A GUIDE TO GEOLOGY FIELD TRIPS

in Michigan’s Upper Peninsula

Produced by Western Upper Peninsula Center for Science, Mathematics and Environmental Education
Credits

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Introduction

How to Use this Guide
This guide is prepared for educators to aid in using sites in Michigan’s Upper Peninsula for teaching geologic concepts and providing examples of geologic processes. The Upper Peninsula, with its wealth of mines, past and present, offers a wide array of minerals and geologic formations that are sure to intrigue students. Hopefully, a lifelong passion for rocks and geologic beauty will be kindled.

This guide describes publicly accessible sites in the Upper Peninsula that are appropriate to take a class of middle or high school students to visit. The logistical considerations of having 25+ persons in an area, safety, parking a school bus, and the need for bathrooms nearby, are provided to aid the teacher in getting students outdoors to learn about geology.

Geology faculty, grad students, and educators from Michigan Technological University, Northern Michigan University, Tahquamenon Falls State Park, Porcupine Mountains Wilderness State Park, and Fayette Historic State Park have authored the field trip, mine and museum descriptions contained within. We are grateful to them for sharing their time and expertise. Enjoy!

A Guide to Good Field Notes
Notes need to be taken in the field so the geologist and anyone else who reads the notes should have a clear picture of key geologic features found in the field. Key points to remember include:

1. It must be clear.
2. It must be fully detailed.
3. It must be useful for the note recorder.
4. It must be useful for those who were not in the field.
5. It must hit all major geologic features of the region.

Notes should be ordered in the order they are noticed. If a large scale geologic feature stands out, then it should be first in the notes. Relative adjectives are useless in most instances. Either set a scale or give dimensions of features.

Things to put in all notes about all rocks
1. Color (break off a fresh piece for better detail)
2. Shape
3. Size
4. Grain size
5. Hardness
6. Mineral components
7. Major shape of rock unit
8. Minor shape of individual rocks
9. Pictures

Things to put in all notes about geologic features
1. Size
2. Shape
3. 2 or 3 dimensional measurements (trend, plunge or strike, dip)
4. Location
5. Rock unit that is in
6. Orientation
Things to note on **sedimentary** rocks
1. Grain size
2. Color
3. Textural maturity (roundness of grains)
4. Bedding
5. Clasts
6. Hardness
7. Secondary features (ripple marks)

Things to note on **igneous** rocks
1. Grain size
2. Color
3. Texture (smooth or uneven)
4. Hardness
5. Reflectivity
6. Secondary features (pothole, vesicules/amygdules)

Things to note on **metamorphic** rocks
1. Color
2. Texture
3. Grain size
4. Surrounding rocks
5. Relative density
6. Mineralogical features
7. Secondary features

Things to note on **faults**
1. Location
2. Amount of offset
3. Contact region?
4. Rock units it is within

Things to note on **contacts**
1. Size
2. Shape
3. Rock units in contact
4. Type of contact (hidden, faulted, etc…)

Things to note on **bedding**
1. Attitudes (strike, dip)
2. What unit is it in?
3. Vertical thickness of bed

Things to note on **folds**
1. Orientation
2. Location
3. Size of major and parasitic (minor) folds
4. Trend and plunge of fold axis (i.e. does it dip down and die out in some direction?)
FIELD TRIP • Length 2.5 hours for three lessons
Fayette Historic State Park
13700 13.25 Lane, Garden, Michigan 49835 • Tel: (906) 644-2603

Overview
Students will learn the value of geologic resources to humans and the natural world. Geologic based knowledge has long benefited humans from knowing what kinds of stone to make tools out of to extracting chemicals and elements found in particular rock types. Geology based knowledge is utilized in virtually all areas of modern and past life. Fayette Historic State Park is a great example of how humans have benefited from the knowledge gained through geology.

History
In the 1870s through the 1880s, Fayette was a busy iron smelting town. It was named after Fayette Brown, who was the agent from the Jackson Mining Company and visited the site in hopes of locating a smelting facility. In 1867, Fayette Brown traveled to the Garden Peninsula of Michigan's Southern Upper Peninsula and visited the site. He quickly recognized the value of the location with the dolomite cliffs, local area forest, and a protected harbor. He immediately purchased the property from the local farmer and the Jackson Iron Company went to work building the facility. As the facility grew, so did the town. During its peak operation during the 1870s & 80s, the town had a population of about 500 people. Fayette had a hotel, company store, town hall, a boarding house, a doctor, a race track, a school house, a church, and many work sites for the production of iron. It had all the amenities of a modern small town.

During this time there was not a well-connected system of highways, as we know today. The main modes of transportation were either by train or by boat. This contributed to the choice of location.

The smelting facility was closed in 1891. Most of the workers moved to other work locations, while a few remained as commercial fishermen and others to supply the demand for tourism. In 1959, the State of Michigan acquired the property and it became Fayette State Park, where its historical value is being preserved for the public.

Background
The law of superposition states that generally as you proceed down layers of undisturbed rock, the rock gets older. This is a fundamental principle of geology.
Three main rock types are igneous, sedimentary, and metamorphic.  
**Igneous** rock forms from molten magma.  
**Sedimentary** rock forms from deposition of material then pressed under normal pressures and temperatures.  
**Metamorphic** rock is formed under great heat and pressure.

The Niagaran Escarpment is not a fault but instead a “cuesta” (an asymmetrical ridge, with a long gentle slope on one side conforming with the dip of the underlying strata, and a steep or cliff-like face on the other side formed by the outcrop of resistant beds). It is Spanish, etymologically meaning ‘hill, sloping ground.’

The cliffs at Fayette are the Hendricks Dolomite in the Burnt Bluff Group of the Middle Silurian-Niagaran age.

Dolomite is Limestone which had magnesium added after its formation.

**Compositions:**  
Limestone (CaCO₃)  
Dolomite (MgCaCO₃)

The Silurian and Devonian Periods are divisions of the Paleozoic Era. The Silurian Period, 438 to 408 million years ago, is characterized by the appearance of large coral reefs and the diversification of fish species. Life, in the form of primitive plants and insects, made the first brave advances to existence on land. The Silurian was followed by the Devonian Period, from 408 to 360 million years ago. During the Devonian, land plants grew into the first forests, and the first vertebrate animals colonized the land. At this time, North America was attached to Europe in a large landmass situated at the equator.

As early as the mid-1600s, the Danish scientist Nicholas Steno studied the relative positions of sedimentary rocks. He found that solid particles settle from a fluid according to their relative weight or size. The largest, or heaviest, settle first, and the smallest, or lightest, settle last. Slight changes in particle size or composition result in the formation of layers, also called beds, in the rock. Layering, or bedding, is the most obvious feature of sedimentary rocks.

Sedimentary rocks are formed particle by particle and bed by bed, and the layers are piled one on top of the other. Thus, in any sequence of layered rocks, a given bed must be older than any bed on top of it.

This *Law of Superposition* is fundamental to the interpretation of Earth history, because at any one location it indicates the relative ages of rock layers and the fossils in them. Layered rocks form when particles settle from water or air. Steno’s *Law of Original Horizontality* states that most sediments, when originally formed, were laid down horizontally. However, many layered rocks are no longer horizontal. Because of the *Law of Original Horizontality*, we know that sedimentary rocks that are not horizontal either were formed in special ways or, more often, were moved from their horizontal position by later events, such as tilting during episodes of mountain building. Rock layers are also called *strata* (the plural form of the Latin word *statum*), and stratigraphy is the science of strata. Stratigraphy deals with all the characteristics of layered rocks; it includes the study of how these rocks relate to time.
Learning Objectives

Students will be able to:
1. Explain how sedimentary rocks are formed.
2. Identify sedimentary features and depositional environment.
3. Explain the iron smelting process.
4. See how geologic based knowledge is used in everyday life.
5. See example of how the natural world benefits from geology.

Activity

The understanding of geology has played a major role in the location of Fayette as an 1800s smelting town. Geologic based knowledge is used in everyday life and this especially holds true in regards to human uses of limestone. Not only humans benefit from geology, the natural world relies on it.

Length: 2.5 hours for three lessons

Michigan Grade Level Content Expectations

Science:

Earth Science, Solid Earth, Middle School (V.SE.M.2,4,5)
2. Explain how rocks and minerals are formed
4. Explain how rocks and fossils are used to understand the age and geological history of the earth.
5. Explain how technology changes the surface of the earth.

Earth Science, Solid Earth, High School (V.SE.H.3)
3. Explain how common objects are made from earth materials and why earth materials are conserved and recycled.

Materials
- Notebook per student
- Pencil

Procedure

There are 3 components (activities) to this lesson. Before starting, enter the visitor center and watch the five-minute presentation to get an overview of Fayette’s history. The three accompanying activities can take as much or as little time as desired. Exploring the town further in addition to the activities is recommended, but not necessary in understanding the lesson.

Activity 1 (1 hour)

Background Geologic Information for students:
The first component of this lesson is the role of the geologic formation as a value to humans. The Niagara Escarpment, with its dolomite and limestone cliffs played a very crucial role in the location of the iron ore smelting facility of which the town of Fayette was formed around.

There are three main ingredients needed to smelt (process) iron ore into iron. The first ingredient is iron ore. The iron ore used at Fayette was transported from Negaunee, Michigan (where it was mined) to Escanaba, Michigan via the Peninsula Railroad. The ore was then loaded onto boats and shipped across the bay to the port at Fayette. This was an efficient mode of transportation. The
second ingredient needed is charcoal to fuel the furnaces, which transformed the iron ore into molten metal. The charcoal was made on site from hardwood trees from the local forests. The third ingredient is limestone (at Fayette, it is Dolomitic Limestone) to use as a fluxing agent. Dolomite was quarried from the cliffs at the site and crushed. It was added to the ore when placed in the furnace and caused the impurities to rise to the top of the molten metal where it was scraped off (called “slag”) and discarded. The remaining molten metal was poured and allowed to cool and was known as “pig” iron.

Have students explore the town site, reading the informational plaques. Ask them to write a paragraph describing the iron smelting process, including the three main ingredients needed to make iron. Have students re-group to discuss findings.

**Discussion Questions:**
What are the three ingredients in the iron smelting process? Iron ore, charcoal, and limestone.
Why was this locality ideal for Fayette’s industry? Protected, deep harbor, massive limestone bluffs, hardwood forest for charcoal, iron ore nearby, efficient transportation by boat and rails.
What caused the demise of Fayette’s industry? The price of iron dropped dramatically due to the rise of more advanced smelting processes using coal instead of charcoal.

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**Activity 2 (30 minutes)**

*Background Geologic Information for students:*
The second component of this lesson explores the dolomite geological formation. Dolomite is limestone that has been enriched naturally with magnesium after deposition. It is a sedimentary rock and is formed chemically in marine environments. The dolomite cliffs at Fayette (part of the Niagara Escarpment) are the Hendricks Dolomite in the Burnt Bluff Group of Middle Silurian-Niagaran age.
Walk towards the dolomite cliff. On your way, notice how the dolomite was used in the building of the furnace complex. Walk past the furnace complex to the edge of the cliff where the dolomite was quarried. If you look close you can see the remains of a broken drill and other tool bits still in the rock. For a closer look at the dolomite, walk along the base of the cliff, staying as close to the water's edge as possible. The cliffs are steep, so be very cautious and aware — rocks from above could fall at any time.

At the cliff, explain that dolomite is a limestone, which is a sedimentary rock. Then explain how sedimentary rocks are formed. Talk about the chemical composition of limestone (calcium carbonate, CaCO₃) and dolomite (magnesium rich calcium carbonate, CaMg(CO₃)₂) and how it is formed from living organisms. Shallow warm-water seas once covered this area. In these seas there were great barrier reefs, which is where the material for the formation of the limestone came from.

Have students pick up a piece of dolomite that is lying on the ground. Tell them to smell it, crush it, and examine it. Look for features that are indicative of sedimentary rocks such as fossils, mud cracks, and individual lamina (layers of deposition).

**Discussion Questions:**
What do Life Savers candy, electricity, and a steel can all have in common?
They all rely on limestone in their production!

Have students try to think of the human uses for limestone in everyday life and make a list in their notebooks.

Once they have completed their list, go over the Uses of Lime/Limestone/Dolomite sheet with students.
Activity 3 (1 hour)

Background Geologic Information for students:
The final component of this lesson is a lesser-recognized role of the geologic formation as a value to the natural world. Very rare land snails, state threatened ferns, and recently discovered ancient forests all call Fayette's section of the Niagara Escarpment home. Because of the escarpment, the species are able to exist while others of the same species are long gone.

The ruggedness and inhospitable aspects of the escarpment is what actually protects some of the natural world. These same cliffs that make growing so difficult also dissuaded the saws during the logging era that claimed most of Michigan's old growth forests. That is kind of like saying the very reasons that plants and animals have a hard time surviving here are the same reasons they are protected. As you are walking on the nature trail and you happen to see some of the trees that grow right out of the side of the cliff, take a good look at them. Those Northern white cedar trees, *Thuja occidentalis* are part of an ancient forest that still exists. In fact, the oldest known cedar in the park is estimated at 1,414 years old. That means the tree sprouted before the year 600 AD. Considering that most of the forests in this area are second and third growth (very few old growth) and only around 80–100 years old, this makes the age of these trees impressive. What is even more impressive is the size of these trees. One tree measuring only 6 feet tall and seven inches thick was 350 years old. These trees live in an extremely challenged environment that makes growing a very slow process.

With surface temperatures comparable to a desert in the summer and the arctic in the winter, the escarpment is one tough place to live. In fact, you would think that when a tree dies, it would decompose really quickly. The opposite is true. Another fascinating aspect of these ancient forests is the dead trees. Some of these dead trees have been dead for almost 1,000 years. Take a 1400 year-old tree that has been dead for 1,000 years, that means the tree sprouted in the years around 400 BC. This may not sound too impressive, but when you consider that scientists can tell a lot about an area's climate from a tree—that means they have a climate record for this area that goes back 2,400 years. That is impressive!

Not only do these trees benefit from the rugged landscape, there are also three different rare land snails found in the rock crevasses at Fayette Historic State Park. These tiny (<2mm) and rare little snails make their homes in the dolomite cliffs. One of the land snails is more commonly found in the Rocky Mountain Region, one is found in Iowa and Minnesota, and the other is the first documented occurrence in Michigan. These land snails do not have common names but their scientific names are *Vallonia gracilicosta albula*, *Vertigo hubrichti*, and *Vertigo iowanesis*.

This portion of the lesson is a hike along the top of the bluffs to see an ancient forest that has been protected by the geologic feature we call the Niagara escarpment. Start at the Visitors Center and follow the signs to the nature trail. This trail will take you to three overlooks that will give your group one of the best views of the park. Often, we discuss the value of the natural world to us humans, but rarely do we consider the value of the natural world to the natural world. This value is in no place more evident than along the Niagara escarpment and at Fayette Historical State Park.

Summary Assessment Questions for Field Trip
How is the value of geology to humans so prevalent at Fayette Historic State Park?
How does the geologic feature known as the Niagara Escarpment explain the theory of continental drift?
What does the limestone tell us about history?
Pre- and Post Assessment Quiz (Correct answers are underlined)

1. Dolomite is a limestone.  \(T\) or \(F\)
2. Limestone is a sedimentary rock.  \(T\) or \(F\)
3. This area was once covered by warm-water seas and large barrier reefs which contained many corals.  \(T\) or \(F\)
4. Limestone is formed from ground up remains of other rocks.  \(T\) or \(F\)
5. Limestone is used to make sugar.  \(T\) or \(F\)

Post-Site Classroom Activities

- Follow up comparative study on Niagara Escarpment in other locations
- Detailed study and analysis of the mineral composition of dolomite vs. limestone
- A study of common fossils found in the Middle Silurian-Niagaran age limestone and dolomite.

Uses of Lime/Limestone/Dolomite for Activity 2

Steel Manufacturing  Water Treatment
Soil Stabilization  Rubber Products
Feed Supplements  Agricultural Liming
Soap Manufacturing  Adhesives
Ore Refining  Chemicals
Sewerage Treatment  Petroleum Refining
Industrial Waste Treatment  Tanning
Paint Manufacturing  Construction (buildings, highway, and railroad)
Glass Manufacturing  Paper Manufacturing
Treatment of fruit  Making of Baking Powder
Gelatin  Sugar
Tortillas, corn chips,  Processing Dairy Products
Swimming pool cleaners  Emission control in coal fired power plants

References/Websites:
Geology of Michigan John A Dorr, JR. and Donald Eschman
Fayette Historic Townsite 2nd edition; Michigan Historical Center, Michigan State Historical Society.
Overview
Students should be introduced to the rock cycle, plate tectonics theory, and glaciers and glaciation prior to participating in this field trip. During the field trip, students are encouraged to take notes, make sketches of the bedrock and surrounding landforms, and take photos of each site. The various stops provide examples of bedrock geology (erosion, sedimentary rock formation, fossils, isostatic rebound uplifting) and glacial geology (fluvial rivers, outwash, drumlins, glacial till, moraine, Lake Superior stages, glacial erratics). Students observe several local rock types:
- Allouez Conglomerate
- Copper Harbor Conglomerate
- Jacobsville Sandstone
- Portage Lake Volcanics

Learning Objectives
Students will be able to:
- Describe and identify surface features using maps.
- Explain how rocks are formed.
- Explain how rocks are broken down, soil is formed and surface features change.
- Explain how rocks and fossils are used to know Earth’s age and geological history.
- Explain how technology changes the surface of the earth.
- Explain the surface features of the Great Lakes region using Ice Age theory.

Michigan Grade Level Content Expectations
Science
Earth Science, Solid Earth, Middle School (E.SE.M.1-5)
1. Describe and identify surface features using maps
2. Explain how rocks and minerals are formed
3. Explain how rocks are broken down, how soil is formed and how surface features change
4. Explain how rocks and fossils are used to understand the age and geological history of the Earth.
5. Explain how technology changes the surface of the earth.

Earth Science, Solid Earth, High School (E.SE.H.1-2)
1. Explain the surface features of the Great Lakes region using Ice Age theory.
2. Use the plate tectonics theory to explain features of the earth’s surface and geological phenomena and describe evidence for the plate tectonics theory.

Materials Needed
- Digital camera(s)
- Notebooks — one per student
- Pencils, pens
- Mineral Identification Guide for the Copper Country’s Poor-Rock Piles brochure by Susan Robinson
- Is It An Agate by Susan Robinson
- Geologic Map of the Keweenaw
Keweenaw Geologic History
The geology of the Keweenaw begins with a mantle hotspot plume around 1200 million years ago. The plume raised the land which caused stress fractures and faults to create a boundary around the region. As the hotspot continued, the crust broke open to create a mid-continent rift. Lava flows poured from this rift creating the various volcanics within the region. In between flows, erosion would drop various other rocks in between the lava flows. This created the trapped conglomerate layers within the volcanics. After the volcanism stopped, shales and sandstones deposited over the region. The region then sank slightly with the weight of the rocks and weakness caused by the faults. A continental collision from the southeast then tilted the rocks and created more fractures allowing the mineralization of the copper famous to the region. Around 500 million years ago, seas rose over the region depositing limestone and other sedimentary rocks. The most recent geologic event was a series of glaciations over the past few million years. This scraped most of the limestone away, carved Lake Superior out of the weak sediments that lay on top of the volcanics, and exposed the lodes of copper.

Field Trip Itinerary

Stop 1 • 1 hour • Keweenaw Fault at Hungarian Falls (Tamarack City, MI)

<table>
<thead>
<tr>
<th>Stop Time</th>
<th>Fees</th>
<th>Parking</th>
<th>Site Capacity</th>
<th>Restroom Facilities</th>
<th>Handicap Accessible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td>NO</td>
<td>YES</td>
<td>Flexible</td>
<td>NO</td>
<td>NO</td>
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Driving Directions
From Houghton — Cross the lift bridge from Houghton to Hancock. Take an immediate right onto M-26 heading east towards Ripley. Drive approximately 8 miles to Tamarack City. Turn left (north) onto 6th Street and stay to the left at the fork (Golf Course Road). Follow the road about ½ mile to the top of a steep hill. Park on the right side of the road opposite a yellow gate. Please do not block the yellow gate.

Geology

Rock types: Copper Harbor Conglomerate, Portage Lake Volcanics, and Jacobsville Sandstone

Geologic Feature: Keweenaw Fault

What you will see…
Follow the path that begins at the yellow gate beyond the reservoir up stream to the Upper Hungarian Falls. Please take caution, staying on the trails up on the ridge, not going down into the ravine. Once at the upper fall, it is possible to traverse down to the base of the falls, but do so very carefully. It is very steep and there is loose soil. It is possible to view the geology from up on the ridge without going down to the base of the falls.
The trail to the Upper Hungarian Falls is composed of Jacobsville Sandstone. The falls are composed of Copper Harbor Conglomerate and Portage Lake Volcanics (see Keweenaw Introduction for relative ages). The Copper Harbor Conglomerate is located at the large fall drop and the Portage Lake Volcanics is located slightly downstream from the base of the big falls at the smaller falls/rapids. Beyond the Portage Lake Volcanics is the Jacobsville Sandstone (the trail to the falls). The Keweenaw Fault is responsible for juxtaposing the old units (Copper Harbor Conglomerate and the Portage Lake Volcanics) next to the younger rocks (Jacobsville Sandstone). At this location, the Keweenaw Fault runs between the Portage Lake Volcanics (seen at the rapids) and the Jacobsville Sandstone (downstream). If you are standing between the Jacobsville Sandstone and the Portage Lake Volcanics, you are standing on the fault zone.

**Hungarian Falls Activity**

1. Have students sketch the Upper Hungarian Falls in their journals. Tell them to describe the three rock types (units) that they see, emphasizing the physical differences between rock types. Ask students to brainstorm the geological processes that could have formed Diagram C above.

2. When students are finished with their drawings, discuss the three types of rock units, their ages, and the sequence of geologic events that resulted in the formation of Hungarian Fall.

3. Can students point out the location of the Keweenaw Fault? Have them sketch in the Keweenaw Fault on their drawings. Ask students to give reasons why they chose to put the fault where they did on their sketches. Ask students to hypothesize what this area looked like before the fault and what the vertical sequence must be (see “Keweenaw Introduction”).

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**Block Diagram showing Keweenaw Fault.**

A. Original sequence of rock units with Portage Lake Volcanics at the bottom, Copper Harbor Conglomerate in middle, and Jacobsville Sandstone on top.

B. Keweenaw Fault displaces rock units, juxtaposing old units next to young units.

C. Jacobsville Sandstone erodes away due to glaciation; continued stream erosion leads to what you see now at upper Hungarian Falls.
Stop 2 • 15–30 minutes • Glacial Groves at C-L-K Elementary Playground (Calumet)

<table>
<thead>
<tr>
<th>Stop Time</th>
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<th>Site Capacity</th>
<th>Restroom Facilities</th>
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</tr>
</thead>
<tbody>
<tr>
<td>15-30 min.</td>
<td>NO</td>
<td>YES*</td>
<td>Flexible</td>
<td>YES*</td>
<td>YES</td>
</tr>
</tbody>
</table>

Parking* — If school is in session, please call the C-L-K Elementary School in Calumet at (906) 337-0311 to make parking and visitation arrangements.

Restrooms* — Restrooms are available within the Elementary School. Stop at the school office first.

Driving Directions
From Stop 1 — Return to M26 and turn left (northeast) back onto the highway. Follow M26 through Lake Linden (the highway turns left in town, follow the M26 signs). Continue on to Laurium and Calumet. The road intersects US 41 at a stoplight. Turn right (north) onto US 41. At the second blinking light, turn left (west) onto Red Jacket Road. Enter the Calumet Schools (CLK Schools) on the right (north). Follow the drive to the parking lot behind the school and near the playground.

Geology

Rock types: Portage Lake Volcanics.
Glacial Geology: Glacial Groves

What you will see...
From the parking lot, walk the sidewalk between the school and playground towards the basketball court and soccer field. At the end of the playground (Northwest end of the school) are exposed outcrops of basalt in a grassy area. The glacial grooves exposed here were caused by rocks at the bottom of the glacier being dragged over the basalt, carving groves into the bedrock. The polished appearance of the basalt is due to finer grained material in the glacier passing over the rock.

Ask students:
What causes glacial groves?
Why are the groves all in the same direction?
How thick do you think the glacier must have been to make this feature? (In many areas over the Keweenaw Peninsula, the glacier was over 3000 meters thick!)
Stop 3 • 30 minutes • Wolverine Mine Poor Rock Piles & Amygdules

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<th>Stop Time</th>
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<th>Restroom Facilities</th>
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<td>YES*</td>
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Driving Directions
From Stop 2 (Calumet) — Head North (turn left out of CLK Schools) onto US 41 to the town of Kearsarge. Just after the Veterans Memorial (a boat made of rocks) and before the Wolverine Market, turn right onto Smith Ave. Continue through the residential area until you see an old building made of stone on the right. There is a gravel road just beyond this building on the right, which leads into the rock pile area. There is plenty of room to turn a school bus around here.

Geology
Rock types: Portage Lake Volcanics (amygdaloidal basalt)

What you will see…
The rock piles are remnants of old mining operations (NOTE: collecting is allowed at this site!) The rock types are typically massive basalt and amygdaloidal basalt. Amygdules are formed when gas bubbles become trapped in the top of the lava flow, leaving spaces or vesicles in the basalt that later can be filled with mineral deposits. Calcite, quartz, epidote, copper and other minerals are found within the amygdules. These rock piles are extremely steep. Climbing the piles is strongly discouraged. Allow students to only collect rocks from the base of the rock piles. These rocks were piled here as they were removed from the mine, because they did not have copper in them—hence the name “poor” rock. However, if the mine manager was not feeling cooperative that day, he directed the copper-bearing rocks to this “poor” rock pile, too! Can you find any rocks with copper?

Poor Rock Pile Activity
Have students explore the rock piles and try to find and identify the minerals that fill the amygdules. For a more advanced group, have students make rock descriptions and sketches in their journals.
Stop 4 • 30 minutes • Bumbletown Hill & Allouez Mine Specimens

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Contact Information: Please call Brian Sickler, Keweenaw Specialty Wood Products (906) 337-5496, in advance to obtain permission to explore this site.

Driving Directions
From Stop 3 — Return to US 41 and travel North (right off Smith Ave.) to the town of Allouez. Take a sharp left (west) onto Bumbletown Road directly before the BP Gas Station. Travel through a residential area. Just prior to ascending a hill after 6th Street, there will be a two-track gravel road on the right (north side) of the road. If traveling in a school bus, park on the side of Bumbletown Road near the gravel road entrance.

Geology
Rock types: Allouez Conglomerate — an interflow sedimentary layer within the Portage Lake Volcanics

What you will see…
Follow the two-track gravel road a short distance. The road winds back to an open area containing the rock piles.

The rock piles are remnants of old mining operations (collecting is allowed at this site!). The rock piles consist of Allouez Conglomerate. Minerals, such as chrysocolla (a hydrous silicate of copper and is blue to green in color) and copper can be found within conglomerate specimens. The Allouez Conglomerate has many jagged edges and care should be taken when navigating rock piles.

Allouez Mine Activity (variable time)
Have students explore the rock piles and try to find and identify the minerals that are within the Allouez Conglomerate. For a more advanced group, have students make rock descriptions and sketches in their journals. How are these rocks different from the poor rock pile at Mohawk? How are they similar?
Stop 5 • 1–2 hours • Hunter’s Point Cobble Beach

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<tr>
<th>Stop Time</th>
<th>Fees</th>
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**Driving Directions**
*From Stop 6* — Follow US 41 north to Copper Harbor. At the flashing stoplight, turn left (west) onto M26. Follow M26 out of town to the Copper Harbor Marina (less than a half mile). The marina will be on the right (north) side of M26. Park in the marina parking lot.

**Restroom Facilities** — Indoor unisex facility available during the boating season; outdoor facilities are available. Copper Harbor Community Center (located in town) also has facilities.

**Trail Information** — A well-established hiking trail is in place. The trailhead begins at the west edge of the parking lot. The trail is often muddy.

**Safety Concerns** — The trail is winding with tree limbs exposed along the route. Caution should be taken when navigating the trail. Be prepared for a one-mile hike.

**Ecological Considerations** — Care should be taken to stay on the well-established trail to prevent damage to surrounding vegetation.

**Geology**
- **Rock types:** Copper Harbor Conglomerate and Lake Shore Traps
- **Current geologic processes:** Beach deposition

**What we will see...**
Follow the trail from the west side of the parking lot along the harbor. The trail will split after about a quarter mile. Take the trail to the north along Lake Superior to the cobble stone beach. This roundtrip hike will take one hour or longer, depending upon how long students engage in the activities.

![Cobble beach, Hunter's Point looking west](image-url)
There are several outcrops along the shore that can easily be seen at the trail’s end. These outcrops include massive basalt flows, vesicular basalt, and Copper Harbor Conglomerate.

The massive basalt flows occurred during the same period of the Copper Harbor Conglomerate deposition. The basalt flows that are inter-bedded with the conglomerate are called the Lake Shore Traps. In geology the term ‘Traps’ is used to describe rock formations, like this one, which have a stair step like appearance. Massive basalts layers are far more resistant to erosion than the Copper Harbor Conglomerate or vesicular basalts and often form the points or ridges seen along the shore. The more easily eroded rocks form bays. These differences in durability are responsible for the shape of Copper Harbor along with much of the shoreline along the northwestern Keweenaw Peninsula. (At Stop 6, Brockway Mountain Overlook, this concept is elaborated upon as the shape of Lake Superior shoreline can be observed.)

The massive basalt occurs at the bottom to upper middle of a lava flow. Towards the top of a flow, gas bubbles have risen and settled. This zone of a flow is called vesicular basalt due to the bubbled appearance of the basalt. Later, long after the lavas hardened, the vesicles were filled in with minerals, such as calcite, chlorite, prehnite, epidote, quartz and even copper. Once vesicular basalts are filled with secondary minerals they are referred to as amygdaloidal basalt. On top and below each flow of Lake Shore Traps is the Copper Harbor Conglomerate.

**Hunters’ Point Activity**

1. Have students explore the beach outcrops and make detailed sketches and descriptions of what they see in their journals. Rock collecting at this site is allowed, so encourage students to gather samples that are representative of the outcrops they noted in their journals.

2. After it seems students had adequate time, regroup. Have students make piles of the rock samples they collected according to the location of the outcrop they represent. This will create a mini version of the outcrops along the beach at a smaller scale.

3. Discuss the characteristics of each type of outcrop that was observed and recorded in the journals. At this point, students should be able to draw conclusions about the Lake Shore...
Trap flow orientation, locating the top and bottom of the lava flow. Remember that all the units have been tilted from their original horizontal orientation as they make up a limb of the huge syncline that dips below Lake Superior.

4. This location also shows active deposition. The cobbles on the beach, eroded by glaciers, wind and wave action, are the beginning of a new conglomerate unit. Ask students if they were to come back to this area a million years from today what they would find. They should draw conclusions about the cobbles turning into a conglomerate unit, continual deposition of more cobbles, and erosion of the older rocks. Make connections between the current beach processes and deposition and the Copper Harbor Conglomerate unit, which was formed by an environment very similar to the beach today.

Stop 6 • 30 minutes • Brockway Mountain Viewpoint

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Driving Directions
From stop 6 — Almost directly across from the Copper Harbor Marina entrance on M26 is Brockway Mountain Drive. Follow the road about 4 miles to the viewpoint where there is a gift shop and rustic bathrooms. Be sure to follow the one-way loop that circles the gift shop. Park along the side of the loop.

Geology

**Rock types:** Copper Harbor Conglomerate, at the viewpoint. It is also possible to observe Portage Lake Volcanics and Lake Shore Traps in the distance.

**Geological Processes:** Keweenaw geology, including faulting, folding, and erosion. *This is the best stop to get a “big picture” view of what shapes the Keweenaw.*
What we will see...
From the far end of the one-way loop, look west down the Keweenaw Peninsula. Notice the gradual slope of the west side of the hills and the steep slope to the east side. The Keweenaw Peninsula is the limb of a large syncline underneath Lake Superior. The other limb is exposed at Isle Royale and dips in the opposite direction. From this viewpoint, it is possible to see how the limb has been faulted (as shown in the picture below). Notice the trend of the hills and that they form several ridges running in the same direction, parallel to the lakeshore. Observe the lakes and harbors, which are formed and shaped by differential weathering of the Lake Shore Traps. Softer materials, usually the basaltic flow tops have eroded away. These become the bays in the harbor, while the more resistant rock remains to become points or ridges. Lake Bailey to the west is elongated, also parallel to the hills and lakeshore.

Brockway Mountain Activity (approximately 30 minutes)

1. Have students sketch the topography, including the hills, lakes, and lakeshore. Tell them to label where the rock units (Copper Harbor Conglomerate, Portage Lake Volcanics, and Lake Shore Traps) and geological features are located.
2. Ask students:
   - What rock unit makes up Brockway Mountain? (Copper Harbor Conglomerate)
   - Where are the faults located and how can they tell?
   - How must the other side of the syncline at Isle Royale look?
   - What rock units are present at the other side of the syncline? (The units dip underneath the lake, so the same units would be exposed at Isle Royale that are exposed here!)

Stop 7 • 30–60 minutes • Lakeshore Traps at Esrey Park

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Driving directions
From stop 6 — Turn around and head North on M26 towards Copper Harbor. Follow M26 for less than 1 mile to Esrey Park on the left (north) side of the road. There is plenty of parking and picnic tables. This is an excellent place to stop for a group lunch.

*Accessibility — Although the path to the top of the outcrop is not handicap accessible, it is possible to view the lakeshore traps from the parking lot.

Geology
Rock types: Lake Shore Traps, the youngest known volcanic flows in the Keweenaw igneous rocks

What we will see...
From either end of the parking lot, take the footpath that leads up the huge Lake Shore Trap outcrop located between the parking lot and Lake Superior. Once on top of the outcrop from the path, several other Lake Shore Traps are visible on the shore and in the lake. Rock collecting is permitted at this site.
Esrey Park Activity #1 (20 minutes)

1. Have students try to identify as many individual flows as they can see (there are a lot!).
2. Tell students to sketch the flows in their journals, clearly identifying one flow from another. Some flows have small outcrops, while others outcrop for quite a distance along the beach. These flows are responsible for the shape of the shoreline, so make sure the students are drawing how the flows shape the beach.
3. Ask Students:
   - What type of rock lies between the Lake Shore Traps? (Conglomerate)
   - Why are the Lake Shore Traps, not the conglomerate, sticking out of the water and shaping the shoreline? (The Lake Shore Traps are more resistant to weathering.)

Esrey Park Activity #2 (10 minutes)
From the east end of the parking lot, have students follow footpaths along the beach about 100m. Ask students to stop when they think they have reached a flow top. Recall that a flow top has many vesicles, often filled in with minerals such as calcite, chlorite, prehnite, epidote, quartz, and even copper. For a more advanced lesson, have students make rock descriptions and sketches of the flow top and the massive basalt emphasizing the differences between two.
Stop 8 • 30-45 minutes • Ripple Marks at Silver River

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<tr>
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Driving directions
From Stop 7 — Turn around at Esrey Park and back track on M26 to where Brockway Mountain Drive intersects the road. Travel just beyond this intersection across the Silver River Bridge. There is an area to park on the left side of M26 directly across the bridge. If traveling in a school bus, park on the left side of M26 just prior to the bridge. There is an adequate area to pull over safely.

Geology
Rock types: Copper Harbor Conglomerate.
Current geologic processes: River deposition

What you will see…
Once you have arrived at the Silver River Bridge, cross the road so that you are on the downstream or north side of the bridge. Here you will see many outcrops of the Copper Harbor Conglomerate (CHC) and a few different sedimentary features present in the CHC. The most impressive features are ripple marks formed from water motion. There are also some mud cracks present here.

Silver River Activity (30–45 minutes)

1. Have students try to locate and identify any interesting sedimentary features. There are two or more locations that exhibit ripple marks and one location showing small-scale mud cracks.
2. Ask students what kind of environment they think would produce these types of features.
3. Point out how the layers change from sandstone to conglomerate and how the finer grained rocks were deposited in a lower energy environment (slower water movement) than the conglomerate.
4. If you have compasses and protractors, have students attempt to get a strike and dip of a bed within the Copper Harbor Conglomerate.
Stop 9 • 5 minutes • Sand Dunes

*From “Stop” 8 — Continue on M26 southwest past Eagle Harbor and Cat Harbor. Pull over into one of three viewing areas on the right (west) side of the road.*

**Geology**

*Current geologic processes:* Wind deposition of sand

If you have time, walk the Michigan Nature Association’s Redwyn Dunes trail.

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Stop 10 • 15 minutes • Eagle River Falls

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<th>Stop Time</th>
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**Driving directions**

*From “Stop” 8 — Continue on M26 southwest into Eagle River. At the edge of town, right before the Eagle River Bridge, turn left into a parking lot at the historical marker.*

**Safety Concerns** — The foot bridge is the safest place to view the falls. Stay on the bridge and don’t hike down to the base of the falls. There are steep cliffs and it is dangerous to try to walk down to the falls.

**Geology**

*Rock types:* Copper Harbor Conglomerate and Portage Lake Volcanics.

*Current geologic processes:* Erosion by a river - potholes

**What we will see…**

From the parking area, walk across the historic footbridge that parallels M26 to view the falls. The falls occur at the **contact** between the **Portage Lake Volcanics** and the **Copper Harbor Conglomerate**. This is because the Portage Lake Volcanics is much more resistant to erosion than the Copper Harbor Conglomerate that has been eroded away to make the falls. The water is running down the top surface of a Portage Lake Volcanics flow.

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Eagle River Falls, notice the color and texture contrast between the Portage Lake Volcanics and the Copper Harbor Conglomerate
Eagle River Falls Activity (approximately 15 minutes)

1. Have students make a sketch of the site in their journals. Tell students to identify the features and rock types they see including potholes, Copper Harbor Conglomerate, and Portage Lake Volcanics. Also, have the students sketch in a line to represent the contact between the two rock types.

2. Ask students:
   - Why are the falls in this exact location, not farther up or down the river?
   - What did this area look like a half billion years ago?
   - What will this area look like in a half billion years?

3. Point out and discuss the pothole erosional features.

Assessment

Using the notes from their science journals and photos taken by each student during the field trip, student groups will make a powerpoint presentation to the class on the local geology.

Extension


References


3. Petroleum Engineers of America: *Geologic Map of the Great Lakes Region*
FIELD TRIP • Activity Time: 2–3 hours
Miners Castle Area of Pictured Rocks National Lakeshore

SITE LOGISTICS

Location — Near Munising, MI (See site map)
Site Parking — There is ample parking for a bus, vans, or several cars.
Site Capacity — Please limit field trips to no bigger group size than one class.
Trail Information — Trails are fairly level paths except for the hike to see the drumlin and to Miners Falls, which has about 80 steps.
Accessibility — All restrooms are accessible. Trails are accessible except those noted above.
Safety Concerns — The hike to the drumlin involves uneven terrain and crossing some fallen logs.
Special Considerations — Please stay on marked trails in all locations except during the hike to the drumlin. No picking of plants or removal of any beach stones or other objects is permitted in the National Lakeshore.
Contact — For additional information, call (906) 387-2607. A ranger may be able to assist you with your field trip. The road to the Miners area is not open in the winter snow season.

Overview

During this self-guided field trip, participants will explore four areas of Pictured Rocks National Lakeshore near Munising. These areas are the entrance to the Miners area, the Miners Falls area, Miners Castle, and Miners Beach. Participants will learn about the geologic history of the area and its many changes from the ancient Cambrian Era when the Upper Peninsula was near the equator to the Pleistocene Era of the most recent great ice age. This field trip to the west end of Pictured Rocks National Lakeshore visits some of the most spectacular cliffs found in Michigan. Participants will see geologic formations first-hand, while exploring several areas near Miners Castle. Students will have opportunities to draw examples of some of the components of the lesson in a journal. Have fun!

Welcome to Pictured Rocks National Lakeshore

Pictured Rocks is part of the National Park Service. The mission of Pictured Rocks is to conserve the ecosystem integrity of Pictured Rocks National Lakeshore, a mosaic of geologic, biologic, scenic and historic features, offering opportunities for recreation, education, inspiration and enjoyment forever.

Leave No Trace

Please practice Leave No Trace outdoor ethics during your visit to Pictured Rocks. We ask that you stay on designated trails (except during your visit to the drumlin at the Miners Falls area) and please do not disturb or remove any natural objects found within the National Lakeshore.

Vocabulary to Review Prior to Field Trip

Glacier, drumlin, moraine, esker, fluvial, glacial till, watershed, fossil, conglomerate, oligotrophic, eutrophic, mesotrophic, cambrian, pleistocene, isostatic rebound, trilobites, mudstone, global climate change.
Learning Objectives

Students will be able to:

1. Explain the formation and significance of the Pictured Rocks cliffs.
2. Describe what the Upper Peninsula region was like when trilobites left their tracks in the Pictured Rocks stone.
3. Describe the formation of glacial moraines and drumlins.
4. List the five different lake stages of Lake Superior.
5. Explain one way humans may soon be causing global changes to the earth features.

During this field trip students will observe glacial formations (moraines and drumlins) and try to visualize how they were formed. Students will observe the Pictured Rocks cliffs and understand how different lake levels and isostatic rebound created this formation and what fossils are found in the different layers. Exploring the beach area, students will search for erosion, beach stones, fossils, and fossilized tracks. They will record their findings in journals.
Michigan Grade Level Content Expectations

Science:
*Earth Science, Solid Earth, Middle School (V.SE.M.1-5)*
- 1. Describe and identify surface features using maps
- 4. Explain how rocks and fossils are used to understand the age and geological history of the earth.

*Life Science, Ecosystems, Middle School (III.LEC.M.6)*
- 6. Describe ways in which humans alter the environment

*Earth Science, Solid Earth, High School (V.SE.H.1-2)*
- 1. Explain the surface features of the Great Lakes region using Ice Age theory.

Social Science:

*II. Geographic Perspective, Standard 2, High School*
- 1. Describe the environmental consequences of major world processes and events.

Materials Needed
- Compass
- Binoculars
- Pencil
- Clipboard
- Journal book
- Fossil identification and beach stone identification books for each student or group of students

Stop 1 • Miners Castle Road
From downtown Munising, follow H-58 east to the Miners Castle Road, then turn left and head north. The “flat” area you are driving on is an outwash plain from the last melting glacier (perhaps a mile high block of melting ice) beginning its retreat northward about 11,500 years ago. Imagine a flat sheet of meltwater washing out across the land carrying sand, gravel, and boulders.

Stop 2 • Miners Falls area
Turn right and park in the Miners Falls parking lot. There are vault toilets here, but no drinking water. From directly behind the vault toilets hike 320 degrees a couple of hundred yards to see an esker!

The Miners drumlin or flute was formed by torrents or outbursts of water flowing under active ice near the terminus or end of the glacier. The feature is parallel with the flow of the glacier, e.g. north/south and is an oblong shape. Flutes are more linear, so the northern portion of this feature may be a flute. Water carried sand, gravel, and rocks to form this linear feature on the landscape. See: Canadian Landform Inventory Project.

Hike to Miners Falls. The Miners River flows north to Lake Superior. Do you know why? As the last glacier pushed its way south, it stopped a few miles south of here and pushed a hill on the land creating an end or terminal moraine. It was like a bulldozer suddenly stopping and backing up. Where the “bulldozer blade stopped” is the tall pile of till (moraine), which created a north flowing watershed here.
The Miners River valley is what is called a “tunnel channel” and was likely carved in bedrock by intense glacial river action before glacial sediment covered this area. It is oriented north/south and is interrupted by Miners Falls where the Au Train and Munising formations of sandstone bedrock create the waterfall. Other tunnel valleys exist in the park, notably at the Kingston Lake chain of lakes. The floor of Lake Superior is marked by several tunnel valleys. The trail between the parking lot and the falls borders a side channel or valley (see the topographic map) where glacial meltwater carved a smaller feature.

**Journal Entry 1**

Draw a picture of a glacier forming an end moraine of till in front of it. Draw the lateral moraines on the sides of the glacier. Next draw a picture of a drumlin. The wide end of the drumlin teardrop shape points in the direction the water ran. Identify that feature in your drawing.

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**Stop 3 • Miners Castle Viewing Platform**

Take a minute to enjoy the view! Lake Superior is the largest, deepest, and coldest of the Great Lakes. Is Lake Superior the largest body of water on earth? Is it the largest by surface area or by volume? It is the largest body of fresh water on earth by volume. (Lake Baikal in Siberia is the only lake bigger by surface area — but it is not as deep). Just 26 miles to the northeast from this platform is the deepest area in the lake — 1,333 feet deep! Lake Superior is a cold deep lake. It is called an oligotrophic lake. Because it is so cold and deep it does not contain much biological diversity. Warm shallow lakes are called eutrophic and are very productive for life forms. Mesotrophic is the term for a lake in between these two extremes. Lake Erie is a eutrophic lake.

Over time Lake Superior has gone through many changes. Let’s investigate some of these now! The current Lake Superior has looked roughly the same for the past 2000 years. However, its fresh water life started roughly 75,000 years ago just prior to the last great ice age.

<table>
<thead>
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<th>Lake Description</th>
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<tbody>
<tr>
<td>75,000 years ago</td>
<td>Pre-glacial Lake Keweenaw Drained into the Mississippi through the Brule and St. Croix Rivers in Wisconsin. Much larger lake area than today.</td>
</tr>
<tr>
<td>10,700 years ago</td>
<td>Glacial Lake Minong Glacial reshaping of area. Lake much higher than today. Drained out the North Bay Ontario outlet.</td>
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<tr>
<td>10,000 years ago</td>
<td>Glacial Lake Duluth Sediment dams made lake 500 feet higher than today. Drainage swept across the flooded Upper Peninsula and also drained out the U.P.’s Whitefish River and into the Mississippi River through Wisconsin.</td>
</tr>
<tr>
<td>9500 years ago</td>
<td>Glacial Lake Houghton (Houghton Low) As drainage shifted back to North Bay Ontario, the lake level dropped to several hundred feet below its current level.</td>
</tr>
<tr>
<td>6000 years ago</td>
<td>Glacial Lake Nippising (Nipissing High) As the land rebounded in the northern portion of the lake from its “depressed state” the outlet at North Bay Ontario was eventually blocked about 5000 years ago, creating drainage out the St. Mary’s River. Lake levels rose to 35 feet higher than the present lake.</td>
</tr>
<tr>
<td>2000 years ago</td>
<td>Current Lake Superior Modern drainage pattern out the St. Mary’s River continued and established the current lake level and shorelines.</td>
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</table>
Journal Entry 2
The earth is about 4.5 billion years old. How many zeros are in a billion? Around 520 million years ago here, (how many zeros in that number?) you would have seen a warm shallow ocean and a barren rocky plain. Draw a picture of a landscape with no animals on it.

During the eons of bedrock formation, the eastern half of what would much later become Lake Superior was oriented just 10 degrees south of the equator! The ocean was salt water, but complex life did not exist in this area except for primitive algae and bacteria. The exposed bedrock here in the Lakeshore has two basic sources of sediment from two directions – south and northeast.

About one million years ago, the most recent ice age began in North America. A huge mass of ice perhaps one mile high weighed down the landscape. This glacial event began melting or retreating about 9,500 years ago and as that occurred, the land rebounded or raised up through a process called isostatic rebound. Rebound is partially responsible for the Pictured Rocks Cliffs that today stretch for some 15 miles along the shoreline.

Looking At Miners Castle
The rock formation you see here is Miners Castle. In the 1700’s, explorers were searching for minerals but found none at this location, though the name “Miners” continued to be used to this day. The sandstone “castle” was sculpted by waves, wind, freeze and thaw action, and from a previously higher lake level.

The pink-orange colored sandstone just above the water is the Chapel Rock layer or member. This layer resulted from deposits which began about 520 million years ago. The sediment that later hardened to become this layer came from erosion of the Northern Michigan Highlands, a mountain range that once existed south of here.

Near the top of this layer, rangers have found evidence of small animals called trilobites that once lived here. They left tracks in a mudstone that is part of this bedrock deposit.
The layers of whitish-yellow-grey rock above the orange sandstone is the Miners Castle member. It began forming about 500 million years ago. It reveals evidence of higher forms of life such as worms, clams, snails, sponges and corals.

The top most rock layer is the Au Train formation. The viewing platform rests on this layer of rock, but is not visible on the “castle.” These layers represent deposition ending about 430 million years ago. It contains dolomite and is harder than the other two layers. Dolomite is formed from ancient shelled sea creatures that were crushed, dissolved, and reformed into a hard rock that is more resistant to erosion than the layers beneath it.

**Journal Entry 3**

Put the time each formation began or ended next to the drawing of the Miners Castle cross section. List what value each layer is to earth science.

The name “Pictured Rocks” comes from early explorers who saw multi-colored stains on the sandstone rocks. These stains reminded them of abstract pictures or paintings. The stains come from minerals in the sandstone leaching from the rock out onto the surface.

- Traces of iron create the red and orange stains.
- Traces of copper create the green stains.
- Traces of limonite create the yellow and white stains.
- Traces of manganese create the black stains.

Look closely with your binoculars to see if you can spot different mineral stains. If you were to take the Pictured Rocks Boat Cruises or kayak along the shore, you would discover many of these beautiful “Pictured Rocks” along 15 miles of cliffs.

**Stop 4 • Miners Beach**

While driving down the steep road to the beach, remember you are driving down into what used to be a large powerful glacial river channel that scoured out the Miners River valley. The power of water is impressive!

Have the bus let you out at the left or west end parking lot. Follow the trail off the west end of the parking area (not toward the beach.) Before arriving at Miners River, you will walk through an old road cut through a small hillside. Notice the dangling plant roots in the side of the sandy bank. Plant roots are vital to keep erosion in check and for keeping the sand from washing into the Miners River. More about that later!

Do not cross the bridge, but instead, follow the river downstream along the narrow trail toward the beach. As you arrive at a small waterfall, notice the river becomes wider and deeper. Collect some pebbles and sand. Holding several pebbles in your hand, explain how the pebbles lie on the stream bottom and how spaces form between them. These “between the stone spaces” are important for fish eggs as they are protected from predators in the small spaces. Cool, flowing water also helps provide oxygen to the eggs and keeps them free of fungus or bacteria.
Discuss what might happen here if people caused bank erosion by walking off trail, or if off-road vehicles were ridden here. Would the plants be affected? Would sand and soil wash into the river? How could that affect the fish eggs lying on the stream bottom? Please stay on trails to eliminate erosion.

Continue hiking to Miners Beach. Stop and look for beach stones. Use your beach stone guide to identify what you find. The stones you see are likely from the nearby conglomerate layer of rock in the Chapel Rock member. Other igneous or metamorphic pebbles may be from farther north of Lake Superior and transported by glaciers. All have been worn smooth by erosion.

**Journal Entry 4**

Make a sketch of two beach stones and a fossil you might find. List identifying characteristics of your rock before returning them to the beach (remember: all rocks must remain in the park as they are protected.)

Walk to the east end of the beach where you will find a small waterfall. Walk toward the high bank and look for a grey-blackish rock called mudstone. What formation did you see at Miners Castle is represented here? (Chapel Rock member.) Search rock fragments for trilobite tracks (see picture at right). These are called cruziana. Take care to not disturb any layers from the eroding hillside.

Here at the beach you have traveled back in time to see 500 million year old rock. You have looked at several landscapes and imagined the forces that have been at work to shape them. Consider that changes in the earth are constantly occurring due to the forces of nature like weathering, freeze and thaw, and erosion. Think about how most change occurs very slowly over hundreds of thousands of years. It is a challenge for humans to consider this evidence with our 70-80 year life span! We are a mere blink on the screen compared to the age of the earth!

**What “tracks” will our species leave behind during the next 100 years?**

Scientists are concerned about how climate change is occurring through increased carbon dioxide levels in the atmosphere. Evidence shows that most of this change is caused by humans as we shape future earth history. As earth’s climate changes, some areas grow warmer and other cooler. Glaciers in Glacier National Park may disappear in the next 20 years. The summer arctic ice mass may also disappear in the near future! Ocean levels are rising rapidly from melting of both ice caps and the Greenland ice sheet. Ocean shorelines are changing and the southern part of Florida may become inundated with water as the ocean rises. Learn more about climate change and what you can do to help reverse this trend.
Journal Entry 5
Sit somewhere a short distance from another classmate. Relax for a minute and reflect on what you have seen and done and learned today at Pictured Rocks National Lakeshore. Describe in your own words how this field trip may have changed your perspective in some way about earth science.

References
Geology of Michigan by Dorr and Eschman
Cambrian Sandstone of Northern Michigan by Hamblin
Geology and Landscape of Michigan’s Pictured Rocks National Lakeshore and Vicinity, by William L. Blewett
Geology of the Lake Superior Region by LaBerge
Overview of Cambrian Sandstone, Pictured Rocks Resource Report 97-1
Environments of Deposition by Rose
Is this an Agate? by Robinson
Golden Guide to Fossils by Rhodes, Zim and Shaffer
(With excerpts from Cannon et al, 1995)

Pre and Post Test
1. What are the Pictured Rocks Cliffs and how were they formed? (They are layers of sandstone sediment from different time periods. Stains on rocks from minerals make “pictures.” Uplifting of earth from weight of glaciers helped form cliffs along with erosion from earlier Great Lakes.)

2. What can fossils tell us? (Fossils can tell us what past climate was here, what the time period was when the fossils were alive here, and the location of previous earth features like a warm ocean.)

3. What is the relationship between glacial rivers, outwash plains and eskers? (Glacial rivers poured across the land, creating an outwash plain by carrying a load of sediment. At times, glacial rivers occurred under the ice, gouging grooves in the bedrock or filling tunnels in the ice with sediment creating eskers.)

4. What current human activity may shape the earth in the next 100 years and how? (Increases in human caused CO2 is leading to climate change by increasing the temperature of the earth’s atmosphere. Shifts in regional temperature, precipitation, storm patterns, melting of polar ice and glaciers, and rising sea levels, will result.)
FIELD TRIP
Porcupine Mountains Wilderness State Park

Porcupine Mountains Wilderness State Park, 33303 Headquarters Rd., Ontonagon, MI 49953
Tel: (906) 885-5206 • Email: wildr@michigan.gov

Overview
This field trip guide is designed for educators seeking to explore Earth Science with their students in Porcupine Mountains Wilderness State Park. It can be used to plan a self-guided field trip or a visit guided by the park interpreter. The field trip guide is divided into five sections; a Unit Topic, which covers the overall geology of the region and Porcupine Mountains, followed by Lessons 1-4. Each lesson in the guide is tied to a field location in Porcupine Mountains Wilderness State Park. The lessons and field locations are listed in stratigraphic order, oldest to youngest. (1-Igneous rocks, volcanism — Summit Peak Scenic Area, 2-Igneous rocks, volcanism, sedimentation — Lake of the Clouds Scenic Area, 3-Sedimentary rock features, sedimentation — Union Bay Campground, 4-Sedimentary rock features, sedimentation — Presque Isle River Scenic Area). A geologic map and map showing location of lesson sites are found at the back of this guide. Any or all of the lessons and field locations may be utilized on a visit, depending on the time available. A valid Michigan State Park Recreation Passport is required for all vehicles entering the park.

Background
The bedrock of the Keweenaw Peninsula and the Porcupine Mountains reveals the story of a great tectonic event that occurred here nearly 110 Ma (Ma=million years ago), an event that produced earthquakes, vast lava flows and that threatened to tear the North American continent in tow. A quick review of the basics of plate tectonics theory will help to understand this awesome geologic event and the formation of the bedrock of the Porcupine Mountains. Plate tectonic theory holds that the Earth’s rigid outer shell, or lithosphere, consists of a layer of crust and an underlying layer of the upper mantle. This shell, which sits atop the much hotter and more fluid rock of the asthenosphere, is broken into various sized sections called plates. These plates, which are from 60 to 150 miles thick, move and extend themselves across the Earth’s surface driven by the convective flow of molten rock within the lower mantle.

![Figure 1. Keweenawan Supergroup](image)

Figure 1. Keweenawan Supergroup
As the plates move, their margins push and slide against and overtop one another with immense force, producing earthquakes, volcanoes and mountain belts. Geologists believe that continents form and grow along converging plate boundaries through the accumulation of mountain belts and small plate sections. The forces that fuel plate tectonic activity can also cause plates to split and spread apart. The system of geologic faults that results from the spreading or extension of a geologic plate is known as a rift. Rifts are characterized by block faulting as a result of tensional forces and volcanic activity.

This field trip to Porcupine Mountains Wilderness State Park examines the geology of rocks of the Keweenawan Supergroup; a thick sequence of volcanic and sedimentary rock deposited during and shortly after an episode of continental rifting that occurred in this region. Rocks of the Keweenawan Supergroup exposed in the Porcupine Mountains are, (from oldest to youngest); the Porcupine Volcanics, the Copper Harbor Conglomerate (which is divided into an Upper part and a Lower part, and includes interbedded lava flows known as the Lakeshore Traps; the Nonesuch Shale; and the Freda Sandstone. These rock strata were deposited one above the next, with the older layers currently exposed only where the younger ones have been removed by erosion. See Figure 1. for a stratigraphic chart of the rocks of the Keweenawan Supergroup. See ROCK.PDF for additional photos and description of bedrock types seen in Porcupine Mountains Wilderness State Park.

The great geologic rift that produced the rocks of the Porcupine Mountains and the Keweenaw Peninsula is known as the Midcontinent rift system (MRS). The MRS is a major geologic feature of our continent and one of North America’s best-kept geologic secrets. Using gravity surveys and seismic reflection imaging, geologists have traced the MRS from the lower peninsula of Michigan, through the Lake Superior region and south into Kansas, a distance of 1,500 miles.

Geologists believe that the MRS formed in response to a mantle plume or “hot-spot” underneath the North American plate. (See dynamic.pdf, page 48 for more information on hotspots.)

The length of the basin formed by the MRS was marked by volcanic activity on a scale unlike anything seen on Earth today. For a period of almost 20 million years, volcanic eruptions poured vast quantities of lava into the basin formed by the growing rift. Following this volcanic period of the rift’s development, sediment and erosional debris began filling the rift basin. By the time the rift had stopped growing, a layer of volcanic and sedimentary rock nearly 12 miles thick had been deposited over the center of the rift basin. In upper Michigan, the main axis of the rift basin is located over what is now the Lake Superior basin.
The growth of the MRS ended about 40 million years after it began. Geologists believe that at this time the North American plate collided with another plate section. The great compressive forces of this event, called the Grenville Orogeny, halted the growing continental rift and caused considerable uplifting along the margin of the rift basin.

Learning Objectives

Students will be able to:
1. Explain continental rifting, rift development in terms of plate tectonics and the relationship of the Midcontinent Rift System to the rocks of the Keweenawan Supergroup.
2. Explain the four events that lead to the formation of sedimentary rocks, be able to recognize types of four types of clastic sedimentary rock and identify sedimentary rock features.
3. Explain how igneous rocks are formed, name the two major types of igneous rock, understand the classification of igneous rock using texture and composition and recognize structural features of extrusive volcanic rocks.
4. Explain how rocks are used to determine the age and geological history of the Earth using relative and absolute dating methods.
5. Identify surface features using geological maps.
Michigan Grade Level Content Expectations

Science:
*Earth Science, Solid Earth, Middle School (V.SE.M.1-3)*
1. Describe and identify surface features using maps.
2. Explain how rocks and minerals are formed.
3. Explain how rocks are broken down, how soil is formed and how surface features change.

*Earth Science, Solid Earth, High School (V.SE.H.2)*
2. Use the plate tectonics theory to explain features of the earth’s surface and geological phenomena and describe evidence for the plate tectonics theory.
Lesson 1 • Igneous rocks, volcanism — Summit Peak Scenic Area, Porcupine Volcanics

**Igneous Rock Concepts**

Igneous rocks are formed by the cooling and solidification of magma or lava. The word Igneous is derived from “ignis,” the Latin word for fire. Igneous rocks are classified by composition and texture. As magma cools, minerals begin to crystallize from the molten material. The various minerals that crystallize from the magma do not develop simultaneously, but develop in a sequence as the lava cools. Lava — which is magma that has erupted onto the Earth’s surface — has been measured at 1000°C to 1200°C, (approximately 1800°F to 2200°F).

The composition of igneous rocks depends primarily on the composition of the magma that produced them. Silica, one of the most abundant elements in the Earth’s crust, is a primary ingredient of nearly all magmas. Silica content of magma varies, however, and distinguishes the three most common types of magma. *Felsic* magma has over 65% silica; rhyolite and granite are produced from felsic magma. *Intermediate* magma has between 53% and 65% silica; andesite and diorite are produced from intermediate magma. *Mafic* magma contains between 45% and 52% silica; basalt and gabbro are produced from mafic magma.

The texture of igneous rocks (the size, shape and arrangement of a rock’s grains or crystals) is determined largely by the cooling history of the magma or lava that produced it. Intrusive or plutonic rocks are produced by magma that cools slowly under the Earth’s crust, permitting relatively large crystal grains to grow. As a result, intrusive rocks have a coarse-grained or phaneritic texture. Extrusive or volcanic rocks are produced from lava that flows out onto the Earth’s surface and cools relatively rapidly, producing rocks with a fine-grained (small crystals) or aphanitic texture.

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**SITE LOGISTICS**

**Location** — Travel to the Summit Peak Road, which is along the South Boundary Road 12 miles west of the junction of the South Boundary Road and Hwy M-107, and 11 miles east of the junction of the South Boundary Road and County Road #519. Follow Summit Road two miles north to the Summit Peak parking area. From the parking area follow the trail to the observation area and (optional) hike down the Beaver Creek trail 0.5 miles.

**Site Parking** — Paved parking area with turn-around can accommodate buses except during periods of peak visitation.

**Site Capacity** — 15 persons at a time on the tower.

**Restroom Facilities** — Composting toilets, no water.

**Trail Information** — Trail to Summit Peak tower is packed gravel/boardwalk, Beaver Creek Trail is packed earth hiking trail.

**Accessibility** — Not handicap accessible.

**Safety Concerns** — If group leaves the trail steep rock faces may be encountered.

**Special Considerations** — Groups leaving the trail should take care not to trample vegetation growing on bedrock areas.

**Contact** — For additional information, call (906) 885-5206. A ranger may be able to assist you with your field trip.
At 1,958 feet above sea level, Summit Peak is the highest point in the Porcupine Mountains and one of the highest points in the state. Summit Peak is one of the best places in the park to view the Porcupine Volcanics, a formation of volcanic rock, which consists primarily of rhyolite, andesite and basalt. The abundance of felsic rocks distinguishes the Porcupine Volcanics from the underlying Portage Lake Volcanics (do not outcrop in the park), which are dominated by flood basalts or mafic flows and contain only minor felsic volcanic rocks.

Geologists believe that this area of the Porcupine Mountains contained a volcanic center that became active late in the volcanic history of the MRS. The present arc shape of the Porcupine Mountains and the “hook” shape of the Porcupine Volcanics (see the geologic map at the back of this guide) are a reflection of the original shape of the volcanic shield. Aeromagnetic surveys of the region to the south and southeast of Summit Peak reveal prominent structural breaks in the bedrock. These breaks are believed to be the result of fault lines which outline the central caldera of the volcano.
Looking north from Summit Peak, the interior uplands of the Porcupine Mountains are visible. These uplands are composed of a series of rhyolite flows and domes typified by the felsic rocks seen at Summit Peak. As the rocks of the Porcupine Volcanics were broken up by stress faulting and occasional explosive volcanic eruptions, pieces and blocks of rock tumbled down the sides of the volcano creating debris blankets. Magma welling up between the rock fragments welded them together in a solid mass of rock called *breccia* (brech’-ee-uh).

Good exposures of coarse rhyolite breccia can be seen along the trail leading to the summit and at the overlook platform west of the summit. Exposures of coarse rhyolite breccia can also be seen along the Beaver Creek Trail, on the steep rock walls on the south side of Beaver Creek, about 0.5 miles from the Summit Peak parking lot.

**Lesson 1 Vocabulary**

- **andesite** — a medium-grained igneous rock (53 – 65%), produced from intermediate magmas.
- **basalt** — a fine-grained igneous rock (45 – 52% silica), produced from mafic magmas.
- **breccia** — a general term for rock consisting of angular fragments in a matrix of finer particles or igneous rock.
- **clasts** — fragments produced by the mechanical breakdown of rock.
- **felsic** — volcanic rock derived from magma with more than 65% silica, but little iron, calcium or magnesium. Silica-rich felsic magmas are relatively thick and flow slowly.
- **lava** — magma at the Earth’s surface.
- **mafic** — volcanic rock derived from magma with 45 to 52% silica and more iron, magnesium and calcium than felsic and intermediate magma. Silica-poor mafic magmas are relatively thin and flow readily.
- **magma** — molten rock produced within the Earth.
- **Midcontinent rift system (MRS)** — a late Proterozoic intracontinental rift that developed within what is now the North American continent, it contains thick accumulations of volcanic and sedimentary rock. See *rift*.
- **mineral** — A naturally occurring inorganic crystalline solid with characteristic physical properties, a definite internal structure and chemical composition that varies little.
- **orogeny** — a major episode of mountain building.
- **plate** — a broad segment of the lithosphere (including the rigid upper mantle, plus oceanic and continental crust) that floats on the underlying asthenosphere and moves independently of other plates.
- **plate tectonics theory** — the theory that large segments of the Earth’s rigid outer shell move relative to one another. First proposed in 1912 by the German scientist Alfred Wegener as the theory of “continental drift.”
- **rhyolite** — a fine-grained igneous rock (greater than 65% silica), produced from felsic magmas.
- **rift** — a major geologic process occurring at divergent plate boundaries, sometime referred to as a “spreading center.” Rifts are characterized by tensional stress (stretching), block faulting and basaltic volcanism.
- **stratigraphic** — the order of the strata in a sequence of rock.
Lesson 1 Activities

Using a geologic map — Geologists measure the angle and direction of tilted rock layers in terms of strike and dip. Strike is the direction of a line formed by the intersection of a horizontal plane and an inclined rock layer. Dip is the angle of an inclined rock layer from horizontal. Locate a flow of rhyolite breccia and using a tape measure, compass and protractor, measure its thickness, strike and dip. Compare your results with the strike and dip indicated on the large USGS geologic map of the area. From Summit Peak tower, locate the aeromagnetic trend lines on the large USGS map. Determine the location of these and other geologic features on the landscape.

Absolute Dating

How did geologists determine the age of the Porcupine Volcanic at Summit Peak? Although most of the isotopes of the 91 naturally occurring elements are stable, some are radioactive and spontaneously decay to other more stable isotopes of elements. Geologists use the decay rate of unstable isotopes to determine the absolute age of igneous rocks, this process is known as radiometric dating. The beta decay (the emission of a single electron from a neutron in the nucleus) of rubidium 87 to strontium 87 is often used to date minerals and igneous rocks and has been used extensively to date rocks in the MRS.

Other radioactive isotope pairs (a pair consists of the unstable parent isotope and more stable daughter isotope) commonly used in radiometric dating include uranium 238 and lead 206, uranium 235 and lead 207, thorium 232 and lead 208, and potassium 40 and argon 40.

The decay rate of radioactive elements is measured in terms of half-life, the time it takes one-half of the atoms of the unstable parent isotope to be converted to the more stable daughter isotope. The half-life of a given radioactive element is always constant. The time that is measured using radiometric dating is the time of crystallization of the mineral containing the radioactive element. Radiometric dating, therefore, is seldom valuable in dating sedimentary rock.

Commonly used radioactive isotope pairs (parent/daughter, half-life of parent) used in radiometric dating are:

- Uranium 238/Lead 206, 4.5 billion years.
- Uranium 235/Lead 207, 704 million years.
- Thorium 232/Lead 208, 14 billion years.
- Rubidium 87/Strontium 87, 48.8 billion years.
- Potassium 40/Argon 40, 1.3 billion years.

1. If a radioactive element has a half-life of 100 million years, what fraction of the parent material remains in a sample after 300 million years? (1/8)
2. How many half-lives are required to yield a mineral sample with 1525 atoms of Potassium 40 and 4575 atoms of Argon 40? (two half-lives) How old would this sample be? (2.6 billion years old).
**Classifying Igneous Rocks**

Using the igneous rock chart (Figure 4.) classify the following rock samples:

1. A dark colored, fine-grained rock whose primary minerals are calcium rich plagioclase and pyroxene. (andesite)
2. A coarse-grained rock with lots of potassium feldspars and lesser amounts of quartz, sodium rich plagioclase, biotite and amphibole. (granite)
3. A fine-grained rock with nearly equal amounts of potassium feldspars and sodium rich plagioclase along with quartz, biotite and amphibole. (rhyolite)
4. A fine-grained rock dominated by olivine and pyroxene. (basalt)
5. Which of the following pairs of igneous rocks have approximately the same mineral composition?
   a) andesite/rhyolite, b) granite/rhyolite, c) granite/basalt, d) andesite/gabbro.
Lesson 2 • Igneous rocks, volcanism, sedimentation — Lake of the Clouds Scenic Area, Lower Part of the Copper Harbor Conglomerate

SITE LOGISTICS

Location — From the junction of the South Boundary Road and Hwy. M-107 near Union Bay, follow Hwy. M-107 west 7 miles. Along the road leading to the overlook are several exposures of the Upper Part of the Copper Harbor Conglomerate. On the way to Lake of the Clouds, the highway passes a small copper mine on the south side of the road and a waste rock pile on the north side of the road. From the overlook parking lot, a short hike leads to the Lake of the Clouds Overlook and a spectacular view of Lake of the Clouds and the interior of Porcupine Mountains Wilderness State Park. Additional rock exposures can be seen from the very scenic Escarpment Trail. Hiking one mile east along this trail will provide students with access to additional rock exposures.

Site Parking — Paved parking area with turn-around can accommodate buses.

Site Capacity — 40+ persons

Restroom Facilities — Composting toilets, no water

Trail Information — Trail to the Lake of the Clouds overlook is blacktop and has accessible boardwalk.

Accessibility — ADA accessible

Safety Concerns — Cliffs and steep rock faces may be encountered.

Special Considerations — Groups leaving the trail should take care not to trample vegetation growing on bedrock areas.

Relative Dating Concepts

Geologists use the following principles to reconstruct geologic history:

1. Superposition — in a sequence of undisturbed sedimentary rock the oldest rock layer is at the bottom and the youngest rock layer is at the top.

2. Original horizontality — sedimentary rocks are originally deposited in nearly horizontal layers, therefore steeply tilted sedimentary rock layers must have been tilted after deposition.

3. Lateral continuity — At deposition, sediment spreads in all directions until it thins out or hits the edge of the basin.

4. Inclusions — Fragments included in sedimentary rock must be older than the rock itself.

5. Cross-cutting — Faults or igneous intrusions into rock layers must have occurred after the rock was deposited and therefore must be younger than the rock itself. Geologists use the position of rock strata to in relative dating to place geologic events in the order that they occurred.

Description

The eruption of the Porcupine Volcanics marked the end of major volcanism in the MRS, and further geological events were dominated by fluvial and lesser lacustrine sedimentation into the basin of the MRS. The first sedimentary unit to fill in above the Porcupine Volcanics is called the Copper Harbor Conglomerate, a thick sequence of red volcanogenic conglomerate and sandstone. The Lake of the Clouds overlook is along the south escarpment of a high ridge supported by a series of north-dipping basalt flows within the Copper Harbor Conglomerate. These basalt flows (known as the Lake Shore Traps) represent the last stages of volcanism in the MRS. From the overlook, the low area south of the ridge, including Lake of the Clouds, is underlain by the Lower part of the Copper Harbor Conglomerate, which is composed primarily of sandstone and siltstone. The higher peaks farther south are knobs of rhyolite and andesite in the Porcupine Volcanics. The sandstones and siltstone of this unit can be seen about 0.5 miles east of the Overlook along the Escarpment Trail.

Towards the east end of the overlook, past the small retaining wall, a glaciated surface shows a series of thin basalt flows. A number of distinctive lava flow features can be observed here, enabling us to identify and measure individual lava flows. The
most obvious of these flow features are called vesicles. Gases dissolved in the magma are released after eruption because of the drop in pressure (much like soda releases carbonation when the bottle is opened). These gases form bubbles that rise to the top of the lava flow. Since the top of the lava flow cools relatively quickly the bubbles may be trapped in the cooling rock forming a “frothy” or “bubbly” flow top. These bubbles or cavities are called vesicles. If the lava underneath continues to flow after the vesicles have begun forming, a “rubbly” or broken texture might be produced at the flow top. Vesicles often fill with secondary minerals such as calcite, epidote, quartz or even copper.

The bottoms of lava flows often show development of pipe vesicles. Pipe vesicles form when lava travels over wet ground. Water at the base of the flow quickly turns to steam, creating vertical tubes or “pipes” in the overriding lava flow. These pipes are often bent, providing a clue to the direction that the lava was flowing.

Thin veins of clastic material cut a number of flows. These may have formed as the lava cooled and cracked and were later filled with wind-blown sand. The basalt flows are also cut by a small fault.

Lesson 2 Vocabulary

basalt — a fine-grained igneous rock (45 - 52% silica), produced from mafic magmas.
clastic — of clasts
clasts — fragments produced by the mechanical breakdown of rock.
conglomerate — a coarse-grained sedimentary rock composed of rounded fragments of pebbles, cobbles or boulders.
fluvial — pertaining to rivers or streams, sediment deposited in a river or stream environment.
lacustrine — pertaining to lakes, sediment deposited in a lake environment.
lava — magma at the Earth’s surface.
mafic — volcanic rock derived from magma with 45 to 52% silica and more iron, magnesium and calcium than felsic and intermediate magma.
magma — molten rock produced within the Earth.
Midcontinent rift system (MRS) — a late Proterozoic intracontinental rift that developed within what is now the North American continent, it contains thick accumulations of volcanic and sedimentary rock. See rift.
orogeny — a major episode of mountain building
rhyolite — a fine-grained igneous rock (greater than 65% silica), produced from felsic magmas.
rift — a major geologic process occurring at divergent plate boundaries, sometime referred to as a “spreading center,” rifts are characterized by tensional (stretching) stress, block faulting and basaltic volcanism.
sandstone — a sedimentary rock composed of sand-size particles, cemented by calcium carbonate, iron oxide and silica.
volcanogenic — means “derived from volcanic rock.”
Lesson 2 Activities

Strike And Dip
Geologists measure the angle and direction of tilted rock layers in terms of strike and dip. Strike is the direction of a line formed by the intersection of a horizontal plane and an inclined rock layer. Dip is the angle of an inclined rock layer from horizontal, (See graphic on page 9 of this guide). Using a compass and protractor, estimate the strike and dip of the lava flows in this area. Compare your results with the strike and dip indicated on the large USGS geologic map of the area.

Relative Dating
Using the principles of relative dating determine the following:
Locate one of the thin veins of clastic material that cuts through the basalt lava flows at the Lake of the Clouds Overlook. Using the radiometric dating information in Figure 1, what can you say about the relative date of the event that produced the thin veins of clastic material?

Using the radiometric dating information in Figure 1, what can you say about the age of the Lower Part of the Copper Harbor Conglomerate?
1. Identify several lava flow layers on the area just east of the overlook wall by looking for the layers of vesicles that characterize the flow tops.
2. Measure the thickness of three lava flows, using flow-top structures to identify the individual flow layers.
3. Look for pipe vesicles at the bottom of a flow layer. Can you determine the direction that the lava was flowing when these vesicles were formed?
Lessons 3: Sedimentary rock features, sedimentation — Union Bay Campground, Upper Part of the Copper Harbor Conglomerate

Sedimentary Rock Concepts
Sedimentary rocks are composed of rock particles weathered from preexisting rock. The sequence of events that leads to the formation of sedimentary rock are:

1. The weathering or chemical and mechanical breakdown of preexisting rock producing rock fragments or sediment.
2. The transportation of this sediment by wind or water.
3. The deposition of sediment.
4. The compaction and cementation of the sediments into rock, calcite, quartz and limonite are common cementing minerals.

Most sediment is transported by streams, rivers, lakes, along shorelines and in shallow seas. For this reason, sedimentary rocks usually show layering or other features that formed as the material was moved, sorted and deposited by water currents. Common structural features found in sedimentary rock are:

1. stratification or layering,
2. cross-bedding,
3. graded bedding and
4. ripple marks and mud cracks.

Description
The eruption of the Porcupine Volcanics (Lesson 1) marked the end of major volcanism in the MRS, and further events were dominated by fluvial and lesser lacustrine sedimentation. In the Porcupine Mountains, the first sedimentary unit to develop over the Porcupine Volcanics is known as the Copper Harbor Conglomerate, a thick sequence of red volcanogenic conglomerate and sandstone. A series of thin basalt lava flows in the Copper Harbor Conglomerate (Lesson 2) mark the last volcanic episode in the development of the MRS.

Good exposures of tilted, reddish sandstone containing thin conglomerate beds of the Upper Part of the Copper Harbor Conglomerate are found along the shore of the Union Bay campground. This sandstone is primarily composed of clasts derived from the weathering and erosion of volcanic rocks marginal to the rift basin. Excellent examples of cross-bedding, (indicating a northeastward current vector), and other sedimentary features, including mud cracks and ripple

SITE LOGISTICS

Location — The Union Bay campground is one mile west of the junction of the South Boundary road and Hwy. M-107. If the campground office is open, stop and ask for permission to drive into the campground and examine the bedrock along the shoreline of Lake Superior.

Site Parking — Paved road and parking area at campground boat launch can accommodate buses.

Site Capacity — 40 or more persons

Restroom Facilities — Yes, pit toilets at boat launch

Trail Information — No trail, access is via campground road and along Lake Superior shore.

Accessibility — Not ADA accessible

Safety Concerns — Wet rock on shore can be very slippery; the water of Lake Superior can be very cold.

Special Considerations — Stay on durable surfaces to avoid trampling vegetation.
marks, are visible in the Copper Harbor Conglomerate. These sedimentary structures provide clues to the depositional environment present when this rock formation developed.

Several large boulders are distributed along the beach and are composed of conglomerate typical of the Lower part of the Copper Harbor Conglomerate as seen farther north on the Keweenaw Peninsula. They were probably transported here by glaciers from the vicinity of Isle Royale. These conglomerates contain clasts almost exclusively of the Keweenawan Supergroup volcanic rocks common in the region.

**Lesson 3 Vocabulary**

- **basalt** — a fine-grained igneous rock (45–52% silica), produced from mafic magmas.
- **clastic** — of clasts.
- **clasts** — fragments produced by the mechanical breakdown of rock.
- **conglomerate** — a coarse-grained sedimentary rock composed of rounded fragments of pebbles, cobbles or boulders.
- **cross-bedding** — a sedimentary rock feature in which sediment is deposited in strata that are inclined to the horizontal surface upon which the sediment accumulates, produced by wave or wind action.
- **fluvial** — pertaining to rivers or streams, sediment deposited in a river or stream environment.
- **graded bedding** — sedimentary beds characterized by a decrease in grain size from the bottom of the bed to the top. Often produced when sediment-laden water flows into a large body of water. Denser, sediment-laden water flows along the bottom of the water, with the larger sediments settling out of the water first and the smallest sediments settling out last.
- **lacustrine** — pertaining to lakes, sediment deposited in a lake environment.
- **mud cracks** — a sedimentary rock feature produced when fine sediment dries out and shrinks, can be observed today in areas where a mud puddle has dried-up.
- **sandstone** — a sedimentary rock composed of sand-size particles, cemented by calcium carbonate, iron oxide and silica. Sand is sedimentary material made of fragments of rock whose diameter is between 0.0625 to 2 mm.
- **siltstone** — a sedimentary rock composed of silt-size particles, cemented by calcium carbonate, iron oxide and silica. Silt is sedimentary material made of fragments of rock whose diameter is between 0.038 to 0.0625 mm.
- **stratigraphic** — the order of the strata in a sequence of rock.
- **ripple marks** — a sedimentary rock feature, asymmetrical ripple marks are produced as a result of current flow, in cross section the are gently sloped on the upstream side and steep sloped on the downstream side. Symmetrical ripple marks are produced by the back and forth motion of small waves in the sediment as might occur in shallow water.
- **volcanogenic** — means “derived from volcanic rock.”
Lesson 3 Activities

1. A basic principle of geology holds that when sediments are deposited, they accumulate in nearly horizontal layers, thus sedimentary rocks that are steeply inclined must have been tilted following deposition. Geologists measure the angle and direction of tilted rock layers in terms of strike and dip. Strike is the direction of a line formed by the intersection of a horizontal plane and an inclined rock layer. Dip is the angle of an inclined rock layer from horizontal. Using a compass, estimate the strike and dip of the rocks in this area. Compare your results with the strike and dip indicated on the large USGS geologic map of the area.

2. Locate and sketch sedimentary features in the Copper Harbor Conglomerate that provide clues to the sedimentary environment present when this rock was formed. Compose a paragraph or two explaining what your clues reveal about the sedimentary environment present when this formation was deposited.

3. Using radiometric dating methods (see lesson 1) geologists can determine the absolute date of formation of minerals and igneous rocks. Since radiometric dating is seldom helpful in dating sedimentary rock, how can we date this Copper Harbor Conglomerate relative to other rocks and events associated with the MRS? Hint: See age constraints listed in Figure 1.
Lessons 4 • Sedimentary rock features, sedimentation, weathering — Presque Isle River Scenic Area, Nonesuch Shale and Freda Sandstone

SITE LOGISTICS

Location — The Presque Isle River Scenic Area is at the west end of Porcupine Mountains Wilderness State Park. Access from the west is via M-28 to County Road 519 (just west of Wakefield Michigan) follow 519 north 15 miles. Access from the east is by traveling to Silver City (junction of M-64 and M-107 13 miles west of Ontonagon Michigan), follow M-107 three miles west to the South Boundary Road, turn south on the South Boundary Road and follow it 23 miles to the Presque Isle River Scenic Area. From the picnic area at Presque Isle, steps and boardwalks lead to the river corridor. The best location to view the Nonesuch Shale is on and along the small island near the river mouth. The Freda Sandstone is best viewed on the East River Trail near the South Boundary Road Bridge. Site Parking- Paved road and parking area at picnic areas can accommodate buses.

Site Capacity — 40 or more persons
Restroom Facilities — Yes, pit toilets at picnic area
Trail Information — Boardwalk, gravel and earth trail.
Accessibility — Not ADA accessible
Safety Concerns — The Presque Isle River is a large river with rapids, waterfalls, dangerous currents and undertows. Swimming and wading in the river is strictly prohibited.
Special Considerations — Stay on durable surfaces and trails to avoid trampling vegetation.

Description

The eruption of the Porcupine Volcanics (Lesson 1) marked the end of major volcanism in the MRS. Afterwards, geologic events in the rift basin were dominated by fluvial and lacustrine sediment deposition. The first sedimentary formation above the Porcupine Volcanics is the Copper Harbor Conglomerate (Lesson 2 and 3), a thick sequence of fluvially deposited red, volcanogenic conglomerate and sandstone. Deposited on top of the Copper Harbor Conglomerate Formation are the Nonesuch Shale and the Freda Sandstone.

The West River Trail at the Presque Isle River Scenic Area, which can be accessed from either parking area at the site, provides a good look at the upper portion of the Nonesuch Shale and the base of the Freda Sandstone. Since this part of the river is located on the northeast section of the Presque Isle syncline, (a northwest plunging fold that probably developed in response to the Grenville Orogeny), the rock strata along the river dips noticeably to the SW.

The name Nonesuch Shale is somewhat misleading since the formation contains sandstone, siltstone as well as some shale. Sedimentary structures seen in the Nonesuch Formation includes graded beds, symmetrical and asymmetrical ripple marks, mud cracks, and — near the mouth of the river — ball and pillow structures.

The graded beds found in the Nonesuch Formation suggest that the sediment or clastic material that makes up the rock was deposited by sporadic sheet floods which originated high on the alluvial fan produced along the margin of the MRS. Even moderate rainfall on a loose, non-vegetated land surface can produce extensive and fast-moving floods (recall that these events occurred approximately one billion years ago, long before land plants and other modern life forms appeared on Earth. The presence of wave ripples and the absence of cross-bedding structures indicate that
the Nonesuch was deposited in a shallow lacustrine environment. The sediment that produced the Nonesuch Formation was derived from the erosion of older Keweenawan rock and early Proterozoic and Archean crystalline rocks lying outside of the rift zone.

A dark, oily hydrocarbon is found in cracks and crevices of the Nonesuch Formation. Detailed analysis of this material has shown that it contains a variety of complex organic compounds including alkanes and porphyrins, and objects that appear to be the remnants of microscopic organisms. Porphyrins are a group of compounds found in living matter which are the basis of the respiratory pigments in plants and animals (chlorophyll, cytochromes, and hemoglobin are examples). The presence of these materials in the Nonesuch Formation suggests that plants had evolved photosynthesis by the time the rock was deposited approximately 1000Ma. The hydrocarbon deposits found in the Nonesuch Formation are much older than the hydrocarbon deposits utilized today to produce petroleum products, these date to the Mesozoic Era and are less than 200 Ma old.

Only the upper section of the Nonesuch Formation is visible along the Presque Isle River. The basal part of the Nonesuch contains large amounts of copper and silver, and it was this orebody that was mined at the White Pine Mine 20 miles to the east of the Presque Isle River. The ore at the White Pine Mine was composed of chalcocite (a copper-sulfur mineral) and native or metallic copper. Over the course of the mine’s operating life it produced approximately 4 billion pounds of copper and 45 million ounces of silver.

During times of low water, numerous large potholes are exposed in the riverbed. These features are produced by eddy currents that swirl small cobble and rock particles in a spiral path wearing away the bedrock.

The Freda Sandstone is a thick bedded, fine to medium grained reddish-brown sandstone and is the youngest of the Keweenawan rocks exposed in the Porcupine Mountains. The Freda Sandstone marks the return to fluvial deposition in the rift basin following the lacustrine deposition of the underlying Nonesuch Shale. By volume, the Freda Formation is the dominant unit in the post-rift sediment basin. On the Montreal River, 18 miles west of the Presque Isle, a 12,000 foot thickness of the Freda Sandstone is exposed along the river. Seismic reflection surveys indicate that it is even thicker beneath Lake Superior. On the Presque Isle River, near the South Boundary Road bridge, reddish cross-bedded sandstone typical of the lower part of the Freda sandstone can be seen.
Lesson 4 Vocabulary

**alluvial fan** — A fan-shaped deposit of gravel, sand and mud that accumulates at the base of mountain ranges.

**ball and pillow structures** — Rounded sedimentary structures thought to result from soft sediment deformation.

**clastic** — “of clasts.”

**clasts** — Fragments produced by the mechanical breakdown of rock.

**cross-bedding** — Sedimentary rock feature in which sediment is deposited in strata that is inclined to the horizontal surface upon which the sediment accumulates, produced by wave or wind action.

**fluvial** — Pertaining to rivers or streams, sediment deposited in a river or stream environment.

**graded-bed** — Sedimentary beds showing a progressive decrease in sediment grain size upward through the bed, often produced by turbidity currents.

**lacustrine** — Pertaining to lakes, sediment deposited in a lake environment.

**ripple marks** — A sedimentary rock feature, asymmetrical ripple marks are produced as a result of current flow, in cross section they are gently sloped on the upstream side and steep sloped on the downstream side. Symmetrical ripple marks are produced by the back and forth motion of small waves in the sediment as might occur in shallow water.

**sandstone** — A sedimentary rock composed of sand-size particles, cemented by calcium carbonate, iron oxide and silica. Sand is sedimentary material composed of fragments of rock whose diameter is between 0.0625 to 2 mm.

**siltstone** — A sedimentary rock composed of silt-size particles, cemented by calcium carbonate, iron oxide and silica. Silt is sedimentary material composed of fragments of rock whose diameter is between 0.038 to 0.0625 mm.

**shale** — A fine-grained sedimentary rock composed of clay-size particles. Clay is sedimentary material composed of fragments whose diameter is less than 0.038 mm.

**stratigraphic** — The order of the strata in a sequence of rock.

**syncline** — A “downfold” in layers of rock.

**turbidity current** — A sediment-laden water current that enters a body of water and, being denser, spreads across the bottom of the basin. Coarse sediment settles out of the turbid water first followed by the finer sediment particles producing a graded bed.

**volcanogenic** — means “derived from volcanic rock.”

Lesson 4 Activities

1. Locate and sketch evidence that indicates that the Nonesuch Shale Formation was deposited in a lacustrine environment, fluvial environment or combination lacustrine/fluvial environment. Compose a paragraph or two supporting your conclusions.

2. A basic principle of geology holds that when sediments are deposited, they accumulate in nearly horizontal layers, thus sedimentary rocks that are steeply inclined must have been tilted following deposition. Geologists measure the angle and direction of tilted rock layers in terms of strike and dip. Strike is the direction of a line formed by the intersection of a horizontal plane and an inclined rock layer. Dip is the angle of an inclined rock layer from horizontal. Using a compass and protractor, estimate the strike and dip of the rocks in this area. Compare your results with the strike and dip indicated on the large USGS geologic map of the area.

3. Locate and sketch evidence that indicates that the Freda Formation was deposited in a lacustrine environment, fluvial environment or combination lacustrine/fluvial environment. Compose a paragraph or two supporting your conclusions.
References/Websites

(Available at PMSP for loan to educators. Contact Robert Sprague (906) 885-5206.)

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Unit Overview
At Presque Isle Park, several geological features or processes may be observed. Jacobsville sandstone and serpentinized peridotite form the bedrock of the Island, and a thin veneer of glacial sediment blankets most of the island’s interior. Outcroppings along the shore provide excellent views of the Early Cambrian/late Proterozoic Jacobsville Sandstone, and its nonconformable contact with the underlying peridotite. Also, shoreline processes (wave action) may be observed from many places in the park. Glacial features (erratics and a postglacial lake wave-cut bluff) may also be observed.

Learning Objectives
Students will be able to:
1. Identify sandstone, sedimentary structures, sedimentary texture
2. Recognize glacial erratics and former glacial shorelines
3. Measure shoreline (wave) physical characteristics
4. Recognize mineralization veins and identify several sulfide minerals
5. Identify an unconformity

Synopsis of Lessons in the Unit
At several locations around the park, students will observe, collect, and measure various geologic phenomenon. At the first stop, three different lessons may be undertaken. The Jacobsville Sandstone can be examined near the Upper Harbor breakwall, as can glacial erratics and elevated wave-cut bluffs of former lakes occupying the Lake Superior basin, and shoreline (wave) processes.

Michigan Content Standards Addressed

Science:
Earth Science, Solid Earth, Middle School (V.SE.M.1-5)
1. Describe and identify surface features using maps
2. Explain how rocks and minerals are formed
3. Explain how rocks are broken down, how soil is formed and how surface features change
4. Explain how rocks and fossils are used to understand the age and geological history of the earth.

Earth Science, Solid Earth, High School (V.SE.H.1-2)
1. Explain the surface features of the Great Lakes region using Ice Age theory.
2. Use the plate tectonics theory to explain features of the earth’s surface and geological phenomena and describe evidence for the plate tectonics theory.

Physical Science, Waves and Vibrations (IV.PWV.3)
3. Describe waves in terms of their properties
Introduction
Presque Isle Park, owned by the City of Marquette, has many features of geologic interest. This two-mile hike or drive around the park allows earth scientists to easily examine these features. To learn more about the park: http://www.mqtcty.org/departments/parksrec/presque.htm

Stop 1 • Activity 1 — Jacobsville Sandstone
GPS Coordinates 470841E, 5158365N, Zone 16N, NAD27 Datum
Time to Complete • 30 minutes

Introduction
Examine the Jacobsville Sandstone and collect samples. The Jacobsville Sandstone is a fluvial, continental (red-bed) sandstone of Late Proterozoic to early Cambrian age. It has abundant reduction markings along permeable zones (texturally and in fracture zones) where the red iron cement has been leached away or by local chemical reactions (spots).

Materials Needed
- Rock hammer
- magnifying (hand) lens
- safety glasses
- compass
- collecting bag
- notebook

Characteristics of the Jacobsville Sandstone
a. Is thinly to very thinly bedded here.
b. Very poorly cemented and easily fractured — note the joint system — useless as building stone at this site. In the south Marquette (Brownstone) quarry, much thicker beds are found that are also well-cemented — both are characteristics necessary for a good building material.
c. Note the cross bedding — indicates a deltaic origin?
d. Note the pebbles in it — also indicate a near shore depositional environment.
e. Note the white streaks due to leaching of iron along joint cracks and highly permeable areas. Also, note the round white spots (created by a reduction reaction) surrounding some tiny mineral fragments in the sandstone.
f. The reddish-brown color is mostly due to hematite cement.
**Procedure**
Display a sample of sandstone to show its textural and composition characteristics.

Examine the texture — use the hand magnifying lens to view the size, range of sizes, and composition of the grains.

Examine the color and variation in color of the sandstone (also reduction spots and bands).

Examine the sedimentary structures (cross bedding) in the vertical outcrop face (to determine flow direction) and measure their orientation.

**Student Discussion Questions**
- What is the texture? (sand? Gravel? Mix? too small to tell?)
- What is the range of sizes? (all one size or wide range?)
- What is the composition? (quartz, feldspar, ferromagnesian minerals?)
- What is the cement? (use dilute HCl to test for carbonate, if desired)
- What is the overall color? (Mostly red hematite staining, with white mottles and bands due to leaching of iron)
- What are the sedimentary structures? What do they tell us? (cross bedding, flow direction, and likely depositional environment)
- What was the flow direction?
- Do you see any fossils? Why not?

Paleogeography during Cambrian time, and deposition of the Jacobsville Sandstone (from Hamblin)
Summary
The site exhibits a continental “red-bed” sandstone originally deposited in a stream environment, probably transitional shoreline such as a delta. The coarse sandstone varies from some fines to mixed with gravel. Cross bedding suggests fluvial environment (Flow is basinward, toward NNE). In places (as in a later stop) thin beds of silt/mud are found with the sandstone. This suggests a periodically inundated (lacustrine) environment. Compositionally, it is immature, having a mix of quartz, feldspar, and ferromagnesian minerals (mostly quartz, though). It can be considered a feldspathic quartz sandstone. It is weakly cemented and therefore a poor building stone here. At other places the Jacobsville Sandstone is quarried. Many buildings in Marquette and across the U.P. use the Jacobsville Sandstone for foundations and wall construction.

Post-Field Trip Classroom Activities
View the samples under a microscope, if possible, for further analysis of texture and composition.

Glossary/New Vocabulary
- Sandstone maturity
- Environment of deposition
- Cross bedding
- Cement

Common use of Jacobsville Sandstone as building material.
Stop 1 • Activity 2 — Glacial Features

Time to Complete Approximately 15–20 minutes

Introduction
While at Stop 1, Activity 1, observe the boulders resting on the Jacobsville Sandstone. Lithologically, they are gneiss. Because they are different (lithologically) from bedrock found anywhere on the Island, they are considered to be glacial “erratics.”

Materials Needed

- Notebook

Procedure
Identify the lithology of boulders resting on the Jacobsville Sandstone, then discuss their origin and how they got there. Cite evidence for glaciation.

Activity Descriptions
Have the students identify lithologies of boulders greater than about 1 cubic foot in volume. Record them. Determine the most abundant lithology. Potential source?

Student Discussion Questions
How did rocks of lithologies different than the bedrock anywhere on the island get here?
How many different lithologies are there? Is one dominant?
Can you tell where they came from?

Summary
The erratics provide evidence they were transported there by glaciers. It is not easily possible (if at all) to determine their origin. Only through detailed lithologic comparison may it be possible to estimate their provenance (origin).

Glossary/New Vocabulary

- Erratic
- Provenance
Stop 1 • Activity 3 — Wave-cut Bluff

Introduction
After Activities 1 and 2, return toward the parking lot, near the gazebo (or for a better view, walk to the bandshell, about 100 yds northwest) to observe the a wave-cut bluff. The bluff was eroded by a lake stage some 25 feet higher than modern Lake Superior, called Lake Nipissing. Lake Nipissing waves eroded the shoreline in the same way that Lake Superior is eroding the shoreline today. Lake Nipissing existed from about 5000 years before present (ybp) to about 3500 ybp. A drop in lake level was due to the opening of lower outlets and erosion of the sill at Sault St. Marie, which now controls the lake level. Such landforms provide evidence of former lakes that occupied the Lake Superior (and other Great Lake) basin.

The Story of Successive Lake Levels:

a. Lake Duluth stage — ice occupied most of eastern Lake Superior, the outlet for Lake Duluth was down Mississippi River. Lake levels were as high as 1,200' (modern Lake Superior at 602') in the western Lake Superior Basin but ice still occupied the Marquette area and eastern U.P. 9,000 years ago.

b. Lake Minong — ice front aligned NW-SE blocking the east end of Lake Superior basin (Lake levels at 800'+) but now a continuous lake in the eastern and western Lake Superior basin. 7,000 years ago.

c. Lake Nipissing — about 25 ft. higher level than now — Much of northern Marquette was under water. The shoreline was here, at the base of the bluff. Shorelines may also be seen at little bluff along NMU campus and many places in Marquette, as well as around the southern shoreline of Lake Superior. 3,500–5,000 years ago.


Materials Needed

Notebook

Procedure
At this activity, start by describing the glacial lakes that occupied the Great Lakes basins after retreat of the glaciers (after 10,000 ybp). Retreat of the ice allowed ice-marginal lakes (which stood at much higher levels than the modern lakes) to drain at lower outlets. Also, the crust subsided under the weight of the ice, and after the ice retreated, the crust began to “rebound” to its former position.

Activity Descriptions
Have the students identify the bluff, and estimate the slope (it is around 35 degrees). Also, the bluff may be observed at many places around the island. It is very prominent on the west side, behind the large pavilion.

Student Discussion Questions
What process created the steep bluff?
Why is it so prominent? (not eroded away, and lake must have persisted for a long enough time to create this significant landform)
Summary
The bluffs eroded by lakes at higher levels provide evidence of glacially controlled outlets and the history of lake levels in the basin.

Glossary/New Vocabulary
- Lake Nipissing
- Stage
- Wave-cut bluff

Stop 1 • Activity 4 — Waves
Time to Complete Approximately 20-30 minutes

Introduction
At this stop, wave processes may be examined from the breakwall, which serves to protect the upper harbor from large waves.

Materials Needed
- pencil, paper
- a stick from the shore
- wave forecasting chart
- notebooks
- Deep Water wave forecasting nomograph

Procedure
A short walk onto the breakwall will permit students to observe wave action. The period of a wave, wavelength, and wave reflection, and refraction may be easily observed.

Activity Descriptions
Wave period and length: Make a visual estimate of wavelength from a consistent train of waves (there may be more than one set of waves approaching shore of different periods). Then, toss a stick in the water away from the breakwall and with a stopwatch, observe waves approaching passing the stick, and start the watch when the crest of a wave reaches the stick. Count the number of wave crests that pass under the stick in one minute. Divide into 60 seconds to get wave period. Discuss the meaning of wave period and wavelength. Also, observe the changes in period, wavelength, and wave height, and refraction as the waves approach shore. Explain the process. Discuss factors in wave size (fetch, wind speed, duration of wind at that speed). Refer to wave height chart (nomograph) below.

Discuss the purpose of the breakwall (affords safe harbor for ships and boats).
Student Discussion Questions

Are wave period and wave length related in some way? What?
Why do wave periods and lengths vary?
Why do waves slow down as they approach shore? Does the period change?

Compare waves one the north side of the breakwall to those on the south side. How effective is the breakwall in reducing the wave energy (as it was designed to do)?

Summary
Wave action and size is the result of frictional resistance as winds blow across the water. The 3 important variables in wave size are 1) Fetch, 2) Wind speed, and 3) Wind duration.

Glossary/New Vocabulary
Wave period
Wavelength
Wave height
Wave reflection
Wave refraction
Breakwall
Stop 2 • “The Cove” and Sulfide Mineralization

GPS coordinates — 470931E, 5195723N, Zone 18 UTM, NAD27 Datum
Time to Complete 30–60 minutes

Directions
Proceed along the circle drive (traveling counter-clockwise around island) down the long, sloping hill almost to the northwest end of the Island (about a mile from the entrance where the one-way road starts). Near the bottom of the hill, you will see an entrance road leading to a dirt parking lot. The entrance road trends at almost 180 degree angle to the main, paved road, so a sharp downhill turn to the right is required. Park toward the right side of the lot, near the large cove. A trail is found along the right side of this cove, leading uphill at first, then back downhill to the lake and will bring you to the exploration pit and the mineralized veins.

Introduction
At this stop, students can find and collect samples of sulfide minerals often associated with precious metal mineralization. Veins containing the minerals pyrite (FeS), chalcopyrite (CuFeS), galena (PbS) cut across the serpentinized peridotite bedrock. Additionally, a small exploration pit is found at the site. The serpentinized peridotite was originally an olivine-rich ultramafic igneous rock (peridotite) that was metamorphosed. The light veins in the rock are dolomite and the reddish-colored veins are chert. Serpentinized peridotite weathers to a brown, black, or light green color. Note the joints that make a blocky pattern when the rock is exposed at the surface. The intrusion was apparently quite small — perhaps 1-2 miles in diameter at the top — is surrounded by granitic rocks at Dead River on the south, and the “White Rocks” toward the north.

Materials Needed
- rock hammer
- safety glasses
- collecting bag
- magnifying hand lens
- flashlight
- field notebook.

Procedure
At this stop, veins of quartz containing small crystals of several different sulfide minerals are found trending SE-NW and generally dipping steeply toward the NE, although some dip at a nearly vertical angle. The minerals pyrite, chalcopyrite, and galena may be found. Although many collectors over the years have extracted the best specimens, small crystals may still be found with a bit of effort. Look for brownish staining at the surface (oxidation) and explore those areas further. One of the major veins terminates in a small, vertical “cave” about 3–4 feet deep on the south end of the exposure, and at the back are crystals, but just out of arm’s reach (bring a flashlight to see them). Exploration around the area will certainly be rewarded with new “finds.” An old exploration pit, about 2.5m diameter and 3m deep is found at the south end of the outcropping. The New York and Lake Superior Mining Company, in 1845, extracted only three tons of ore, because the galena had microscopic traces of silver in it. The exploration ceased once it was determined the ore body did not improve with depth. The bottom of the pit has a small opening to Lake Superior (forming a small arch).

Asbestos, a natural, fibrous form of serpentine, is found in veins cutting the peridotite. The veins tend to follow faults (a brittle fracture of the rock in which significant movement has occurred, which are porous). The amount of movement cannot be ascertained; however the direction of
its last motion is preserved by the slickensides, as seen on the rock surface. Slickensides are fine, parallel “scratches” formed by the movement. Along the large, exposed face of the rock on the footwall side of the fault (aspect faces east), slickensides are nearly vertical. Thus, the fault may be considered a “dip-slip” fault. At this site, we cannot tell whether it is a “normal” or “reverse” dip-slip fault as there is no way we can tell which block moved relative to the other.

Also, describe the shoreline feature “cove” containing the rocks and mineralized veins. A cove is a small sheltered recess in a shore or coast, generally inside a larger embayment. In this case, as in many, the cove is formed because of a weaker portion of the rock mass has eroded away more quickly than the surrounding rock.

**Activity Descriptions**
- Find and extract sulfide mineral crystals. Identify.
- View fault and slickensides.
- View exploration pit

**Student Discussion Questions**
- What is the direction (strike) and inclination (dip) of the main fault?
- How much movement (throw) has there been? (can’t tell…Can only get a sense of movement from the slickensides). The slickensides are oriented “up-down” so this is a “dip-slip” fault. Movement was along the dip direction. We cannot tell whether the fault is a “normal fault” (extensional) or a “reverse fault” (compressional) simply by examining the slickensides. The relative sense of movement must be made by comparing distinct lithologies or features on either side of the fault plane.

**Summary**
Exploration activities on Presque Isle found insufficient mineralization to warrant production. Veins containing sulfide minerals, carried through permeable fault gouge (pulverized material along the fault plane) are recognized as a potential source for silver.

**Post-Site Classroom Activities**
- Examine minerals collected at the site.

**Glossary/New Vocabulary**
- Dip-slip fault
- Footwall
- Hanging wall
- Slickensides
- Throw
- Cove
Stop 3 • The “Great” Unconformity

GPS Coordinates — 470441E, 5159448N, Zone 16 UTM, NAD27 Datum
Time to Complete 20–30 minutes

Directions
Drive or walk counter-clockwise approximately ¼ mile from Stop 2 (Cove), past the NW corner of the island (locally known as “Sunset Point”) to a steep embankment at the shore (most of the shore is steep here), looking for the highly altered and veined peridotite overlain by a conglomerate facies of the Jacobsville Sandstone about ½ ft. thick, which grades sharply into an overlying shale facies. The sedimentary layers dip at about 10 degrees westward here and form the Nonconformity.

Introduction
At this stop, an unconformity (specifically, a nonconformity) between the serpentinized peridotite and the overlying Jacobsville Sandstone may be observed. The hiatus represented by the nonconformity is approximately 1.1 billion years (Jacobsville Sandstone is approximately 600 million years old, the serpentinized peridotite is thought to be about 1.7 billion years old). The peridotite probably intruded into pre-existing metasedimentary rocks and igneous rocks (now eroded away) during the Penokean Orogeny that occurred approximately 1.7 billion years ago. The Penokean mountain range trended east-west across the Upper Peninsula and rivaled the modern Rocky Mountains in size. They have since weathered and eroded away. They formed as the result of continental convergence in a north-south direction between 1.8-1.7 billion years ago. The convergence deformed and metamorphosed most rock that pre-existed in the region. A long period of weathering and erosion nearly leveled the terrain (probably similar to the topography of today) before rifting began, centered along the axis of Lake Superior about 1.1 billion years ago. Subsidence of the Lake Superior basin allowed flood basalt to accumulate, and once volcanism ceased, the still-subsiding basin filled with sediments derived from highlands flanking the basin. The last of this thick sedimentary sequence is the Jacobsville Sandstone. The Jacobsville Sandstone at Presque Isle was deposited directly on top of serpentinized peridotite. Thus, the peridotite must have been exposed at that time. In other places locally, the Jacobsville Sandstone may be viewed with an unconformable contact with other Proterozoic-aged rocks that were exposed at the surface (as an angular unconformity with the Mesnard Quartzite at the southern end of the lower harbor, for example). Thus, the pre-Jacobsville surface exposed at the surface of the earth must have been similar to the topography and relief we see today.

Materials Needed
- notebook

Procedure
Teach about a relative age dating principles, and the significance of unconformities.

Have the class look at the stratigraphy of the rocks in the area, and find a major difference (the unconformity).

Then, identify the rocks above and below (Jacobsville SS above and serpentinized peridotite below). At the base of the Jacobsville SS, there is a basal conglomerate (notably, includes clasts of the peridotite, principle of inclusions). Explain the “Principle of inclusions.”
**Student Discussion Questions**

What are the major lithologies found here?
How can you tell that the rocks were not deposited within a short period of time?
How can you tell that the sandstone is younger?
What is the type of unconformity?
Can you infer the length of the hiatus by studying the rocks?
What is the principle of inclusions?

**Summary**

A nonconformity is well-displayed here. A conglomeritic facies (a basal conglomerate) of the 600 Ma Jacobsville Sandstone lies directly on top of the 1.7 Ga serpentinized peridotite. The peridotite is found as inclusions in the conglomerate, and therefore must have been exposed prior to Jacobsville deposition.

**Post-Site Classroom Activities**

Use relative-age block diagrams to place geologic events into relative order. Cite the relative age principle used in each interpretation.

**Glossary/New Vocabulary**

- Hiatus
- Inclusion
- Nonconformity
- Peridotite
- Serpentinized
- Unconformity

**References/Websites:**

Tahquamenon Falls State Park

41382 West M-123, Paradise, MI 49768  Tel: 906-492-3415

**Field Trip** • Time to Complete: 1–1.5 hours

**SITE LOGISTICS**

**Hours** — 8:00 am to 10:00 pm year-round

**Site Parking** — 195 cars, will accommodate buses

**Site Capacity** — 25–30 people

**Restroom Facilities** — Accessible restrooms are located near the parking area.

**Trail Information** — Map at beginning of trail, or handouts available at office.

**Accessibility** — The parking area and trail are handicap accessible, however the 150 steps down to the sampling area are not.

**Safety Concerns** — Steep and slippery steps, slippery footing, falling objects are all a possibility.

**Special Considerations** — be aware and try to avoid causing erosion steep rock faces.

**Site Description:** Tahquamenon Falls State Park is the second largest state park in Michigan, encompassing more than 38,000 acres. The centerpiece of the park is the Tahquamenon River.

**Topics Addressed:** Law of Superposition, sandstone formation—including cross bedding, ripple marks, and sorting.

**Learning Objectives**

*Students will be able to:*

State the law of superposition
Define the concept of sorting
Define the concept of bedding
Explain how sedimentary rocks are formed

**Synopsis of Lessons**

Geology can tell you a great deal about history. In fact, you can learn a lot about history by studying types of rocks and how they were formed. Sedimentary rocks provide a more detailed and more easily read and understood account of what happened historically than other types of rock.

**Driving Directions**

*From the Mackinac Bridge:*

I-75 north to exit #352. Turn left (west) onto M-123 toward Paradise. Turn left (west) at the blinking light in Paradise to continue on M-123. Lower Falls is 10 miles west of Paradise, Upper Falls is 14 miles west of Paradise.

*From Newberry/M-28:*

Turn north onto M-123 at the blinking light near McDonald’s and Comfort Inn. The Upper Falls is 25 miles ahead, the Lower Falls is 29 miles ahead.

**Michigan Grade Level Content Expectations**

**Science**

*Earth Science, Solid Earth, Middle School (V.SE.M.1-5)*

2. Explain how rocks and minerals are formed
3. Explain how rocks are broken down, how soil is formed and how surface features change
4. Explain how rocks and fossils are used to understand the age and geological history of the earth.

*Earth Science, Solid Earth, High School (V.SE.H.1-2)*

1. Explain the surface features of the Great Lakes region using Ice Age theory.
Introduction and Activity Overview
Tahquamenon Falls State Park has one of the most easily studied extensive outcrops of Cambrian Sandstone in Eastern Upper Peninsula. One of the best areas to view this sandstone is in the gorge below the Upper Tahquamenon Falls. The area between the Upper Falls and the lower level viewing area (the boardwalk) is off limits. Due to eroding rock walls, this area is no longer safe and people are not permitted there. However, downstream of the lower level viewing area is another outcrop of the same sandstone and is relatively easy and safe to get to.

The bedrock at Tahquamenon Falls State Park is composed of Cambrian Sandstone of the Munising Formation. There are two distinct members found here at the park. The Upper Falls area is Miners Castle member and at the Lower Falls is the Chapel Rock member. Sandstone is a sedimentary rock that is formed particle by particle, layer by layer, under normal earth surface pressure and heat. Sedimentary rocks provide an easily read and understood account of what happened historically during the time that rock was forming.

The layers (beds) of the sandstone reveal what was happening during the period the sandstone was forming. Some examples that can be seen are bedding, cross bedding, ripple marks and sorting. These can all be viewed, studied, and learned at this location.

Instructional Objectives

Students will be able to:
1. State the law of superposition
2. Define the concept of sorting
3. Define the concept of bedding
4. Explain how sedimentary rocks are formed

Materials Needed
- Hand lenses
- Plastic resealable bags to collect and label samples
- Student record sheet
- Journals to record observations
- Digital camera

Procedure
1. Gather students at the parking area of the Upper Falls. Give a brief introduction of what the program is going to include. Take students down the paved trail towards the Upper Falls but stay to the left when you come to a “Y” in the trail. Follow the trail until the pavement ends at a set of steps. Go down the 116 steps to the edge of the water. Follow the foot trail on the downstream side of the steps, up the hill to the exposed rock face. Walk the group along the rock face in a single file line, encouraging the students to observe the rock face. Ask the students to describe what they see. Explain that this is a sedimentary rock known as sandstone. This particular type of sandstone is of the Munising formation and specifically is Miners Castle member.

2. Next, point out examples of bedding—or layers of sand—deposited over time. Sedimentary rock is formed by many deposits of small granular minerals and small pieces of older rock that has been worn or broken down. This sandstone was formed by ancient waters that transported and deposited all those particles. Layers began to build up and normal earth surface forces and temperatures compressed all the grains into a more solid rock. Some of the sandstone was formed with gently flowing water and has characteristic well sorted particles. The majority of the particles are all about the same general size. There are also some layers that have a variety of grain sizes and were
deposited by more turbulent waters. As water velocity slows, its ability to carry suspended objects decreases and heavier objects drop out.

3. Some layers will have a diagonal pattern of layers, called cross bedding which is caused by the wave action of water. The waves leave ripple marks in the sand under the water and as time passes, those ripples get filled in. What you see when you look at cross bedding is a side profile of the rock where water has cut through. If you looked at it from the top, then you would see a geologic feature called oscillation or wave ripple marks (visible at the Lower Falls).

4. Pass out hand lenses and have students look at some of the layers to observe the particle size and try to determine if that layer is well or poorly sorted and what kind of water forces produced that sorting. Ask students to point out different layers and state whether the older rock is on the bottom or top. As a general rule the deeper you go, the rock gets older (unless disturbed). That is the Law of Superposition—a fundamental principle of geology. Have students collect samples of grains to study at a later time.

At the end of the field trip, follow the trail back to the parking lot (0.3 miles).

Post-Site Classroom Activities

1. Follow up study on Munising formation sandstone to determine mineral composition of particles forming this sandstone.
2. Compare sandstone found at Upper Tahquamenon Falls with sandstone found at the Lower Falls, or other types of sandstone found at other locations.
3. A comparative study of particle grain size of different sandstones, with measurements.

References/Websites:

2. Geology of Michigan John A Dorr, Jr. and Donald Eschman
3. Cambrian Sandstones of Northern Michigan, WM Kenneth Hamblin

Pre Test and Post Test: Geology at Tahquamenon Falls State Park

Explain the Law of Superposition as it pertains to geology.

Unless disturbed, would the rock closer to the surface of the ground be older or younger than the rock below it?

Explain what sorting means in relation to sedimentary deposition.

How is cross bedding formed?
Glossary/New Terms

**The law of superposition** states that generally as you proceed down through layers of undisturbed rock, the rock gets older. This is a fundamental principle of geology.

**Sorting** is how well the grain particles match each other in size. Well/good sorting is where all grains are approximately the same size usually caused by water or wind. Poor sorting has a variety of grain sizes and is caused by ice or turbid currents.

**Bedding** is the layers/strata caused by periods of deposition. Thin bedding means relatively short period of deposition. Thick bedding means relatively long periods of deposition.

**Cross-bedding** is caused by moving currents (as seen from a side profile of the layer).

**Ripple marks** are also caused by moving currents (as seen from the top of the layer). Current ripple marks caused by currents of water. Wave or oscillation ripple marks are caused by waves.

**Friable** is when a rock such as sandstone, breaks off easily in layers easily because of poor cementing agents.

**Caprock sill** is the harder, more resilient and better cemented layer of sandstone found at the crest of the Upper Falls.

**Sapping** is, in the case of Tahquamenon Falls, where the relatively softer sandstone under the harder more resilient sandstone gets eroded by the moving water of the falls causing the upper layers to fall off and thus the falls “walk.”

The upper layer of the upper falls has a much harder rock at the crest. This harder rock is more resilient and referred to as a **caprock sill**.

Three main rock types:

- **Igneous rock** forms from molten magma.
- **Sedimentary** rock forms from deposition of material then pressed under normal pressures and temperatures.
- **Metamorphic** rock is formed under great heat and pressure.

The Cambrian sandstone found at Tahquamenon Falls State Park is of the **Munising formation**. The Upper falls is of the younger **Miners Castle** member usually poorly sorted and friable. 95% quartz.

The Lower falls is of the older more resilient **Chapel Rock** member; well sorted with better cementing (memorizing trick: “hard as a rock”).

References/Websites:


TAHQUAMENON FALLS STATE PARK—GEOLOGY OBSERVATION SHEET

1. Find an example of bedding (layering).

   a. Is the bedding thick or thin? ____________________

      i. Thick bedding = __________ periods of deposition.

      ii. Thin bedding = __________ periods of deposition.

   b. Are the particles rounded or sharp with edges? ____________________

   c. Are the particles large, small, or mixed? ____________________

   d. Is the sorting good or poor? ____________________

   e. What do the above characteristics tell you about the history of this area? ____________________

2. Find an example of cross bedding. Draw it below.

   a. What forces of nature cause cross bedding? ____________________

   b. Which direction were the particles traveling? Place an arrow representing the direction in your drawing above.
Geologic Concept(s) Addressed: Thousands of years ago, prehistoric miners discovered pure copper in the rock outcrops of Adventure Bluff. They mined these outcrops for centuries and then vanished, leaving behind primitive tools and countless mining pits. These ancient workings were later discovered by mid-1800s prospectors and became the locations for the numerous shafts and miles of tunnels excavated to become the Adventure Mine. From 1850 through the 1920s, the Adventure Mining Company removed over a thousand tons of pure metallic native copper and silver, yet still more remains than has been taken away.

Driving Directions: Adventure Rd. Greenland, MI 49929 (39 miles south of Houghton, or 12 miles east of Ontonagon)

Fees: Adults $10–$50, Children $6–$40 (depending on tour choice)

Site Capacity: Minimum number of participants is 2, call ahead if you have a large group or strict time schedule, space is limited (maximum tour size = 12*)
*groups of 12 or more may receive a discount if arrangements are made in advance (standard discount is 15%)

Restroom Facilities: Restrooms available at the surface, but not underground during tours

Safety Concerns: No open-toed shoes, sandals, clogs, high heels, or other non-suitable footwear

Instructional Objectives
Students will be able to:
1. Explain the distinguishing properties of native copper (soft, shiny, wiry) and explain how these relate to its usability as a resource.
2. Explain some of the safety issues surrounding an underground mine.
Area Mines and Museums

Caledonia Mine — Red Metal Minerals

Richard Whiteman, owner; 28855 Caledonia Rd, Greenland, MI 49948
Tel: (906) 884-2488 • Email: caledoniamine@charter.net or copper@red-metal.com

Site Description: The Caledonia Mine provides students with an opportunity to see modern mining and fresh specimens of minerals and ores. The tour begins at the pavilion outside the mine entrance where everyone will be given a hardhat and receive required hazard training. The history and geology of the mine and mining methods is presented. The students will then tour the mine to see mining techniques, equipment, and geologic features. After, students will have a chance to collect mineral samples inside the mine and on the rock pile outside the mine. The mine is inspected annually to ensure safety. The mine is home to 500,000 bats during most of the year.

Geologic Concept(s) Addressed: The Caledonia Mine is an active copper and silver mining operation that still extracts specimens of copper, silver, and other Keweenaw minerals from a series of lava flows within the region.

Driving Directions: Take M-26 South until it Junctions with M-38 West. Stay on M-38 West to First/Ridge (it is the road after Fourth Street). Turn left onto First/Ridge. This road becomes Ridge Rd. Ridge will veer to the left at the point where Caledonia meets Ridge. Go straight onto Caledonia Road. Follow Caledonia Road to the mine parking area. You will notice the pavilion from the road. Be careful because the road becomes dirt after the split and there is a steep spot covered in rocks near the mine entrance.

Parking: Just outside of the mine entrance is a large dirt parking area. There is plenty of room for buses to turn around and parents to park.

Fees: Reservations Required $4 per person for 1.5 hour tour if hard hats and flashlights provided by school/students; $10–$15 for 2–3 hour tour; $20–$35 for longer tour. Full mining equipment can be rented.

Site Capacity: Minimum of 10 students; maximum of 100. $100 minimum fee

Restroom Facilities: Two port-a-johns located in the parking lot outside the mine

Accessibility: Wheel chair accessibility is limited, but they could go into the mine a short distance to look around.

Safety Concerns: It is damp and cold in the mine (45-48 degrees year round!). Students should wear warm clothes, closed-toe/hiking shoes or boots, and hardhats, and bring flashlights, hammers, gloves, bucket/bag for specimens, and safety goggles (required for collecting). The Caledonia mine is inspected twice a year for safety to insure the supports are strong and there is minimal chance of danger. NOTE: This is private property, ask before collecting.
Instructional Objectives

*Students will be able to:*

1. Explain the distinguishing properties of native copper (soft, shiny, wiry) and explain how these relate to its usability as a resource.
2. Explain some of the safety issues surrounding an underground mine.

**Description of Minerals In the Rock Piles:**

*Native Copper* — Look for the distinctive light green copper stain on the surrounding rocks. The copper is wiry, soft, and metallic red. It can be pounded to flat sheets, a wire brush can remove good amounts of surrounding rock, and 1-2 days in a vinegar bath can dissolve most of the surrounding rock.

*Native Silver* — No green copper stain on surrounding rocks, but similar properties. It is a brilliant white color.

*Datolite* — Look for bumpy, round knobs of varying color. It has a smooth glassy surface rather than a sharp angular surface.

*Epidote* — A solid green mineral that can be smooth or bumpy.

*Orthoclase Feldspar (Potassium feldspar)* — Hard, white to pink in color. Distinguishable because it will create a “Feldspar flash” at the right angle. This flash is a very bright surface reflecting nearly all of the sun’s rays on the surface.

*Calcite* — Creates clear to pink square crystals, softer than most other rocks, and will easily scratch. A good, clear sample will refract light.

*Quartz* — Typically white in color with smooth surface and crystals will come to a point. A sample with multiple points will be more attractive.
Site Description: This museum is dedicated to preserving the Marquette Range Iron Mining Heritage. On December 22, 1967 the Cliffs Shaft mine closed. This ended the longest operation of an underground iron mine in the world. With the ground breaking of the “Old Barnum” pit in 1867 to the last hoist of a skip full of ore on a Friday afternoon in 1967, the operations for this small location in the far north of Michigan operated for a hundred years. The test shafts of “New Barnum” mine had become the expansive operations of the “Old Cliffs Shaft.” The mine had produced 27 Million tons of high grade ore, and had extensive workings below Ishpeming to a depth of 1357 feet.

Driving Directions: Located in Ishpeming, turn south at the stoplight for US-41 and Lake Shore Dr. near McDonald’s Restaurant. Drive until you see the obelisk.

Fees: Nominal admission for adults

Hours: Open May–October, Tuesday–Saturday, Noon–5 pm
Area Mines and Museums

Delaware Mine

7804 Delaware Mine Road, Mohawk, MI 49950 • Tel: (906) 289-4688
Email: info@delawarecopperminetours.com • Website: www.delawarecopperminetours.com

Site Description: Delaware is an authentic copper mine dating back to 1847–87. Eight million pounds of Copper were removed from the five shafts that reached a depth of 1400 feet with ten various levels. The tour takes you to the first level at 110 feet. You’ll see veins of pure copper exposed in the walls of the mine along with other geologic points of interest.

Driving Directions: The mine is located off of US-41, 12 miles south of Copper Harbor.

Hours: Tour schedule 7 days a week, 10 am–6 pm June, July, and August, 10 am–5 pm September and October. Last tour ends 45 minutes before closing.

Restroom Facilities: Restrooms available

Safety Concerns: Students should wear warm clothes, closed-toe/hiking shoes or boots, and hardhats.

Instructional Objectives
Students will be able to:
1. Explain the distinguishing properties of native copper (soft, shiny, wiry) and explain how these relate to its usability as a resource.
2. Explain some of the safety issues surrounding an underground mine.
Iron County Museum

424 East Museum Road, Caspian, MI 49915
Tel: (906) 265-2617 • Email: icmuseum@up.net Website: www.ironcountymuseum.com

Driving Directions: 2 Miles off U.S. 2 at Iron River, or in Caspian, off M-189.

Fees: Admission charged

Hours: May: Mon.–Fri. 8:30 am–2 pm
June–August: Mon.–Sat. 9 am–5 pm, and Sun. 1–5 pm
September: Mon.–Sat. 10 am–4 pm and Sun. 1–4 pm
Other times by appointment.

Site Capacity: Groups welcome

Restroom Facilities: Restrooms available

Accessibility: Wheelchair accessible

Safety Concerns: No open toed-shoes, sandals, clogs, high heels, or other non-suitable footwear
AREA MINES AND MUSEUMS
Iron Mountain Iron Mine
Vulcan, MI 49892 • Tel: (906) 563-8077 • Email: ironmine@uplogon.com
Website: www.ironmountainironmine.com

Site Description: Travel 2,600 feet through drifts and tunnels to 400 feet below the earth’s surface where you will see amazing rock formations and large underground lighted caverns. This is the only underground iron mine tour in Michigan and a state historical site. Free ore samples.

Driving Directions: The Iron Mountain Iron Mine is located 9 miles east of Iron Mountain on US-2 in the town of Vulcan, Michigan.

Fees: Admission charged

Site Capacity: School and bus groups welcome

Restroom Facilities: Restrooms available

Safety Concerns: No open toed-shoes, sandals, clogs, high heels, or other non-suitable footwear


**Site Description:** A collection of boulders have been assembled on Michigan Technological University’s campus to provide an easily accessible teaching and learning tool for educators and students, alike. “These boulders are like [rock] outcrops—they contain as much information as many outcrops, and because they were smoothed by glacial action, it is easy to “read” them to see their details,” explains Bill Rose, Professor of Petrology at Michigan Technological University, and originator of the Keweenaw Boulder Garden. “By carefully choosing them and then moving them together, we have been able to assemble an amazing teacher resource where students can sharpen their skills at reading the rocks.”

The boulders are naturally-shaped (glacially transported) examples of all the major rock types of the Peninsula, including dramatic examples of the important individual rock types that come from solidification of huge lava flows (Vesicular flow tops, fissures, pegmatites, ophitic portions), conglomerates, sandstones. Each of the boulders is a museum specimen, measuring 1–2 meters in diameter, and arranged artistically in a small plaza to allow people to walk around and on them.

**Driving Directions:** Located on the campus of Michigan Tech, between Fisher Hall and Dillman Hall (see X on map) or visit: http://www.mtu.edu/facilities/parking/campus-maps/

**Fees:** Free

**Restroom Facilities:** Available in nearby Fisher or Dillman Hall.

**Accessibility:** Wheelchair accessible

**Parking:** Visitor parking on campus; contact MTU Public Safety to inquire at 906-487-2216.

**Hours:** always available year-round

**Site Capacity:** 25–50 at a time

**Instructional Objectives**

*Students will be able to:*

1. Identify various rock and minerals.
2. Understand solidification
3. Describe the Keweenaw Rift

**Lesson ideas on the following topics are found on the website:**

- Rock identification
- Mineral identification
- Which way is up?
- Understanding Solidification
- Sedimentary rock structures
- Assembling a rift
Area Mines and Museums
Keweenaw National Historical Park

Calumet Visitor Center at the Historic Union Building
25970 Red Jacket Road, Calumet, MI 49913 • Tel: (906) 337-3168 • Fax: 906-337-3169
Website: http://www.nps.gov/kewe/index.htm

Site Description: This facility is located at the entrance to Historic Downtown Calumet in the Union Building, a former lodge hall for various fraternal organizations. Visitors are able to experience extensive interactive exhibits on what life was like for people in the mining community from its establishment through the boom times to the closure of the Calumet & Hecla Mining Company in 1968. The facility provides a staffed information desk and sales outlet for the Isle Royale and Keweenaw Parks Association. The information desk at the visitor center can be reached at 906-483-3176 during hours of operation.

Driving Directions: The Quincy Unit of the park is located just north of Hancock, Michigan. The Calumet Unit is located approximately 12 miles north along U.S. Highway 41 in Calumet, Michigan.

Fees: Free admission

Hours: The Calumet Visitor Center at the Historic Union Building is open seven days a week from late May through September, from 9 am until 5 pm. During July and August, hours are 9 am until 6 pm. From October through late May, the Union Building is open as staffing allows.

Restroom Facilities: Available onsite
Michigan Iron Industry Museum

Site Description: Michigan’s iron built the rails westward and the skyscrapers upward. Find out what it was like to work underground and follow the trail to the site of the Carp River Forge. At the site of the Iron Mining Museum, from 1848 to 1855, the Jackson Iron Company and others manufactured wrought iron from local ore and demonstrated the high quality of Michigan’s iron ore deposits. In that pioneer enterprise was the seed of the Michigan iron industry that flourished for 125 years and continues to produce nearly one-quarter of the iron ore mined in the United States. Museum exhibits, an 18-minute sound/slide program “Life on the Michigan Iron Ranges,” and an outdoor interpretive paths depict the large-scale capital and human investment that made Michigan an industrial leader.

Geologic Concept(s) Addressed: How iron is formed.

Driving Directions: The Michigan Iron Industry Museum is located six miles west of Marquette. Take Jackson Trace Parkway off of U.S. 41, one mile west of Junction M-35; the approximately half-mile-long road leads to the museum.

Fees: Free

Hours: Open daily, 9:30 am to 4:30 pm, from May 1 to October 31.

Restroom Facilities: Restrooms available

Accessibility: Accessible to mobility impaired; wheelchair available upon request. A magnifier, large-print transcripts of the A/V program, and print-outs of the interpretive trail signs are available on request.

Instructional Objectives

Students will be able to:

1. Explain the importance of convenient and efficient transportation to the iron industry. How is iron processed for shipment? In what manufacturing processes is iron used?
2. Explain how iron ore was discovered in the Upper Peninsula. Who were the significant individuals who helped to develop Michigan’s early iron industry?
3. Identify the general locations of the Upper Peninsula’s major iron deposits. Which locations continue to produce iron today?
4. Describe the typical life of an iron miner and his family.
AREA MINES AND MUSEUMS
Quincy Copper Mine

49750 US-41, Hancock, MI 49930 • Tel: (906) 482-3101 • Tel: (906) 482-5569
Email: quincy@quincymine.com • Website: www.quincymine.com

Site Description: Quincy Mine was once one of the largest producing copper mines in the world. The tour focuses on copper mining at the turn of the century and describes what it was like to be a miner in the early 1900s. The walls of the mine are composed of basaltic lava flows. When studied closely, individual flows can be identified. Only open for tours; no actual mining or blasting goes on in the mine. The tour begins in the hoist where students can watch videos about the history of the mine. Students are provided with hardhats (required) and warm coats (optional). Students descend on a tram to the entry to the adit.

Geologic Concept(s) Addressed: Observe native copper lodes in basalt flows.

Driving Directions: On south side of US 41, 1 mile north of Hancock

Parking: Near gift shop and hoist

Fees: $10 Adult, $3 Student (includes surface and below ground tours)

Hours: Weekends only in early May.
Daily mid-May to late October: Mon.–Sat. 9:30 am to 5 pm and Sundays 12:30 pm to 5:30 pm.
Mid-June to Labor Day: 8:30 am to 7 pm, and Sundays 12:30 pm to 7 pm.
Last tour at closing time
Tour length: 1 hour underground, 30 minutes surface

Site Capacity: 28 below ground at a time (can be split between surface and mine)

Restroom Facilities: 100 feet southwest of gift shop and in hoist

Accessibility: Ramps are being built in the near future.

Safety Concerns: Wear closed-toe shoes and warm clothes. Hard hats and jackets are provided. The mine is a damp 42 degrees year round.

Instructional Objectives
Students will be able to:
1. Describe what life was like at the turn of the century in the Copper Country.
2. Discuss whether you would want to dig for copper with a candle to light your work.
3. Speculate what the Upper Peninsula would be like if copper was never found.
**A.E. Seaman Museum at Michigan Technological University**

1404 E. Sharon Avenue, Houghton, MI  
Tel: (906) 487-2572 • Fax: 906-487-3027 • Email: dmcomfor@mtu.edu

**Site Description:** The A.E. Seaman Museum is the official Mineral Museum for the State of Michigan. Teachers may choose to have a guided or self-guided tour. A short video presentation highlights the formation of the Keweenaw Peninsula and the formation of Lake Superior. The geologic history of the local bedrock and the presence of copper deposits in the Keweenaw are also covered. The mineral and rock specimens in the A.E. Seaman Museum are extensive and varied. During the visit, students write their impressions of the minerals and rocks on display in their science journals. Students are required to write descriptions of at least two igneous, two sedimentary, and two metamorphic rocks. Mineral descriptions will be written on at least five different minerals.

**Driving Directions:** From US-41 at the stoplight, take MacInnes Avenue (up the hill) 1.1 miles to the entrance to the museum parking lot. Follow Keweenaw Heritage Site signage.

**Parking:** Up to 50 vehicles.

**Fees:** Admission charged

**Hours:** Open Mon-Sat. 9 am to 5 pm. Museum and gift shop.

**Site Capacity:** 50-100 at a time

**Restroom Facilities:** Available in the museum

**Accessibility:** Handicapped accessible (one floor)

**Instructional Objectives**

*Students will be able to:*

1. Explain how rocks and minerals are formed.
2. Describe at least two igneous, two sedimentary, and two metamorphic rocks.
3. Describe at least five different minerals using mineral classification characteristics: luster, hardness, etc.
TEACHING RESOURCES

How can we integrate technology with an educational outdoor adventure?—with EarthCaching!

With our maps and Global Positioning System (GPS) in hand we hurried down an unfamiliar path in search of nature’s “treasure” an EarthCache! We grew excited as the blinking GPS screen directed us closer to our treasure’s coordinates. The trail led out of the dense woods and on to a beautiful pebble beach at Horseshoe Harbor on the shores of Lake Superior. We were overwhelmed by the breathtaking view. After a few moments of soaking in the grandeur, we pushed on to reach our goal. Hiking along the pebble-y beach...500 feet...300 feet...and there it is our treasure! In front of us stood the EarthCache a one billion year old outcrop of rock and fossilized stromatolites. We weren’t finished yet. We still needed to unlock the metaphorical treasure chest in order to understand the natural and geologic history of this place.

Using description provided, along with observation and inquiry skills, we set out to answer a scientific question about the geologic processes posed in the EarthCache write-up. Got it? We just went EarthCaching!

In Michigan alone, there are hundreds of geologic features that highlight the many Earth systems that shape our world. These places of geo-significance can be found just about anywhere from beaches to forests, from parks and school yards, from the local stream to your favorite vacation spot. While these places may be familiar places, we are often unaware of the geological processes responsible for creating these geologic features or the methods geologists and scientists use to gather evidence and learn more about the Earth’s history. EarthCaching is a fun way to discover and share these unusual and engaging geologic places while improving Earth Science literacy.

The adventure begins by choosing an EarthCache at www.earthcache.org. Each one comes with an easy-to-follow informational write-up that has been reviewed by experts from the Geological Society of America to ensure quality. A “cache” is then pursued using maps and a handheld GPS to navigate to a precise location. These activities build essential skills in map reading, geospatial understanding and scientific methodology while at the same time encouraging people to get outside to discover their world. Once a visitor has located the EarthCache the real learning begins.
EarthCaching, like Geocaching, is an activity in which everyone can participate. The difference with EarthCaching is that there is no physical container to be found. Instead, visitors participate in an educational task related to that place and its features. Visitors can later log their visit at the EarthCache website by submitting their answers to the questions about that site.

EarthCache can be a wonderful place-based educational tool for anyone teaching Earth science in a formal or informal setting. Geology and Earth Science are often left out of Environmental Education programs due to a lack of understanding and knowledge. EarthCaching can help fill that gap by enhancing interest in Michigan Earth Science.

**Note to potential Earth Cache creators:** it is important that we continue to develop a network of high quality Michigan EarthCaches that can be used by educators and the public throughout the state to help translate the Earth’s processes into a local experience. You can help by developing an EarthCache in your local community. Developing an EarthCache to be reviewed and published will not only provide you with an opportunity for scientific publication, but will also allow others to enhance their Earth Science literacy.

**Visit the following for further information:**
EarthCaching: http://www.earthcache.org/
EarthCaching with the Michigan Teacher Excellence Program: http://www.geo.mtu.edu/MiTEP/EarthCache

*By Emily Gochis, a PhD student at Michigan Technological University and a Michigan-certified secondary science teacher.*
GLOSSARY OF GEOLOGIC TERMS

Amygdaloidal Basalt — A type of basalt which contains mineralized gas bubbles. It is often indicative of the top of a basalt lava flow. It is also the main part of the flow which will contain minerals which can be mined.

Amygdale — A mineralized gas bubble in a lava flow.

Asthenosphere — That part of the mantle that lies below the lithosphere; material in the asthenosphere behaves plastically and flows.

Basalt — A type of igneous rock which is typically found in areas of recent volcanism. It has a low quartz content and a large plagioclase feldspar content. It has fine grains, which are barely visible to the eye and a dark grey to green color. It is the primary rock type of the Portage Lake Volcanics and the Hawaiian Island chain.

Bedding — The layers/strata caused by periods of deposition. Thin bedding means relatively short period of deposition. Thick bedding means relatively long periods of deposition.

Bedrock — The geologic unit which is the first solid rock type below the loose soil. This type of rock is what is charted in geologic maps and is found at the various outcrops.

Calcite — A common mineral containing calcium and carbonate (CaCO₃). It is the primary mineral in limestone and forms through late mineralization processes.

Chrysocolla — A hydrous silicate of copper and is blue to green in color. It looks similar to moss growing on conglomerate with occasional bits of pure copper poking out. It is soft (2-4) and not very dense.

Clastic — A classification of sedimentary rocks which were formed purely by physical processes.

Conglomerate — A large grained sedimentary rock. Typically contains large, round, pebbles surrounded by sand working as cement. It is a product of minimal weathering and textural maturing.

Convective flow — Hot material from deep within the Earth rises toward the surface, cools and then descends downward. This flow or movement of material is believed to be the mechanism that drives the movement of the Earth’s plates.

Copper — An element which is commonly found in oxides and sulfide minerals, but is found in its native form only in the Keweenaw. As a pure mineral, it is soft (1-2), red brown in color, and commonly forms twisted veins. It is very ductile and an excellent conductor of electricity.

Cross-bedding — Caused by moving currents (as seen from a side profile of the layer).

Dolomite — Limestone that had magnesium added after its formation.
**Fault** — A break or change in the rock layers. Faults are often the result of stress in rocks layers. The stresses are caused by pressure being exerted by earth forces such as tectonic collisions or rising salt domes. These are the main cause of geologic abnormalities and are often traps for oil and gas.

**Fault zone** — An area which contains a series of faults related to a single major faulting event or one major fault that defines a region.

**Feldspar** — An aluminum silicate mineral which will also contain other elements to distinguish specific properties. It is divided into two categories: plagioclase and orthoclase. The plagioclase is the primary mineral in basalt and orthoclase is a primary mineral in granite. Both types are of average density, above average hardness (6-6.5), and are distinguishable by a flash of light reflected when held at the proper angle.

**Fetch** — The length of water over which a given wind has blown.

**Fissure** — A crack in a rock.

**Friable** — When a rock such as sandstone break off layers easily because of poor cementing agents.

**Glacier** — A large ice sheet that slowly moves forward and recedes with the seasons. It causes erratic geology by moving and scraping rocks. The glacial periods started about 5 million years ago when the earth began a cooling period.

**Glacial grooves** — A glacially polished surface with streaks carved by rocks trapped in the glacier which repeatedly fell onto the surface and were dragged along by the movement of the glacier.

**Grenville Orogeny** — A major mountain-building event produced by the collision of North America with another continental land mass, the compressive forces of this event, which occurred approximately 1040 Ma, deformed rocks from the coast of eastern Canada southwestward to what is now Lake Huron.

**Igneous** — Rock formed from molten magma.

**Lava** — Magma at the Earth’s surface.

**Law of superposition** — States that generally as you proceed down layers of undisturbed rock, the rock gets older. This is a fundamental principle of geology.

**Lithosphere** — The relatively rigid outer, which includes the continental crust, the oceanic crust, and the part of the mantle lying above the softer asthenosphere.

**Mafic** — Volcanic rock derived from magma with 45 to 52% silica and more iron, magnesium and calcium than felsic and intermediate magma.

**Magma** — Molten rock produced within the Earth.
**Mantle plume** — A localized column of hot mantle material moving upward and spreading outward in all directions. The tensional forces produced by this mantle plume causes block faulting, fractures and open fissures to develop in the rigid lithosphere. (See “hot spots”, page 48 of DYMANIC.PDF file).

**Metamorphic** — Rock that is formed under great heat and pressure.

**Midcontinent rift system (MRS)** — A late Proterozoic intracontinental rift that developed within what is now the North American continent, it contains thick accumulations of volcanic and sedimentary rock. See rift.

**Orogeny** — A major episode of mountain building.

**Plate** — A broad segment of the lithosphere (including the rigid upper mantle, plus oceanic and continental crust) that floats on the underlying asthenosphere and moves independently of other plates.

**Plate tectonics theory** — The theory that large segments of the Earth’s rigid outer shell move relative to one another. First proposed in 1912 by the German scientist Alfred Wegener as the theory of “continental drift.”

**Rift** — A major geologic process occurring at divergent plate boundaries, sometime referred to as a “spreading center,” rifts are characterized by tensional (stretching) stress, block faulting and basaltic volcanism.

**Ripple marks** — Marks caused by moving currents (as seen from the top of the layer). Current ripple marks caused by currents of water. Wave or oscillation ripple marks are caused by waves.

**Sandstone** — A large grained sedimentary rock not containing pebbles. This is the most common clastic sedimentary rock. It consists primarily of silica (SiO2 or quartz).

**Sapping** — In the case of Tahquamenon Falls, where the relatively softer sandstone under the harder more resilient sandstone gets eroded by the moving water of the falls causing the upper layers to fall of and thus the falls “walk.”

**Sedimentary** — Rock that forms from deposition of material then pressed under normal pressures and temperatures.

**Sorting** — How well the grain particles match each other in size. Well/good sorting is where all grains are approximately the same size usually caused by water or wind. Poor sorting has a variety of grain sizes and is caused by ice or turbid currents.

**Stratigraphic** — The order of the strata in a sequence of rock.

**Stope** — An ore removal technique which used vertical steps to extract rock from above the main mine level. The remaining inverse pits are known as stopes.
**Tectonics** — The study of geological structural features.

**Volcanics** — A general term referring to a series of igneous rocks. Volcanics can consist of a variety of rocks, but is typically limited to the main six types: rhyolite, granite, diorite, andesite, basalt, and gabbro. The Portage Lake Volcanics group is primarily basalt.
A GUIDE TO GEOLOGY FIELD TRIPS
in Michigan’s Upper Peninsula

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