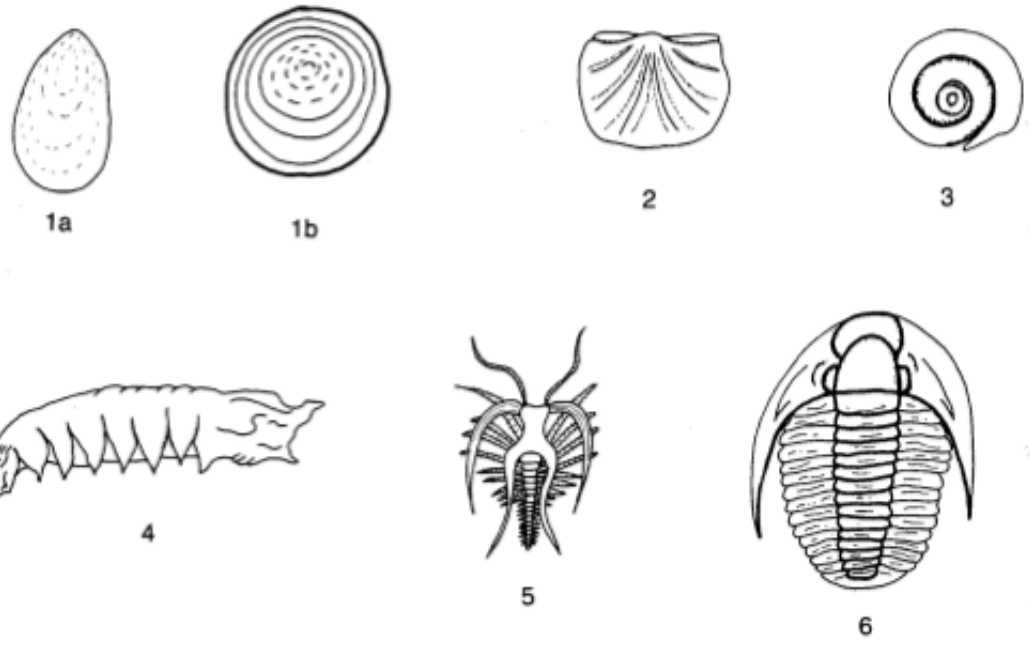
http://www.geo.msu.edu/geogmich/rift_zone.html




A summary sequence of some of the events in the PreCambrian.
Can be used as a supplemental visual for **Stop 8**.

From "Getting a "GLIMPCE" of Michigan's Past" by Karen Litos. Published in Natural Science, Michigan State University, Fall 1988. Reprinted with permission.

# Stop 10 Explosion of Life-520 million years before present




## CAMBRIAN PERIOD

**GENERAL SETTING**

The beginning of the Cambrian is marked by a shallowing of the oceans and the spreading of seas over the continental platforms. The land-masses were stable, while the shallow seas became warmer and more hospitable to life. Massive stromatolites were abundant. An explosion of complex arthropods (trilobites and their kin) led to their becoming the dominant animal during this period, yet they declined in both type and number toward the close of the Cambrian, due to shrinking seas.

**FOSSILIFEROUS OUTCROPS IN MICHIGAN:**

Dickinson County

**FIRST DEVELOPMENT OF:**

- Brachiopods
- Annelid worms
- Trilobitoids
- Trilobites
- Eocrinoids
- Cystoids
- Gastropods (snails)
- Primitive clams
- Nautiloid cephalopods

**SIGNIFICANT FOSSIL FORMS:**

- Massive stromatolites
- Trilobites

**ILLUSTRATIONS:**

1a. Inarticulate brachiopod *Lingula* {1.5x}
1b. Inarticulate brachiopod *Acrothele* {2x}
2. Articulate brachiopod {1x}
3. Gastropod (snail) {2x}
4. Annelid worm {1.5x}
5. Trilobitoid ❁ {1x}
6. Trilobite {2r}

❁ have not been reported from Michigan.

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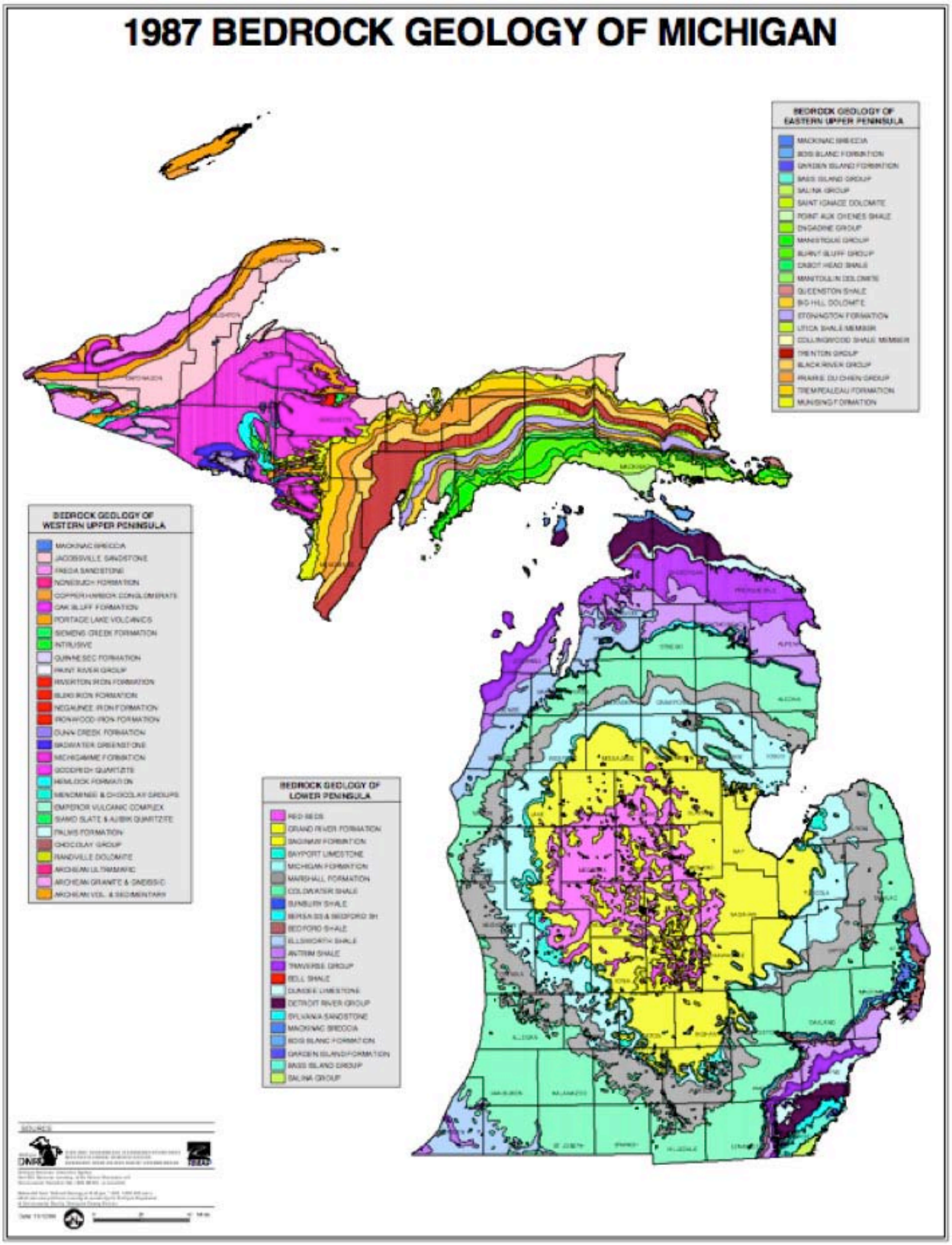
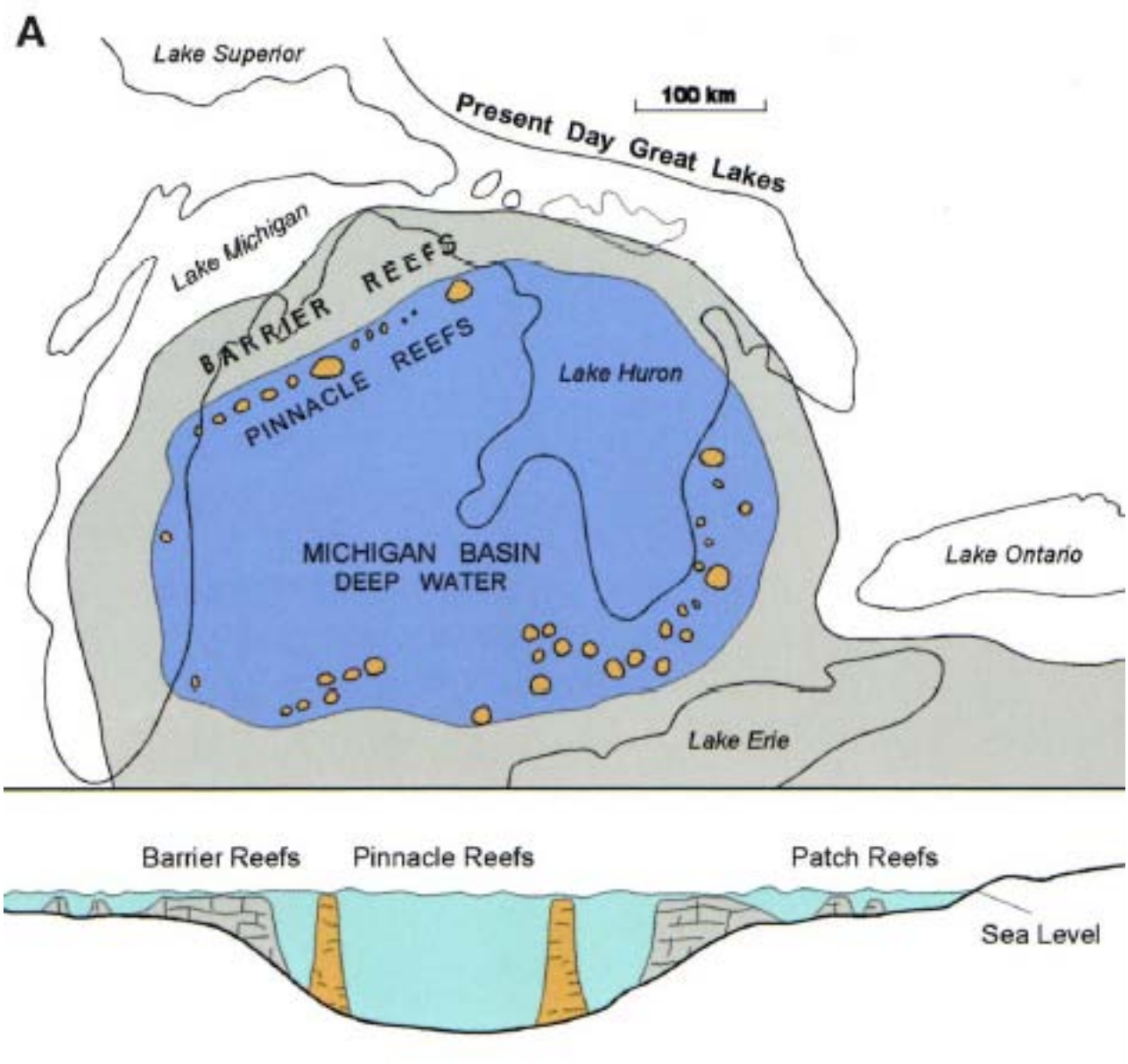
Written, compiled and illustrated by Midwest Mineralogical and Lapidary Society of Dearborn, Michigan As a cooperative Environmental Education Initiative
Published by the Department of Environmental Quality Geological Survey Division — 1994 Made available on the web @ www.deq.state.mi.us/gsd — 2000

## Stop 11 Michigan Basin Forms - 444 million years before present




Reprinted with permission from the Michigan Department of Environmental Quality DEQ Website,
http://www.michigan.gov/documents/deq/1987_Bedrock_Geology_Map_301466_7.pdf

## Stop 12 Coral Reefs and Salt - 430 million years before present



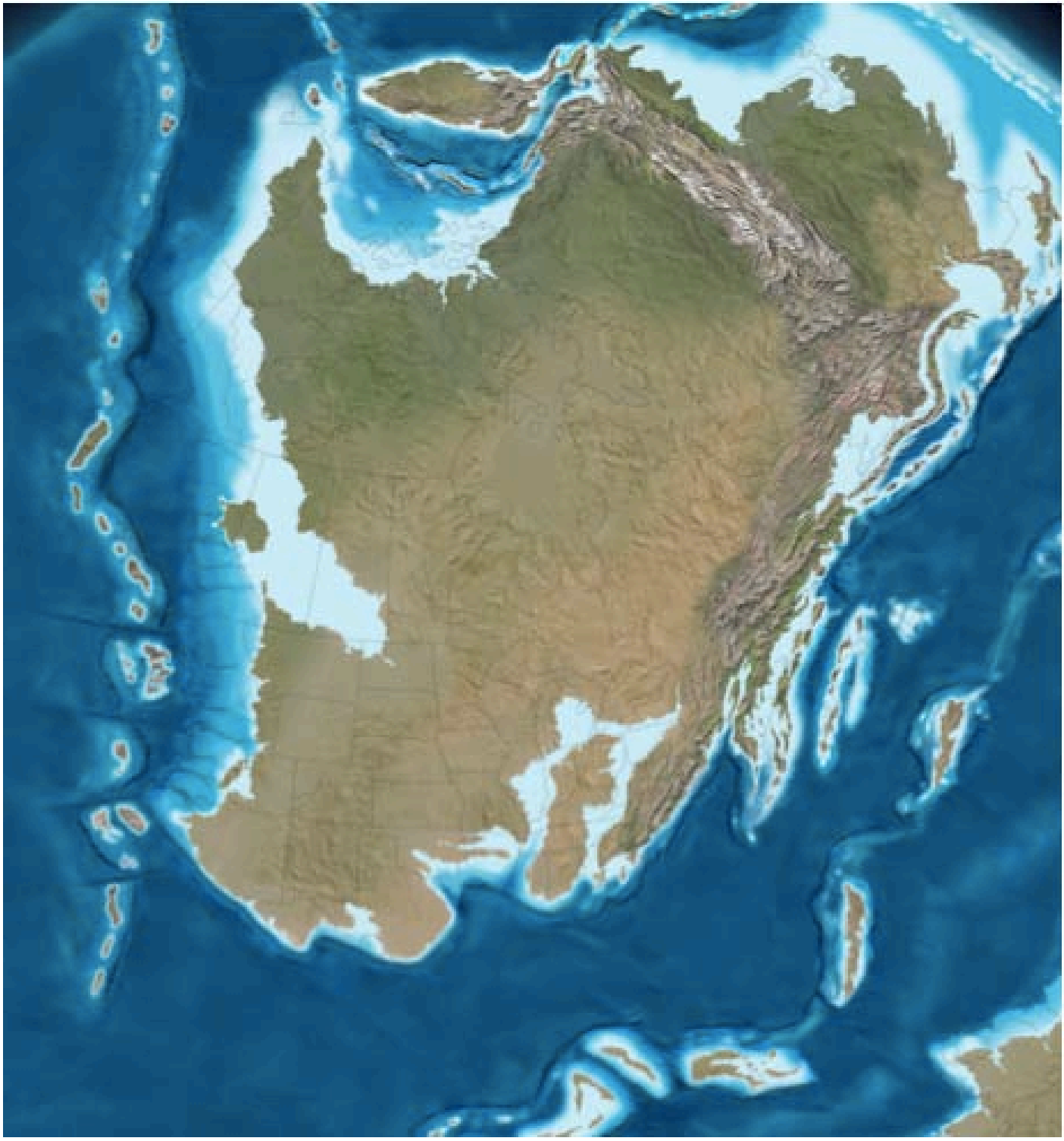

In the Silurian, tranquil tropical seas were re-established in which limestone-forming reefs flourished. The deep Michigan Basin was fringed by different reef types as the organisms adapted to changing water depths.

Reprinted with permission from:
Eyles, Nick. *Ontario Rocks: Three Billion Years of Environmental Change*. Markham, Ont.: Fitzhenry & Whiteside, 2002 p. 136.

# Stop 13 Michigan fossils - 390 million years before present


This is an unpolished, fossilized *Hexagonaria percarinata*, commonly known as Petoskey stone. This sample was found in the Sturgeon River, Cheboygan County. Photo By David J. Fred.

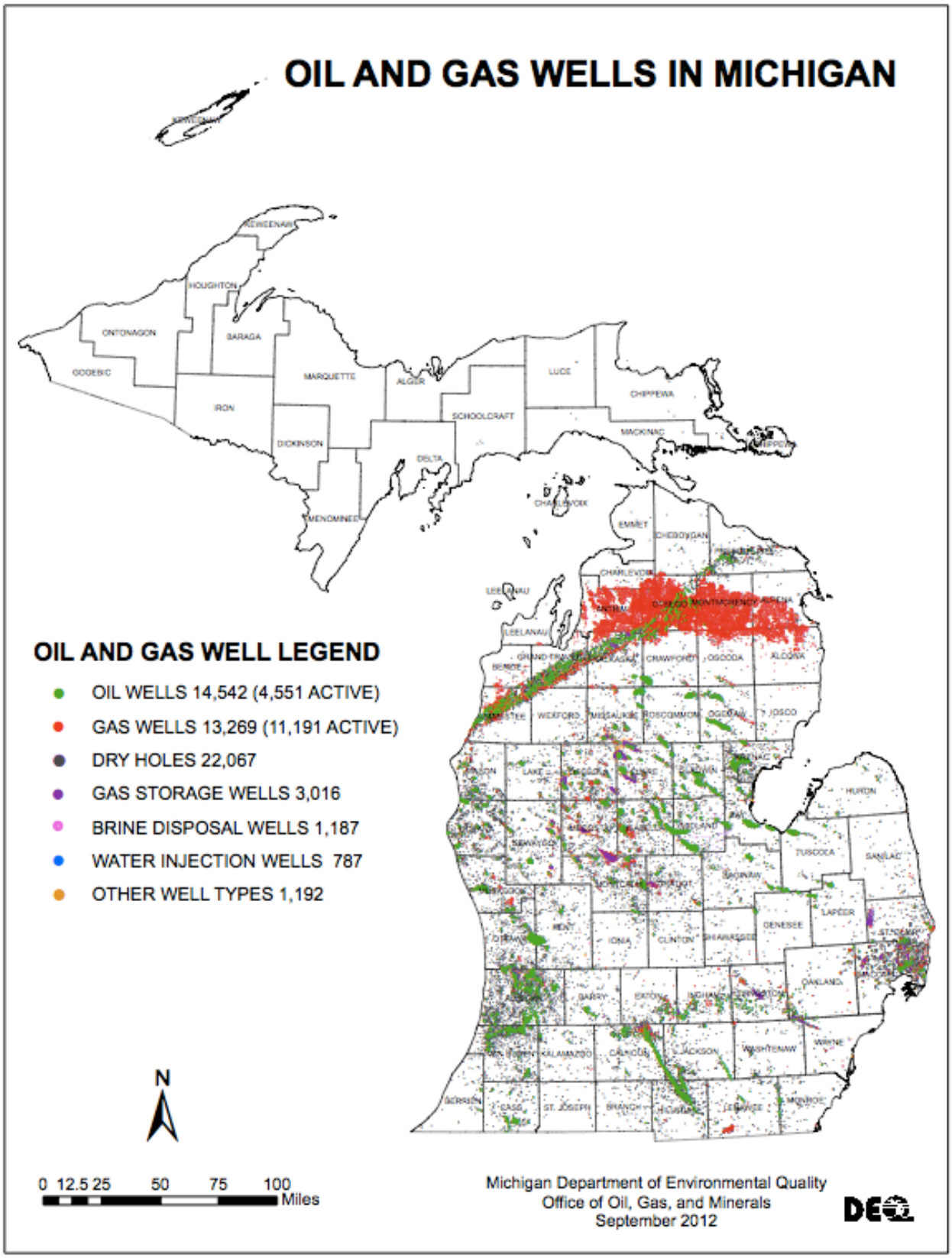
## Stop 13 Michigan fossils - 390 million years before present



**Early Devonian 400Ma**

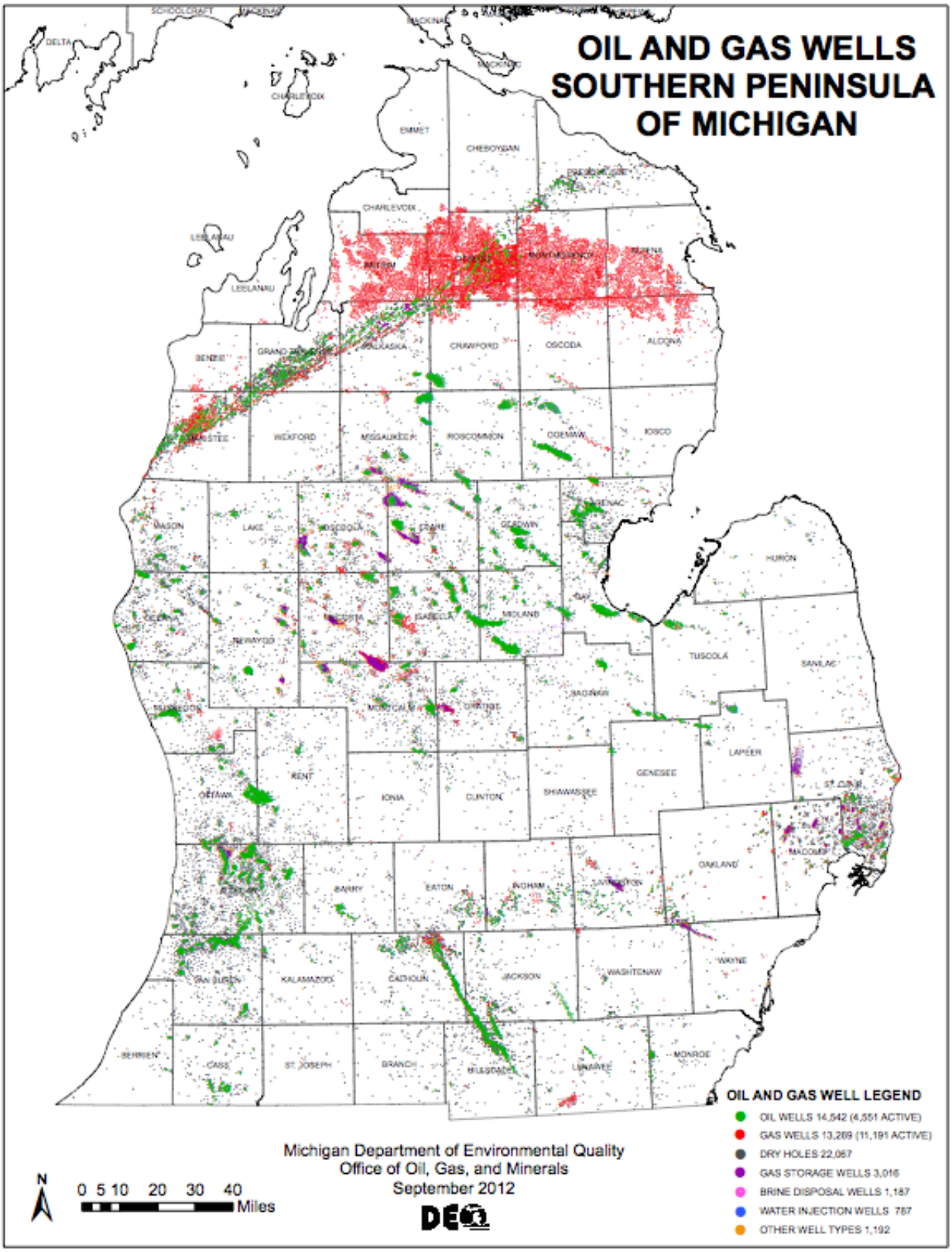
Reprinted with permission from: http://cpgeosystems.com/ **Global and Regional Paleogeography, Ronald Blakey CP Geosystems, Dr. Ron Blakey, Professor Emeritus NAU**

## Stop 14 Oil and Gas Formation - 360 million years before present



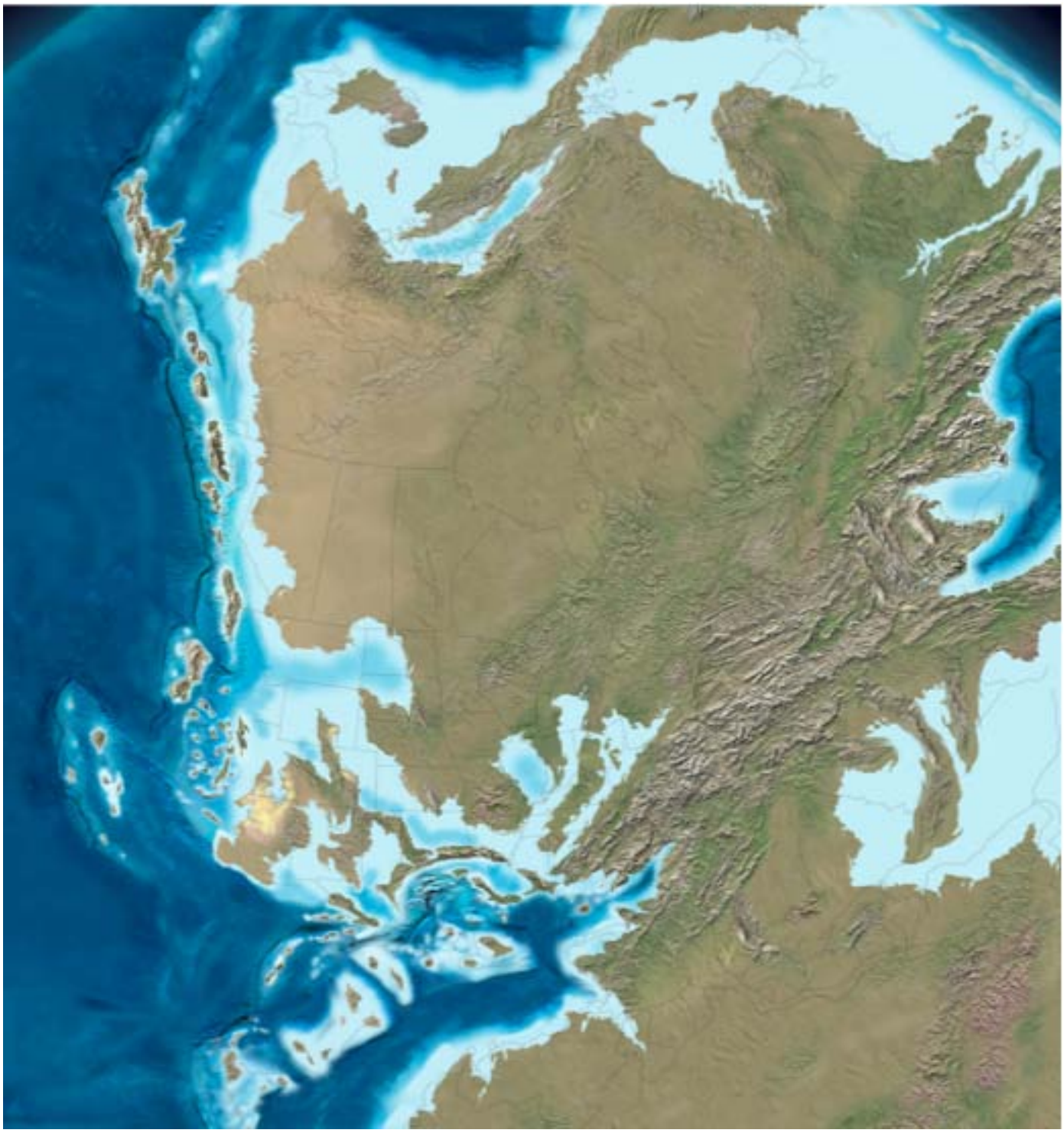

Reprinted with permission from the Michigan Department of Environmental Quality DEQ Website,
http://www.michigan.gov/documents/deq/MICHIGAN_OIL_GAS_MAP_397766_7.pdf

# Stop 14 Oil and Gas Formation - 360 million years before present



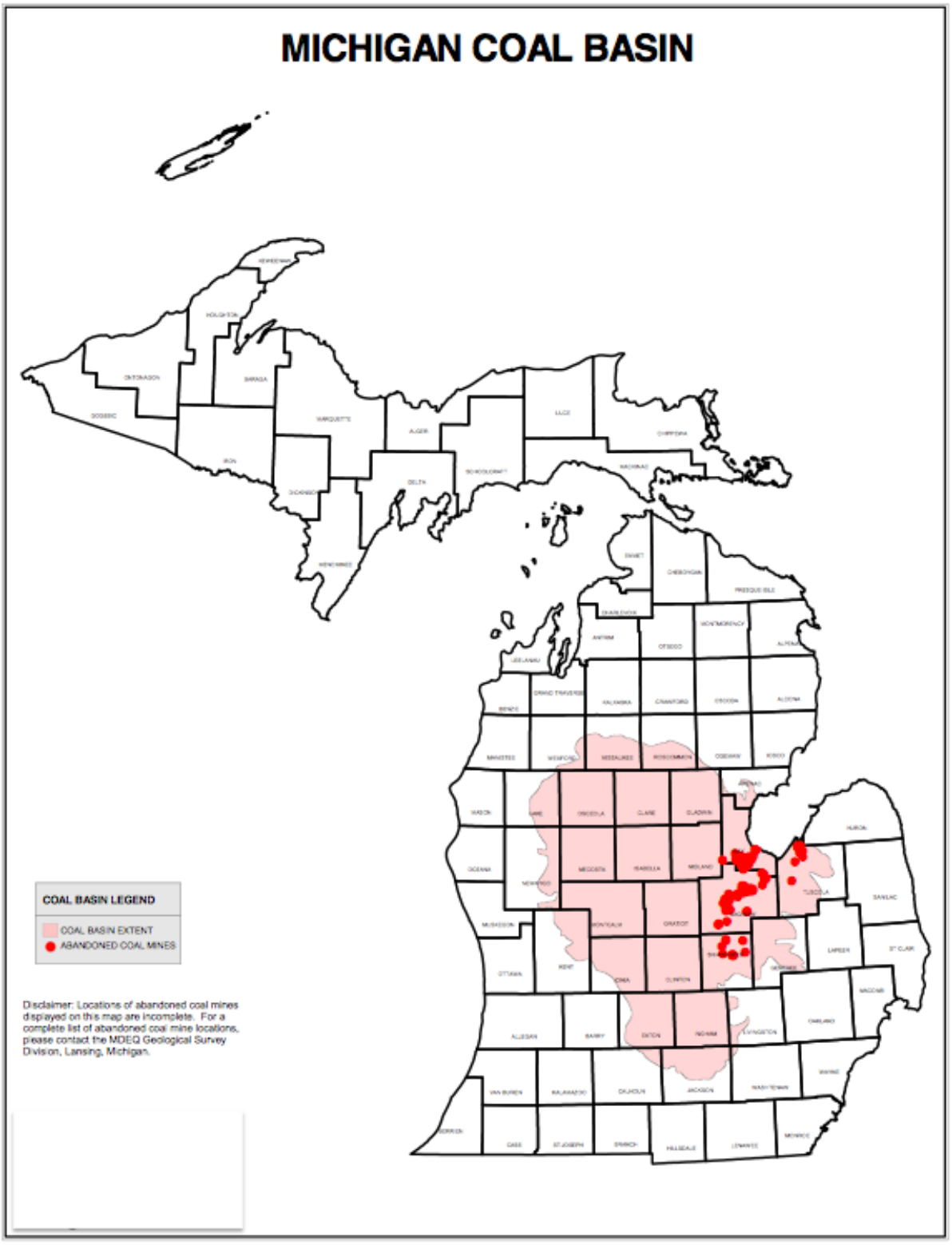

Reprinted with permission from the Michigan Department of Environmental Quality DEQ Website,
http://www.michigan.gov/documents/deq/MICHIGAN_OIL_GAS_MAP_397766_7.pdf

## Stop 15 Gypsum Forms - 320 million years before present



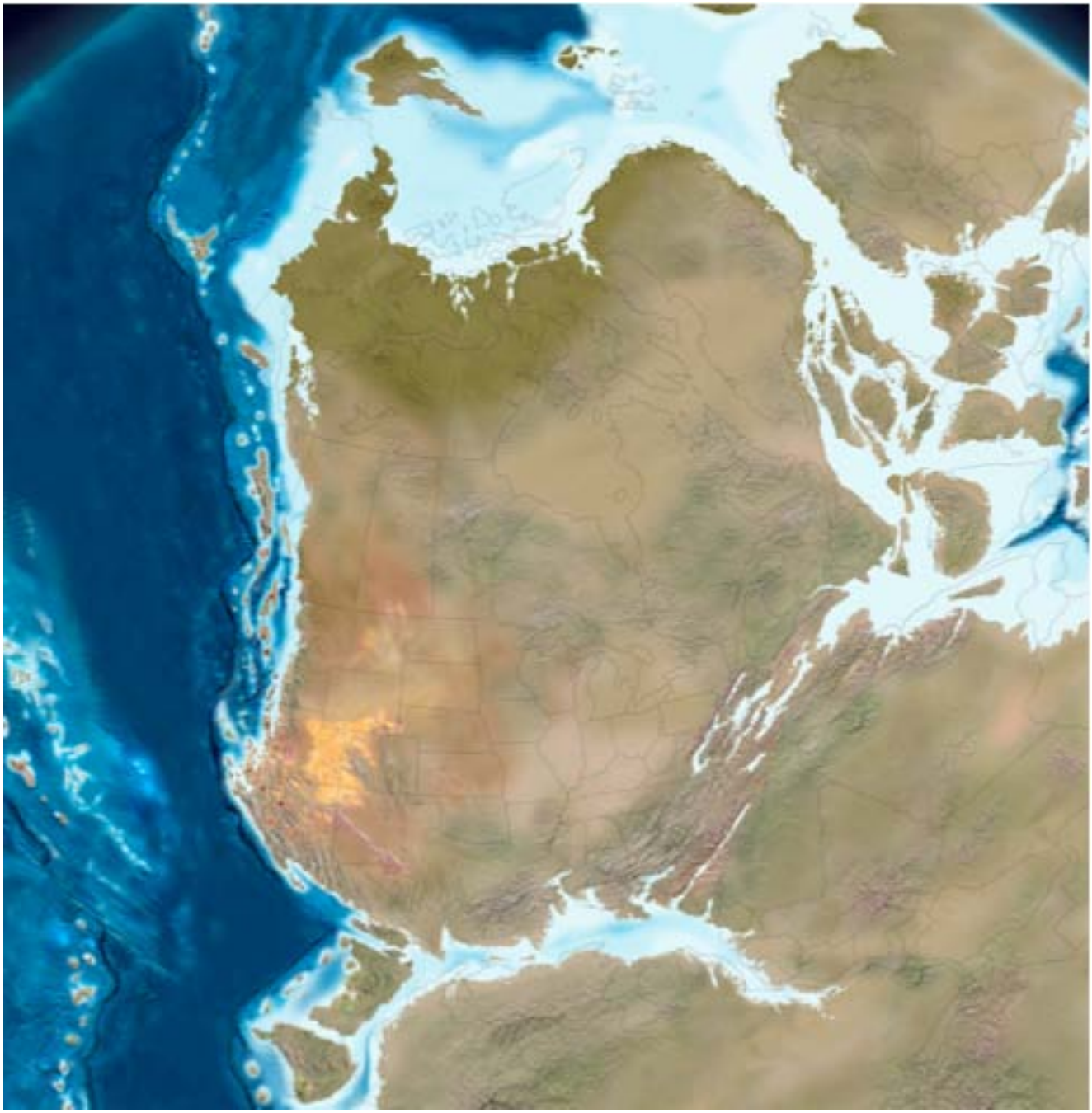
**Early Pennsylvanian 315Ma**

## Stop 16 Coal Forms - 300 million years before present




Reprinted with permission from the Michigan Department of Environmental Quality DEQ Website http://www.michigan.gov/documents/deq/GIMDL-COAL-BASIN_307760_7.pdf

## Stop 17 The Lost Interval - 200 million years before present



**Early Jurassic 180Ma**

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**Background Information and Links to Diagrams Used in this Activity**

A series of plate tectonic snapshots are available at this website: http://www.cpgeosystems.com/nam.html. Several are used in the walk activity.

*Simplified Geologic Time Chart: http://www.michigan.gov/documents/deq/GIMDL-GGGT_307772_7.pdf *used for the follow-up activity

Interactive pdf showing a series of sketches and vignettes from each point of Michigan's history. Some of the maps may be useful for illustrating various time periods in Michigan. http://www.michigan.gov/documents/deq/ogs-gimdl-GTLH_con_307672_7.pdf

Quaternary geology of Michigan color map. This map shows the surface deposits as they are today. http://www.michigan.gov/documents/deq/1982_Quaternary_Geology_Map_301467_7.pdf

The Glacial Lakes around Michigan- a series of printable illustrations dealing with Michigan glaciation. http://www.michigan.gov/documents/deq/GIMDL-BU04pixs_216120_7.pdf

Mastodon image: http://en.wikipedia.org/wiki/File:High_res_mastodon_rendering.jpg

Map of the Michigan coal deposits: http://www.michigan.gov/documents/deq/GIMDL-COAL-BASIN_307760_7.pdf

Sketches of Michigan fossils by period: http://www.michigan.gov/documents/deq/GIMDL-CMG94_307757_7.pdf

Most recent published maps of oil and gas wells in Michigan (2012): http://www.michigan.gov/documents/deq/MICHIGAN_OIL_GAS_MAP_397766_7.pdf

Oil and Gas Well Locations in the Southern Peninsula only map (2012): http://www.michigan.gov/documents/deq/MICHIGAN_OIL_GAS_MAP_LP_397769_7.pdf

Petoskey Stones (illustrated): http://www.michigan.gov/documents/deq/ogs-gimdl-GGPS_263213_7.pdf

Pinnacle reefs and the Michigan Basin: http://www.geo.msu.edu/geogmich/pinnacle-reefs.html

Bedrock geology map of Michigan (color): http://www.michigan.gov/documents/deq/1987_Bedrock_Geology_Map_301466_7.pdf

*Stratigraphic map of the Michigan Basin (color):
http://www.michigan.gov/documents/deq/Bedrock_and_cross_section_301678_7.pdf *
The second page of this document is the blank color bedrock map used for the follow-up activities.

Color stratigraphic column of the Michigan Basin:
http://www.michigan.gov/documents/deq/2000CHRT_301468_7.PDF

Explanation of the Mid-Continent Rift:
http://www.minsocam.org/msa/collectors_corner/vft/mi2a.htm

A generalized map of the mid-continent rift:
http://www.bitterrootresources.com/s/photosandmaps.asp?ReportID=59720

Map of the Great Lakes Tectonic Zone in the Upper Peninsula (see p. 12 of the pdf):
http://pubs.usgs.gov/bul/1904e/report.pdf

## Books


Eyles, Nick. *Ontario Rocks: Three Billion Years of Environmental Change*. Markham, Ont.: Fitzhenry & Whiteside, 2002. (p. 136 has an excellent reef diagram)

Levin, Harold L. *The Earth through Time*. 4th ed. Philadelphia: Saunders, 1994.

Marshak, Stephen, and Donald R. Prothero. *Earth: Portrait of a Planet*. New York: Norton, 2001.

Schaetzl, Randall J., Joe T. Darden, and Danita S. Brandt. *Michigan Geography and Geology*. New York: Custom, 2009.

Ward, Peter Douglas, and Donald Brownlee. *Rare Earth: Why Complex Life Is Uncommon in the Universe*. New York: Copernicus, 2004.