

Geology in Michigan – Precambrian Stromatolites at Horseshoe Harbor

This article and photographs provided by Dave Adler

Latitude: 47°28'30"N ; Longitude: 87°48'02.70"W

Section 36, T59N, R27W , Keweenaw County



Figure 1: Area Map showing the location of Horseshoe Harbor in relation to Copper Harbor. Source: www.mappery.com/maps/Keweenaw-Peninsula-Map.jpg.

Directions

Horseshoe Harbor is located near the tip of the Keweenaw Peninsula approximately 4 miles east of the unincorporated village of Copper Harbor, Michigan's northernmost settlement (see Figures 1 and 2). From Houghton, take U.S. 41 north approximately 45 miles to Copper Harbor. Just before coming to Copper Harbor, you'll pass the Keweenaw Mountain Lodge and Golf Course on your right. Approximately 1 mile beyond the golf course there will be a blinking stoplight at the intersection of U.S. 41 and M-26. Turn right and proceed approximately 2.5 miles east on U.S. 41 through Copper Harbor past Fort Wilkins State Park until the pavement ends at the northern terminus of U.S. 41. Continue east on the improved dirt road for approximately 0.9 miles where there will be an unimproved dirt road that goes to the left (north) and downhill. In recent years there has been a sign at this intersection directing you to Horseshoe Harbor to the left (north) or to High Rock Bay by

proceeding straight (east). Proceed approximately 1.2 miles north on the unimproved dirt road until arriving at



Figure 2: Location Map showing a close up of Horseshoe Harbor. Source: Google Earth Pro.

the trailhead on the left and a small parking area on the right. A vehicle with good ground clearance is advised for this road.

There are signs for Horseshoe Harbor at the trailhead. Take the trail to the beach (approximately 1/3 mile). The trail cuts through the forest on conglomerate bedrock and is not handicap accessible. The trail to the beach at Horseshoe Harbor is not difficult, but care should be exercised as the conglomerate rock along the trail can be knobby with exposed tree roots in some places. When you arrive at the beach, proceed left (north) towards a ridge of inclined brownish-red conglomerate bedrock at

Photo 3: Conglomerate ridge at the edge of the water. The best stromatolite exposures are located along the base of the ridge to the left (west) of the gravel beach.



the edge of the water (see Figure 3). The best stromatolite exposures are located along the base of the landward (south) side of the bedrock ridge to the left (west).

Alternate route: Take U.S. 41 in Houghton to the intersection of M-26 in the hamlet of Phoenix (approximately 25 miles). Turn left onto M-26 and proceed approximately 24 miles to the intersection of M-26 and U.S. 41 at the blinking light in Copper Harbor. You will pass through the old copper mining towns of Eagle River and Eagle Harbor on the way to Copper Harbor. When you arrive at the blinking light in Copper Harbor, proceed straight (east) on U.S. 41 to Horseshoe Harbor as per the above noted directions. This alternate route follows several miles of Lake Superior shoreline and offers outstanding scenery and numerous opportunities to view the Precambrian bedrock (the Outer Conglomerate and the Lake Shore Trap Basalts) exposed along the Lake Superior shoreline.

Horseshoe Harbor is also accessible by boat. There are no docking or marina facilities available. The best time to visit is during the “warm weather” season from mid-May until late October. The dirt roads are not maintained in the winter.

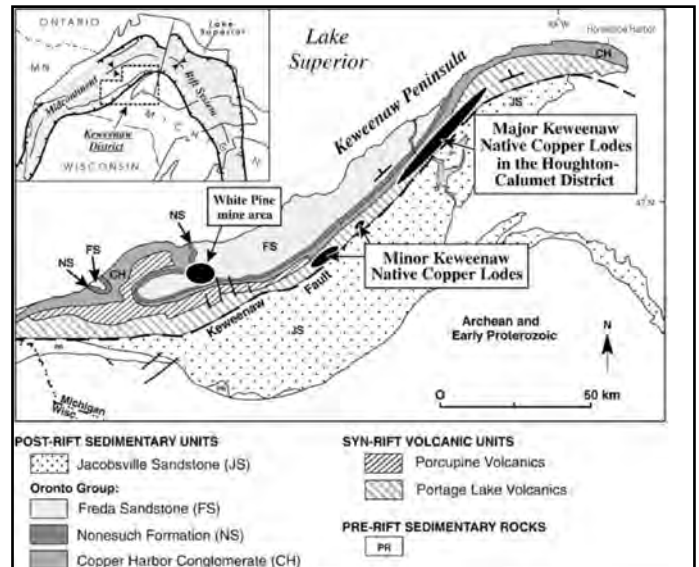


Figure 4: Regional Geologic Setting. Source: Downloaded from https://pages.mtu.edu/~raman/Silver/BlackLavas/Copper_Mining_files/Screen%20Shot%202020-11-15%20at%204.32.50%20PM.jpg ..

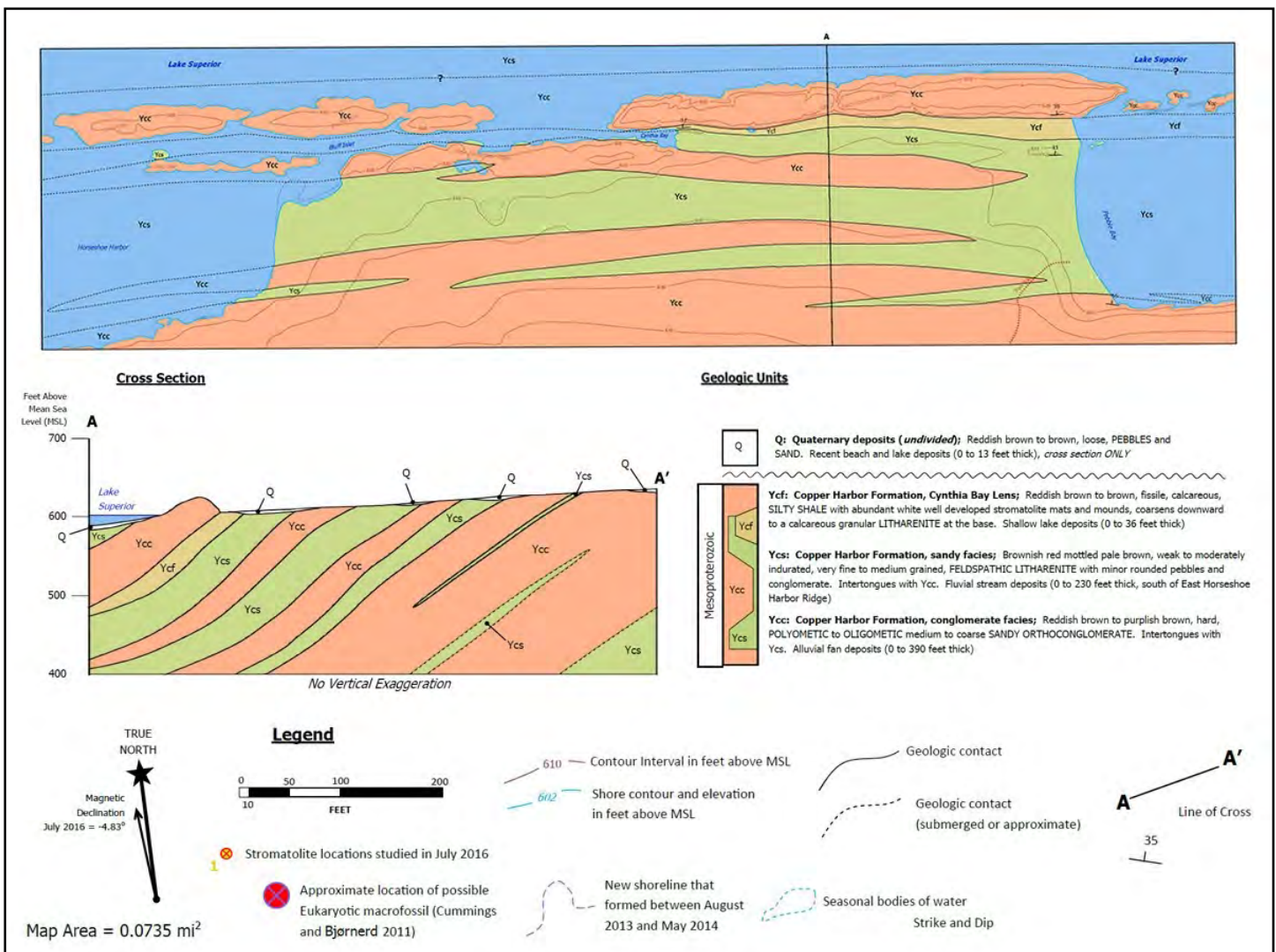


Figure 5: Site Geology. Source: Modified from Baumann et al, 2016 .

Geology and Nature

Horseshoe Harbor is part of the Nature Conservancy's Mary MacDonald Nature Preserve. The preserve encompasses over 1,200 acres of secluded, forested wilderness with five miles of rocky beaches along Lake Superior. The forest contains white pine, balsam fir, white cedar, white spruce, and white birch trees as well as patches of wild blueberries (three varieties), raspberries, thimbleberries, and chokecherry trees. The forest is home to a variety of mammals including white tailed deer, porcupines, snowshoe hare, and the occasional black bear. A variety of northern climate birds including bald eagles, peregrine falcons, ruffed grouse, indigo buntings, cedar waxwings, pileated woodpeckers, ruby-throated hummingbirds, and a variety of warbler species inhabit the forest and beaches.

The Late Precambrian age Copper Harbor Formation, also referred to as the Copper Harbor Conglomerate (CHC), is well exposed at Horseshoe Harbor. The expo-



Photo 6: Conglomerate texture – note the pebble to small boulder range of clast sizes.

sures include conglomerate beds with pebble to boulder size clasts, finer grained beds (sandstone, siltstone, and mudstone), ripple marks and stromatolitic layers. The northward dipping inclination of the CHC towards and under Lake Superior can be readily observed. The stromatolite exposures at Horseshoe Harbor are the best on the Keweenaw Peninsula.

Geologic Setting

Horseshoe Harbor is located in the Lake Superior Basin south of the axis of the Lake Superior syncline (see Figure 4 on page 28). The Lake Superior Basin is one of the basins of the Mid-Continent Rift System that extends northeasterly from Kansas to Lake Superior before turning southeastward underneath the lower peninsula of Michigan. The Mid-Continent Rift System formed approximately 1.1 to 1.2 billion years ago (Keweenawan age) by extensional thinning of the rigid Precambrian Superior crustal block (Bornhorst et al, 1983). Extensive volcanic activity occurred during Keweenawan time. Most of the extruded lavas consist of basaltic rocks, although felsitic lavas (e.g., the rhyolites exposed nearby at Bare Bluff and Mt. Houghton) also formed in Keweenawan time.

The Keweenawan rocks exposed on the Keweenaw Peninsula include the Portage Lake Volcanics (PLV), a relatively thick series of basalt flows with interbedded conglomerates that occurs in a relatively narrow curvilinear belt extending from the tip of the Keweenaw Peninsula southwestward to the Porcupine Mountains area near the Wisconsin border. The PLV are composed primarily of tholeiitic basalts. Many of the basalts contain amygdaloidal flow tops. The interbedded conglomerates are rich in rhyolite and have a distinctive brownish-red color similar to the color of the CHC. The PLV are overlain in succession by the CHC, the Nonesuch Shale and the Freda Sandstone.

The PLV are the host rock for the most extensive native copper deposits known. The native copper deposits are believed to be the result of post-rift volcanism hydrothermal mineralization that occurred after deposition of the Freda Sandstone. The native copper deposits of the PLV in Keweenaw and Houghton Counties were worked extensively from the 1840s into the second half of the twentieth century and were the primary source of copper for the U.S. from about 1880 to 1910. Some of the interbedded conglomerates also contain native copper mineralization. The Calumet & Hecla conglomerate in Houghton County was one of the richest copper lodes.

Subsequent filling of the Lake Superior Basin caused downwarping of the thick pile of volcanic and sedimentary rocks. Regional faulting along the margins of the basin resulted in upturning of the rock units along the Keweenaw Fault. The rocks exposed on the Keweenaw



Photo 7: Sandstone outcrop.

Peninsula west of the Keweenaw Fault, including the PLV, CHC, Nonesuch Shale and Freda Sandstone, were tilted to the northwest towards the interior of the basin. This tilting can be seen today in the exposed rocks at Horseshoe Harbor and throughout the Keweenaw Peninsula. The region's distinct valley and ridge-type topography is the result of erosion of some of the softer sedimentary rocks relative to the more resistant volcanic rocks.

The Keweenaw Peninsula is the type area for the CHC. This Late Precambrian Age formation consists of a relatively thick sequence of red, brownish-red, and brown volcanogenic conglomerates with lesser amounts of interbedded sandstones, siltstones and mudstones, and intervening lavas. The CHC has a maximum thickness on the

order of 6,000 feet (Daniels, 1982). It conformably overlies the PLV and is in turn conformably overlain by the Nonesuch Shale and the Freda Sandstone.

The CHC has been described as a massive piedmont fan deposit with associated flood plain or playa deposits (Huber, 1975), a prograding alluvial fan complex with proximal to distal braided stream and sheetflood facies on coalesced alluvial fans and sand flats (Elmore, 1981), and as a fining-upward, basinward thickening wedge of conglomerate and sandstone with subordinate volcanics that has been interpreted as a piedmont fan deposit (Elmore, 1983).

The CHC is subdivided into the following five members, in succession from oldest to youngest and from



Photo 8: Stromatolites at base of conglomerate ridge.

south to north in their occurrence on the Keweenaw Peninsula:

- The Inner or Great Conglomerate
- The Lower Lake Shore Trap Basalts
- The Middle Conglomerate
- The Upper Lake Shore Trap Basalts
- The Outer Conglomerate (exposed at Horseshoe Harbor)

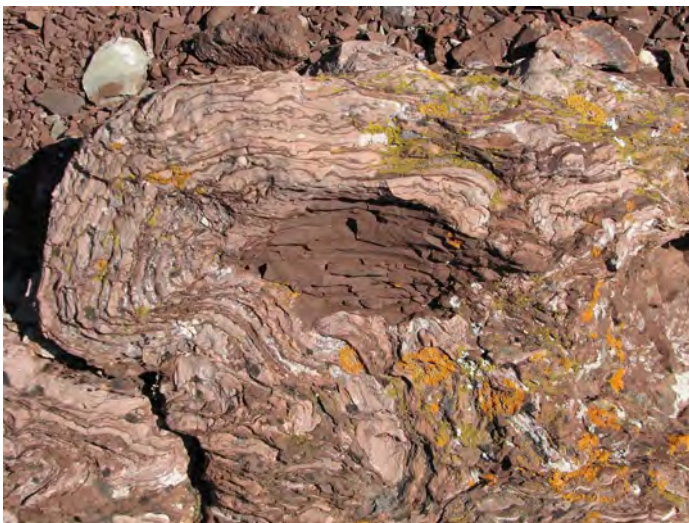


Photo 9: Stromatolites Wrapped Around Mudstone Beds.



Photo 10: View west of sandstone interbedded with stromatolites.

The CHC does not contain significant copper mineralization. The presence of the Lower and Upper Lake Shore Trap Basalts within the CHC represents the last stages of Keweenaw rift volcanism that was followed by a relatively long period of sedimentation as represented by the Jacobsville Sandstone and younger sedimentary formations of the Michigan Basin. The stromatolitic beds occur in the Outer Conglomerate. They are exposed intermittently along the Lake Superior shoreline from Horseshoe Harbor westward to Dan's Point, a distance of approximately eight miles.

Of interest to collectors, the Lake Shore Traps are known to contain agates and more rarely, amethyst. The agates (sometimes referred to as Lake Superior agates) were formed as amygdules in the basalts. The amethyst



Photo 11: Orbicular Top of Stromatolite Outcrop.

occurs in thin veins and as small pods that may also be of amygdaloidal origin. This author has observed high quality crystallized amethyst specimens in private collections and at the A.E. Seaman Mineral Museum at Michigan Technological University in Houghton. The amethyst specimens are reportedly from the Upper Lake Shore Traps just south of the Horseshoe Harbor area. An agate approximately the size and shape of a football was found in the area south of Horseshoe Harbor by a resident of Eagle River while on her very first agate hunting excursion – the find of a lifetime!



Photo 12: Stromatolite, Sandstone and Mudstone Outcrops.

Site Geology

The geology of Horseshoe Harbor is shown in map and cross section form on Figure 5 (page 27). The red and brownish-red conglomerate of the Outer Conglomerate is exposed at Horseshoe Harbor. Sandstone and mudstone beds, some of which are associated with the stromatolitic layers, are also exposed. The bedrock exposures are predominantly pebble to cobble conglomerate with well-rounded clasts of rhyolite and basalt, the rhyolite clasts being more abundant than basalt. Boulder size clasts can also be observed. The wide range of clast sizes in the CHC is depicted in Figure 6. The northward dipping inclination of the bedrock (towards and under Lake Superior) can be observed quite clearly, especially in the sandstone outcrops (see Figure 3 and Figure 7).

As you reach the end of the trail leading to Horseshoe Harbor from the parking area, you'll come to a gravel and cobble beach. Before you enter the beach, look straight ahead. You'll be looking east at the rugged, rocky coastline of the Keweenaw Peninsula. As you step onto the beach, turn to your left and you'll be looking northward toward the inclined conglomerate ridge shown in Figure 3. As you walk north towards the ridge, you'll notice the block-like outcrop shown in Figure 7 on your left. This outcrop is mostly brownish-red sandstone, some of which has a shaly appearance. The east-west strike and north-



Photo 13: Stromatolites Wrapped Around Basalt Clasts.

ward dip of the CHC can be observed and measured in this outcrop.

Continue walking towards the inclined ridge. Just before reaching the base of the ridge, you'll see an opening to the west (on your left). Turn left here and proceed west along the base of the ridge. You'll begin to see the stromatolites exposed at the very base of the ridge on your right as you proceed west. Figure 8 shows a good example of the stromatolites in cross section in this area. The stromatolites in this area are wrapped around mudstone layers and are overlain by siltstone and pebble conglomerate beds. Figure 9 shows a close-up view of a similar feature.

As you continue walking west along the base of the ridge, you'll begin to see the stromatolites at the base of the conglomerate ridge on your right and along the rocky



Photo 14: Stromatolite Outcrop - Cross Sectional View.

path in front of you, as shown in Figure 10. The contact between the cobble/boulder conglomerate that forms the ridge and the finer grained sandstone and mudstone that you're walking on is quite distinct at the base of the ridge. The best exposures of the stromatolites at Horseshoe Harbor are in this area. A striking example of the orbicular red and white tops of the stromatolites in this area can be seen in Figure 11. Figure 12 shows some of the stromatolitic layers along the base of the conglomerate ridge and many of the finer grained beds (sandstone and mudstone). The distinct contact between the conglomerate and the sandstone/mudstone at the base of the ridge can also be seen in Figure 12.

The exposure of the stromatolitic layers at Horseshoe Harbor extends laterally for up to 800 meters, although the ongoing high water levels in Lake Superior have reduced the length of the exposure for the time being. The 1.087-billion-year-old stromatolites occur as calcareous, hemispheroidal, and globular shaped structures up to 10-15 centimeters thick and 40 centimeters in diameter draped over and around pebble to boulder sized clasts. Figure 13 shows a good example of stromatolites formed around basalt cobble-size clasts. The stromatolites also occur as undulating mats grown on substrates of mudstone (see Figures 8 and 9).

Origin of the CHC Stromatolites

Stromatolites have been studied for over 100 years and continue to be studied. There is no unified consensus on their mode(s) of formation. There is no consensus on whether they are the result of biological activity or abiological activity. There is no consensus on the definition of stromatolites. Some example definitions are as follows:

- Layered, early lithified authigenic microbial structures – often domical or columnar in form – that developed at the sediment water interface in freshwater, marine and evaporite environments (Riding, 2011).
- Laminated structures attributed or possibly attributable to the work of blue-green or green algae (Rezak, 1957).
- Macroscopically layered authigenic microbial sediments with or without interlayered abiogenic precipitates (Riding, 2011).
- Megascopic organosedimentary structures produced by sediment trapping, binding and/or precipitation as a result of growth and metabolic activity of organisms, primarily blue-green algae (Awramic and Margulis, 1974).
- Layered mounds, columns, and sheet-like sedimentary rocks that were originally formed by growth of layer upon layer of cyanobacteria, a single-celled photosynthesizing microbe (Wikipedia).

The term stromatolite has been generally used by geologists and paleontologists as applying to laminated structures attributed or possibly attributable to the biological actions of blue green or green algae. Stromatolites have been observed in rocks from a wide range of geologic time including Precambrian and much younger rocks. Living algal mats observed today in both marine and non-marine environments often show a striking resemblance to some of the stromatolites seen in Precambrian rocks. Recent occurrences offer insight into the modes of formation and environmental conditions that allowed for the formation of ancient stromatolites. The living algal mats at Shark Bay in Australia are perhaps the most vivid example of recent occurrences (see Figure 15).

In most cases, stromatolites are not the actual remains of algae. They are laminated structures developed by the reactions of organisms to their physical environment. True fossil algae exhibit recognizable organic microstructures including cell walls. Stromatolites in the rock record rarely exhibit recognizable microstructures beyond a fine lamination. They tend to be headlike mass structures resulting from biological activity of primitive algal life forms. The remains of the algae that built the structures are rarely preserved. All that is left of the algae to attest to their original presence are the stromatolites preserved in the rock record (Rezak, 1957).

So what of the stromatolites in the CHC at Horseshoe Harbor? In an effort to avoid overcomplicating, the stromatolites at Horseshoe Harbor are believed to be the lithified remnant structures of prehistoric algal photosynthetic bacteria (*collenia undosa* species as identified by Cornwall, 1955) that grew in colonies or mats during deposition of the CHC. Their association with the finer grained sandstone and mudstone beds suggests a quiescent,



Photo 15: Living Algal Mats in Hamelin Pool at Shark Bay, Australia. Source: Government of Western Australia Department of Mines, Industry Regulation and Safety (www.dmp.wa.gov.au/geological-survey/geological-icons-of-western-1403.aspx).

fresh-water lacustrine environment, possibly lakes that occupied abandoned stream channels on an alluvial fan surface (Elmore, 1983). The algal mats or colonies consisted primarily of filaments of bacteria and fine-grained sediment particles.

As the algal mats grew, they trapped sediment and became interbound with the surrounding sediment. As additional algal mats formed, they accumulated and became buried in sediment and, over time were lithified, producing the layered or banded pattern commonly seen in the CHC stromatolites. The microstructure of the CHC stromatolites consists of alternating layers of detrital and carbonate laminae, and open-space structures. Radial fibrous calcite fans are superimposed on the laminae (Elmore, 1983).

Collenia undosa is believed to have been a species of photosynthetic cyanobacteria that was a common primitive microbial life form in the Precambrian. They were able to flourish in the Precambrian due to a lack of predators. Expiration of oxygen by *collenia undosa* as a result of the photosynthetic process would have contributed to the oxygenation of the Precambrian atmosphere and the rise of the great diversity of more advanced life forms that are preserved in the fossil record and can be observed today.

Closing

Horseshoe Harbor is a secluded wilderness preserve that is open to the public. It offers excellent opportunities for experiencing nature in a pure form and for observing and examining some of the unique geologic features of the Keweenaw Peninsula, including the Precambrian stromatolites in the CHC. Horseshoe Harbor is intended for visitors to experience and enjoy both nature and some of the unique geology of the Keweenaw.

Visitors to Horseshoe Harbor include families with young children. This author has taken his children there on more than one occasion when they were young. As with any secluded wilderness area, visitors to Horseshoe Harbor should be aware that certain services may not be readily

available. As of the time of this article (June 2020), cell phone service did not extend to Horseshoe Harbor. The nearest medical facilities are located approximately 40 miles away in Calumet. Please enjoy your visit and be cognizant of your own personal safety and the safety of those around you.

Lastly, the stromatolite outcrops at Horseshoe Harbor are a rare and unique geologic feature. **Please don't disturb the intact stromatolite outcrops in any way.** Loose specimens can be found in the nearby beach gravels and cobbles. Thank You.

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