Geologic Resources Inventory Scoping Summary
Pictured Rocks National Lakeshore

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The Geologic Resources Inventory (GRI) provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this document), a digital geologic map, and a geologic resources inventory report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and monitoring and research needs. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues, and if possible include a site visit with local experts.

The National Park Service held a GRI scoping meeting for Pictured Rocks National Lakeshore on July 23, 2010, at the local Historical Society building in Munising, Michigan. A field trip, including an evening boat trip along the lakeshore, followed the discussion. Jim Chappell (Colorado State University [CSU]) facilitated the discussion of map coverage and Bruce Heise (NPS-GRD) led the discussion regarding geologic processes and features at the park. After a welcome from Bruce Deutsch (NPS-PIRO) Walt Loope from the U.S. Geological Survey presented a brief geologic overview of the park and surrounding area. Participants at the meeting included NPS staff from the park and Geologic Resources Division; geologists from the U.S. Geological Survey; and cooperators from Colorado State University (see table 2). This scoping summary highlights the GRI scoping meeting for Pictured Rocks National Lakeshore including the geologic setting, the plan for providing a digital geologic map, a prioritized list of geologic resource management issues, a description of significant geologic features and processes, lists of recommendations and action items, and a record of meeting participants.

Park and Geologic Setting

Authorized on October 15, 1966 and established on October 5, 1972, Pictured Rocks National Lakeshore encompasses 29,637 ha (73,235 ac) of which 14,459 ha (35,728 ac) are Federally owned along more than 64 km (40 mi) of the southern shore of Lake Superior in northern Michigan. The total terrestrial area in the park is 25,545 ha (63,122 ac), the remainder of the park area is offshore. The park boundary extends 0.4 km (0.25 mi) offshore on the lake's surface. Small units within the park are in Munising and Grand Marais, Michigan. The non-Federal Inland Buffer Zone (IBZ) preserves the setting of the Lake Superior shoreline and inland lakes and protects the local watersheds and streams. Certain land uses such as sustained-yield timber harvesting and approved recreational activities are permitted within the IBZ. Geologic features within the park include high bluffs, sea cliffs, sea caves, waterfalls, sand dunes, sand banks, kettle lakes, and arches. Lake Superior's surface is at 183 m (602 ft) above sea level.

More than 450,000 people visit the park each year to see the dramatic geology displayed at the park. The bedrock at Pictured Rocks, exposed along the lakeshore, consists of Late Precambrian to Early Paleozoic (Cambrian to Ordovician) sedimentary rocks including the fluvial/lacustrine sandstone of the Jacobsville Formation; the unconformably overlying, shallow/shoreline, mixed sediments of the Munising Formation; and the resistant, dolomitic sandstone of the Au Train Formation. The Munising Formation consists of three members: a coarse-grained, basal conglomerate; the resistant

Chapel Rock sandstone; and the friable, less resistant Miners Castle sandstone. These units crop out along the northern edge of the Michigan Basin and dip gently southward toward the depocenter of the basin.

Glacial ice covered this area of Michigan during the various major North American glacial stages of the Pleistocene (evidence from the Greenland ice cores, deep sea cores, and coral reefs suggest at least 11 or 12 glaciations). The last major stage, the Wisconsinan, removed most evidence of earlier glaciations. Several substages of the Wisconsinan including the Two Rivers substage and the Marquette substage affected glacial features at Pictured Rocks. During glacial retreat approximately 10,000 years ago, a series of glacial lakes formed at the retreating front of the glaciers. Large rivers at this time deposited vast sheets of outwash over the area. Glacial deposits extensively mantle the underlying formations, only where they crop out along the lakeshore is bedrock exposed.

The dramatic sandstone cliffs at Pictured Rocks National Lakeshore appear painted because of the colorful stripes of mineral precipitates formed as groundwater seeps flow from fissures in the cliff face. Orange and red colors originate in seeps rich in iron, green is from copper, white is from calcium, and black is from manganese.

Geologic Mapping for Pictured Rocks National Lakeshore

During the scoping meeting, Jim Chappell (CSU) showed some of the main features of the GRI's digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of being GIS compatible. The NPS GRI Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation for the GRI Program and allows for rigorous quality control. Staff members digitize maps or convert digital data to the GRI digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase and shapefile format, layer files complete with feature symbology, FGDC-compliant metadata, an Adobe Acrobat PDF help document that captures ancillary map data, and a map document that displays the map, and provides a tool to access the PDF help document directly from the map document. Final data products are posted at http://science.nature.nps.gov/nrdata/. The data model is available at http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm.

When possible, the GRI Program provides large scale (1:24,000) digital geologic map coverage for each park's area of interest, which is often composed of the 7.5-minute quadrangles that contain park lands (fig. 1). Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). The process of selecting maps for management begins with the identification of existing geologic maps (table 1) and mapping needs in the vicinity of the park unit boundary. Scoping session participants then select appropriate source maps for the digital geologic data or develop a plan to obtain new mapping, if necessary.

Table 1. GRI Mapping Plan for Pictured Rocks National Lakeshore

Covered Quadrangles	Relationship to the park	Citation	Format	Assessment	GRI Action
Pigeon Point quadrangle	Covers all of park and QOI	Milstein, R.L., Reed, R.C., and Daniels, Jennifer, 1987, Bedrock geology of Michigan, Michigan Department of Natural Resources, NO MATCH Unpublished, 1:500000 scale	Digital	Yes	Convert to GRI data model – clip to QOI

During the meeting, the following quadrangles of interest (fig. 1) were determined to be relevant for park resource management needs: Grand Marais, Grand Sable Lake, Au Sable Point, Au Sable Point SE, Au Sable Point SW, Trappers Lake, Grand Portal Point, Wood Island, Wood Island SE, Cusino, Melstrand, Indian Town and Munising 7.5 minute quadrangles. Meeting participants noted that the quadrangle north of the Trappers Lake quadrangle and west of the Au Sable Point quadrangle should be included in the area of interest for Pictured Rocks National Lakeshore.

Relying on guidance from Kevin Kincare (USGS), meeting participants agreed that the digital version of bedrock geologic map of Michigan (Milstein, 1987) referenced in Table 1 provides the best coverage and detail available for the park's area of interest. The bedrock was compiled from 1:100,000-scale mapping so theoretically, better maps exist. These are probably on mylars in map drawers at the Michigan Department of Natural Resources (MDNR). At the MDNR, digitizing maps is on a priority basis, and the current focus is on potential oil and gas areas. The Pictured Rocks area would be low on the MDNR's list of priorities. Kevin mentioned a publication currently in review with the USGS, Geology of Pictured Rocks National Lakeshore by Bill Blewett due to be published in March 2012, but stated that, while it contains valuable information for the park, it does not contain useful mapping information.

Detailed surficial geologic mapping for Pictured Rocks National Lakeshore does not exist. Park personnel implied a need for such mapping to assist with resource management needs. Bruce Heise and Kevin Kincare discussed a possible mapping project to provide Pictured Rocks National Lakeshore with surficial mapping but follow-up on that conversation is needed. Other potential sources of surficial mapping include Bill Blewett (Shippensburg State University) and Bob Regis (Northern Michigan University). Currently, the GRI is set to convert data listed in Table 1 and will clip data to the area of interest for Pictured Rocks National Lakeshore.

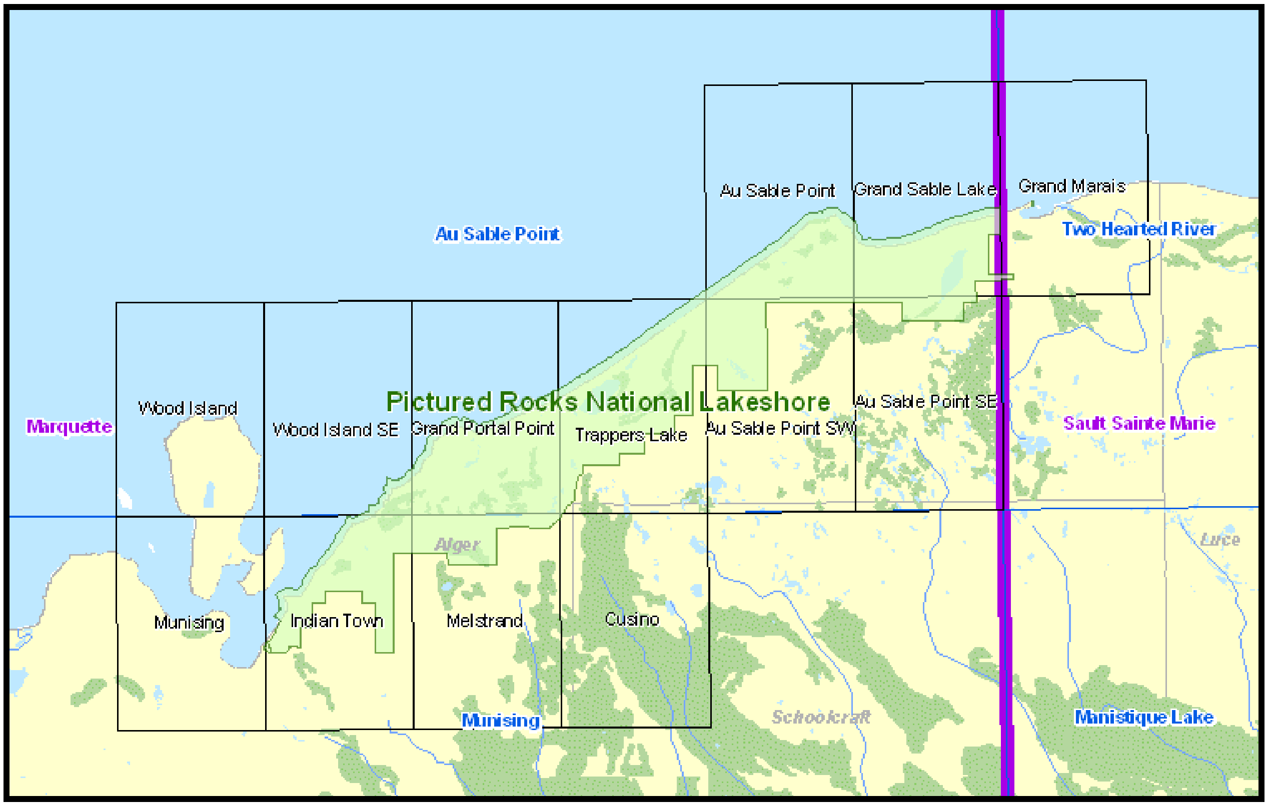

Figure 1. Area of interest for PIRO. 7.5-minute quadrangles are labeled in black; names and lines in blue indicate 30x60-minute quadrangles; 1x2 degree quadrangles shown with purple text and purple boundaries. Green outlines indicate park boundary.

Vegetation mapping and the soils inventory is finished for the park. These maps could provide some guidance for surficial geologic mapping. The vegetation map (UTM 16 NAD 83) extends 400 m (1,312 ft.) beyond the IBZ. There are remnants of 8,500 year old dunes contained in wetland swamps along the southern short of Lake Superior. LiDAR surveys would help delineate these types of features at Pictured Rocks.

[September, 2013 Map Update

While commencing work on converting bedrock map data into the NPS Geologic Map GIS Data Model, GRI team member Jack Garner discovered a number of maps which had not been identified at the scoping meeting which may have utility for the park. Significant effort went into investigating each and, after soliciting input from USGS geologist Kevin Kincare, the map plan identified below was selected for the final deliverable to the park.

Bedrock Map

For the bedrock map itself, we will use the 1987 Bedrock Map of Michigan as originally decided at the scoping meeting (Milstein, R.L., Reed, R.C., and Daniels, Jennifer, 1987, Bedrock geology of Michigan, Michigan Department of Natural Resources).

For unit descriptions of the Jacobsville, Munising, Trempeleau, and Prairie du Chien Formations, we will use Hamblin, Kenneth, 1958; Cambrian Sandstones of Northern Michigan (need proper reference here)

For a unit description of the Black River Formation, we will use Catacosinos, P.A. and Daniels, P.A. Jr., 1991, Stratigraphy of Middle Proterozoic to Middle Ordovician formations of the Michigan Basin, in Catacosinos, P.A. and Daniels, P.A.Jr., eds., Early sedimentary evolution of the Michigan Basin, Geological Society of America Special Paper 256.

For age dates for all formations, we will use Catacosinos, P.A. et al, 2001, Stratigraphic Lexicon for Michigan, Michigan Geological Survey Division Bulletin 8.

The bedrock map was provided to the park in September, 2011.

Glacial Deposits and Surficial Geology Maps

In 2013 the GRI provided funding support for a Geologic Society of America GeoCorps intern to start work on a new glacial deposit/surficial map of the north end of the park. The mapping is overseen by Michigan State Geologist Alan Kehew. This project has the potential, if funding can be found to continue it, to ultimately produce a new map of the entire park.

Older, Water Resources Maps

We located a series of USGS/Michigan Geological Survey Water Resources Maps done in the late 1950s and early 1960s that contained both surficial and bedrock information and planimetric maps. While the information was useful, the maps were dated and impossible to register and we opted not to use them, these references are provided for information purposes only:

Van Lier, K.E., 1963, Water Investigation 1, Reconnaissance of the Ground-Water Resources of Alger County, Michigan; Michigan Geological Survey Division

Van Lier, K.E., 1959, Water Investigation Progress Report 21, Reconnaissance of the Ground-Water Resources of Luce County, Michigan; Michigan Geological Survey Division

Van Lier, K.E., 1959, Water Investigation Progress Report 22, Reconnaissance of the Ground-Water Resources of Schoolcraft County, Michigan; Michigan Geological Survey Division]

Geologic Resource Management Issues

The scoping session for Pictured Rocks National Lakeshore provided the opportunity to develop a list of geologic features and processes, which will be further expanded upon in the final GRI report. During the meeting, participants discussed geologic resource management concerns including shoreline processes, slope processes and erosion, disturbed lands, potential energy development, and seismicity.

Shoreline processes

The park has some concern that human activities in communities such as Grand Marais will negatively impact park resources and locally change the shoreline dynamics. To protect the marina inlet at Grand Marais, developers installed a breakwater. This prevents natural longshore drift from moving sediments eastward and causes a potential pileup and stabilization of sand deposits further west. This backfill would disturb the natural regime within the park. If sediment infilling was sufficient to stop the local undercutting of the lakeshore bluffs, the active dune fields in the park may revegetate and stabilize. Park resource managers wish to monitor this potential issue.

A stretch of shoreline at Sand Point has a stone revetment that is disrupting natural coastal processes there. The park originally installed the revetment to protect homes at risk of damage from lake level rise during the 1980s. The revetment may be removed as part of the Great Lakes Restoration Initiative (GLRI).

Other shoreline stabilization areas include the lighthouse station which is armored by gabions and timbers. The sandspit at Lookout Point would be larger were it not for the presence of armoring which prevents natural sediment accumulation there. The revetment area at park headquarters (the old Coast Guard station) is prone to flooding since the station was constructed during historic low lake levels.

The park includes 0.4 km (0.25 mi) of lake surface beyond the shoreline. However, there are cultural submerged resources of interest to park resource managers. At this time, the jurisdiction over the submerged portion of the park is unclear.

Slope processes and erosion

Hillslope issues at Pictured Rocks National Lakeshore range from dramatic block falls to slower slumping. Block fall and collapse are responsible for the formation of the cliffs of Pictured Rocks (fig. 2). There are hundreds of block falls every year and significant events every five to seven years. For instance, one of the two turrets at Miners Castle (a notable landmark in the park) recently collapsed (fig. 3). A large block fall recently occurred near Indian Head. The steep cliffs pose safety hazards for visitors hiking along the edge. Slumping and collapse at Miners Falls overlook caused the trail and overlook point to be moved. The existing platform is on jointed bedrock exposures and could slump or collapse again. Many overlooks in the park exist on undercut rock ledges and natural fractures within the rocks could render them susceptible to damage or destruction from active slope processes. There are some public safety issues associated with the waterfalls in the park as well. Visitors are no longer allowed to walk behind Munising Falls.

Ongoing erosion is forcing the relocation of the county road inside park boundaries. Erosion has undermined and even removed some sections of the old road. The semi-consolidated deposits at Grand Sable Banks are prone to erosion, slumping, and sloughing. In the past, visitors have dug cavities into the banks. Collapse of these temporary excavations can be fatal. As the wind blows against the banks, the sand is winnowed away leaving armoring stones (analogous to desert pavement except in tilted exposures) in layers of the glacial sediments. Visitors frequently cut trails down to the lakeshore from the Log Slide lookout. Their activity removes the armoring stones and creates 3 to 6 m (10 to 20 ft) deep notches in the face of the banks.

Erosion is occurring along certain stream banks, undercutting the edges. At Sable Creek, the adjacent, active sand dune field inundates the stream channel with sand which is then incised by the continued stream flow. If the dune were to suddenly slump, sand may impound the stream completely forming another lake. There is some aggravated erosion at the popular visitor trail here. The park has infested infrastructure to maintain the trail including raised boardwalks, bridges, and retaining walls (fig.4). The goal is to allow natural slope processes to proceed without impacting visitor access as the slide flows beneath the raised trail. Visitors have also created a social trail up the side of the dune that is removing stabilizing vegetation (fig. 5) and caused the formation of a sand island within the stream channel just downstream of the trail.

Disturbed lands

Disturbed lands within Pictured Rocks National Lakeshore (including the IBZ) include old gravel pits. It is current park policy to leave these disturbed sites alone (particularly in wilderness areas) and allow vegetation and weathering to naturally reclaim the areas. Recent mining for sand occurred along the park's edge for fill and roadway construction. These are not current targets for reclamation. The IBZ is permitted for commercial logging. This would affect at least half of the park area. Logging operations include clearcutting pine tree areas and selective harvesting of hardwood areas. Logging activities would also involve constructing temporary roads and bridges for access.

Potential energy and mineral development

Park staff and local experts are unaware of any oil and gas exploration in the Pictured Rocks area. There is an old fault line, related to faulting on the Keweenaw Peninsula that is now mineralized. Kennecott mining operations could extract nickel and uranium from these deposits at depths of 2,134 m (7,000 ft). It is unknown if this is documented within the park boundaries.

Developers are proposing wind farms in the vicinity of other Great Lakes parks including Grand Portage National Monument and Apostle Islands National Lakeshore. Such proposals may occur near Pictured Rocks National Lakeshore with potential impacts on the park's viewshed.

Seismicity

The cratonic core of the North American continent is not a hotspot for seismicity. Nevertheless, seismic events can occur regionally as buried ancient structures accommodate stresses within Earth's crust. In the Great Lakes area, these stresses are not generally tectonic in nature, but instead are the result of isostatic rebound as the crust adjusts to the lack of weight of the glacial ice since the end of the last ice age in the Pleistocene. There are myriad fractures that cross the state in the subsurface. Earthscope, a multidisciplinary research program, will eventually serve seismic data in its mission to utilize freely available data from instruments that measure motions of Earth's surface and record seismic waves (www.earthscope.org).

Figure 2. Recent blockfall at Pictured Rocks National Lakeshore. View is to the south. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 3. Miner's Castle, the type locality for the Miners Castle member of the Munising Formation. A portion of the outcrop recently collapsed into the lake. View is to the south. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 4. Trail maintenance efforts below Sable Falls. View is to the north. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 5. Social trail up the eastern side of the active sand dune area below Sable Falls. View is to the west. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Features and Processes

Shoreline features and processes

The evolution of the Pictured Rocks is intimately tied to the glacial and post glacial isostatic rebound history of the area. As the Pleistocene glaciers retreated, a series of glacial lakes formed at the edge of the glacial ice. Isostatic rebound has caused lake transgressions that inundate areas and liberate sediments for dune formation and reactivation.

The shoreline system is dynamic with shifting sands evolving into ephemeral landforms that can change in a single storm. Wind and wave energy continually sculpt bedrock shorelines into cliffs, embayments, rocky headlands, sea caves, sea stacks (spires or pinnacles), windows, and arches. In particular, the properties of the Chapel Rock Member of the Munising Formation lend themselves to the formation of sea caves and arches (fig. 6). Spectacular examples of sea caves (and in winter, ice caves) occur along the shoreline where this unit crops out. The presence of faults and joints may influence embayment and cave formation.

The park contains sand-based features such as dunes, beaches, beach ridges, and spits. In general, sand accumulates in sheltered embayments between headlands and at the base of Grand Sable Banks. Beaches also tend to occur at stream mouths with incoming fluvial deposits mixing with lakeshore sediments. Twelve-mile beach is a mixed sand and gravel beach.

Geology and history connections

Pictured Rocks National Lakeshore has a long record of human habitation and land use. Early uses of the landscape included pervasive logging and burning. Some cleared areas called stump prairies are still devoid of forests because slash burning in the 1880s sterilized the soil (fig. 7). The sandy soil in these areas is slow to recover the nutrients necessary to support forest growth. Elsewhere, higher soil clay content helped support regrowth by retaining moisture. The steep slopes of Grand Sable Banks provided log slides for early mining operations. Logs were slid down the slope into the water to be transported to the mill. The aeolian dune sand, winnowed and sorted by the wind was of interest to entrepreneurs such as Henry Ford who saw a potential to provide the auto industry with foundry sand and glass.

Paleontological resources

According to the paleontological resource inventory and monitoring report prepared by the Geologic Resources Division for Pictured Rocks National Lakeshore, the bedrock units in the park contain conodonts (tiny fish jaw fossils). There are also trilobite remains and trace fossils in the Munising and Au Train formations. Fossils from glacial erratics, transported from elsewhere, wash up on the shores at Pictured Rocks. These may include horn corals from the Hudson Bay area. A stick chewed by beavers several thousand years ago was also found within the park. Park resource managers are not concerned with fossil theft or degradation.

Glacial features

During the Pleistocene, episodic cooler climates led to global glaciation events. Of these, the Illinoian and later Wisconsinan events strongly influenced the development of the landscape in the Pictured Rocks National Lakeshore area. Locally, the Superior lobe scoured the Lake Superior basin, blanketing the area beneath a thick sheet of ice. A series of substages including the Marquette substage saw ice advance and retreat across the landscape numerous times before the final retreat. The Marquette lobe filled only the very deep Superior basin and probably did not cover Pictured Rocks.

The relatively small Munising moraine may be present south of the park. This deposit is enigmatic in that most moraines are defined as unsorted ice-marginal deposits; however, the Munising moraine is sorted outwash, marginal in nature as well as a moraine. More research is needed on this deposit to clarify its true nature. Between the moraine and the ice edge are kames, and terraces. The terraces formed where water flowed in channels between the ice edge and terminal moraines and reflects a setting that is relatively uncommon for continental glaciation.

Other glacial features in the park include outwash plains and tunnel channels which are continuations of deep grooves in the floor of Lake Superior. The Miners River currently occupies a tunnel channel. These features are the subject of much scientific interest. Large potholes formed during extreme flow events associated with melting glaciers are evident at Miners Creek and Grand Sable Creek (at Sable Falls). Other glacial features include shallow kettles, dry kettle depressions and kame-like, ice-edge deposits (Grand Sable Bluffs).

A series of glacial lakes formed landward of the large continental glacier during its Pleistocene retreat from northern Michigan. Right before the ice retreated from the area during the Marquette substage, Lake Algonquin covered the upper Great Lakes area (filling lakes Michigan and Huron). As the ice retreated for the last time, water from Lake Algonquin drained through Lake Ontario in a series of steps over approximately 1,000 years as melting ice revealed progressively lower outlets. This left many remnants of preserved lake levels and a complicated record of past shorelines on highlands (or islands). Lake Minong succeeded Lake Algonquin.

The Nipissing lake phase was 15 m (50 ft.) higher than the present lake level. This stage left wave cut cliffs, caves, and other shoreline features perched above the present shoreline. Infilling of Chapel Beach occurred at this time. Associated with the longshore currents of Lake Nipissing was the formation of several small lakes including Chapel Lake. The lakes formed as incoming sediments blocked stream outlets along the lakeshore.

Sand Point contains Quaternary deposits from the Nipissing transgression (sourced from the “punky” sandstone of the Miners Castle Member of the Munising Formation). Transgressions are locally caused by isostatic rebound as Earth’s crust rises in response to the lack of weight from the glacial ice. Rebound continues to occur since the glacial ice finally melted off some 10-11,000 years ago. Lake levels rose for 5,000 years until a new outlet formed. At this point, the proto-Lake Superior approached its modern elevation. According to Farrand and Drexler (1985), rebound at Lake Superior’s outlet separated it from the lower lakes approximately 2,280 years ago.

Aeolian features

Aeolian features at Pictured Rocks National Lakeshore include dunes, interdune swales, perched dunes, and barrier sand spits. Stranded lake deposits and sand dunes initially accumulated at Lonesome Point (downdrift from the bluffs with winds coming from the west) during the Nipissing transgression. The Grand Sable dunes began forming because the Nipissing transgression undermined nearby bluffs freeing vast amounts of sediment. The sand there collected into a series of overlapping sand dunes. Massive volumes of shifting sand have trapped lakes by damming drainages toward Lake Superior. These systems are analogous to barrier and back barrier settings. Active, perched dunes cap Grand Sable Banks more than 61 m (200 ft.) above the lake level. Sand blows up from the lake, loses contact with the wind and collects there. Stones in the underlying glacial sediments are left behind in layers acting as armor for the slope as the wind winnows away the sand. In the interdune swale areas of the dune fields are gravel lag deposits found within glacial sediments at the very base of the dunes and the very top of the glacial sediments.

Although the dunes at Grand Sable Banks may have initially collected during the Nipissing highstand (as was presented at a court case by anti-dune mining advocates), the dunes are actually stabilizing and destabilizing cyclically with the lake level which varies with climate and the degree of isostatic rebound. Lake level fluctuations cause the bluffs to be undercut and control sediment supply to the dunes. In this way, the dunes contain a record of lake level rise and fall that may also be a proxy to climate change over the past several thousand years. The largest dune formed 600 years ago at Grand Sable.

There are windblown silt (loess) deposits covering isolated areas to the east of the park. These types of deposits formed prior to extensive revegetation following glacial retreat. They are easily eroded and/or incorporated into the soil profile resulting from agricultural tillage. Remnant dunes, some as high as 12 m (40 ft.) exist on glacial outwash plain deposits along the “Seney Stretch” a straight portion of Highway 28 that is underlain by imported fill to elevate it above the surrounding marshy landscape.

Fluvial features and processes

Fluvial features at Pictured Rocks National Lakeshore include streams, deltas into Lake Superior, waterfalls, and terraces. Streams include Grand Sable Creek, Hurricane River, Sevenmile Creek, Spray Creek, and Mosquito River. The Lake Superior watershed is very narrow along this part of the lakeshore, and within Pictured Rocks NL, this band is only 3-8 miles wide. As a result, streams within the park are relatively small, with short runs, but cut through steep channels in response to isostatic rebound. The local Taquamenon River’s outlet, the northernmost portion of its channel, is always rising relative to its headwaters because of isostatic rebound. Many regional streams drain southwestward into the Manistique River.

Shoreline processes associated with the big lake overpower fluvial processes of deltaic formation and flow. Waterfalls such as Bridal Veil Falls flow over the cap rock in dramatic sprays to the lake below. Terraces exist at Grand Marais. Some elevated terraces formed during the Nipissing highstand, whereas others form during the winter when ice dams the streams prior to their confluence with the lake, thereby seasonally raising the flow level. Most of the park’s larger streams follow channels originally carved as glacial-affected, ice-marginal features. There are a few abandoned creek channels including remnants of old canyons near Grand Sable Banks that are interesting hiking opportunities.

Lacustrine features

Lacustrine features include lake and lagoon areas trapped by accreting sands and backwater sloughs left stranded as recessional features. Lakes include Grand Sable Lake, Trappers Lake, Beaver Lake, Little Beaver Lake, Chapel Lake, and Miners Lake. Wetlands and marshes are present in upland areas.

Mid-continental rift and regional geology

During the Precambrian, mantle upwelling caused the formation of a series of rift basins. The normal faults bounding these basins provided conduits for vast amounts of upwelling molten rock, or magma to reach the surface and emit forth as lava flows and associated volcanism. Between 1,098 and 1,092 million years ago, the main stage of volcanism produced the Portage Lake Volcanics (famous for native copper deposits) and the Minong Volcanics. Atop and amongst the lava flows are deposits of clastics (sandstone, conglomerate, and shale) primarily located on the rift margins eroded from the surrounding highlands. In general, the sediments are present along the flanks of the rift, whereas the volcanics trend up the middle of the rift.

The rift developed in three stages over some 50 million years approximately 1.1 to 1.11 billion years ago. The first was the initial pulling apart of the continental rocks and accompanying volcanism that spanned close to 14 million years. The second stage involved more extension, sedimentation, and subsidence or sagging with no associated volcanism. In cross section, the rift descends nearly to the Moho, or about 30 km (19 mi) in depth of which two-thirds is volcanics and the remaining third are overlying sediments. The third stage occurred when the extensional regime shifted to compression at the onset of the Grenville Orogeny (mountain building event that formed the supercontinent, Rodinia) to the east of the rift. This caused normal faults to reactivate and change sense to reverse faults. The compressive tectonic forces uplifted the center of the rift valley relative to its flanks.

The failed rift system exists in the subsurface as far south as Kansas, then it arcs north through the Lake Superior basin (the only place it is exposed at the surface), before descending south again into Ohio where it intersects a sutured minicontinent. In the lower peninsula of Michigan, the rift sits beneath 3,048 m (10,000 ft) of sediments in the Michigan basin. On a cross sectional view of the Lake Superior basin including Isle Royale and the Keweenaw Peninsula, a rounded syncline formed as the rift sagged due to thermal subsidence and sediment loading, then rivers carried sediments into the sagging basin causing additional loading. These sedimentary layers fined upwards as the slopes and sediment supply from surrounding areas decreased.

The bedrock at Pictured Rocks National Lakeshore comprises sedimentary rocks of Late Precambrian to Ordovician age. These sediments postdate the failed rift event. There is a history of controversy over the age of the bedrock. Early works lumped all the bedrock at the park as Cambrian sandstones. Later, the Jacobsville Formation was reassigned to the latest Precambrian based on a lack of fossils, flow directions recorded in the unit’s crossbeds, and the original source area for the sediments that was different from that of the overlying, fossiliferous Munising and Au Train Formations. Initially, geologists thought the mountains of the Keweenaw Peninsula acted as sources for Jacobsville sediments. Later, work with crossbedding within the formation (indicating southwest flowing transport) revealed the source was actually in Canada. The northern Michigan highlands were the source of Munising sediments. The Munising contains north-flowing crossbed indicators and was deposited in a coastal-fluvial environment.

The mid-continent rift forms a permanent zone of weakness in Earth's crust. Unlike the other Great Lakes that formed where shales cropped out and were preferentially eroded into lowlands, Lake Superior was already a basin prior to glaciation. The preexisting basin funneled glacial ice causing further erosion to oversteepen the Superior basin. The Straits of Mackinac between Lakes Michigan and Huron formed by a salt collapse within the Silurian age rocks buried at depth there.

After glaciation scoured the basin and left thick deposits on the landscape, the lack of weight pressing on the land from glacial ice caused the land surface to rebound. Due to post-glacial rebound, streams deeply and quickly cut through the ancient sedimentary rocks. Shoreline processes of waves, wind, freeze-and-thaw, and mass wasting continue to sculpt and wear away the bedrock of the lakeshore.

Unique features

The Pictured Rocks area contains outcrops of bedrock from the Late Precambrian through the Ordovician. These units are elsewhere buried beneath thick mantles of glacial deposits in Michigan. The Precambrian Jacobsville Formation (type locality: Keweenaw Peninsula) crops out along the western side of Grand Island. Here it appears red in color with some white layers and veins caused by the leeching of hematite by percolating groundwater. At Grand Marais, the Sable Falls flows over Jacobsville sandstone. The contact between the Jacobville and the overlying Munising Formation is erosional and unconformable; this contact is mappable on the Grand Island quadrangle. The Cambrian Munising Formation (three members: basal conglomerate, Chapel Rock, and Miners Castle members) forms the primary bedrock outcrops within the park including the Pictured Rocks. These are the best exposures of Cambrian rocks in Michigan. The highest cliffs in the park form within the Chapel Rock member whose type locality is at Chapel Rock along the lakeshore. These tall white cliffs are at their highest on the west side of Grand Portal Point. The more friable, "punky" sandstone of the Miners Castle member forms many of the distinctive cliff features at Pictured Rocks National Lakeshore. Its type locality is at Miners Castle.

The resistant, dolomitic sandstone of the Ordovician Au Train Formation supports the formation of cliffs at Pictured Rocks by forming a cap rock unconformably atop the Miners Castle member. This is a regional cliff forming unit that crops out in a concentric pattern within the Michigan Basin similar to the Silurian rocks that underlie the Niagara Escarpment. Another example of the limestone escarpment is at Lion's Head on the southern side of the Upper Peninsula of Michigan.

Water levels within the Great Lakes vary several meters over 100–200-year cycles. At Sleeping Bear Dunes National Lakeshore in the lower peninsula of Michigan, corrugated plains and beach ridges record the drops of the Nipissing lake levels with intermittent ridges recording five or six discrete stands. Evidence at Pictured Rocks includes paleosols, charcoal layers, and plant remains. The Carter Site, near Grand Marais, contains records of periods of lake level stability recorded as lagoon deposits from trapped lakes beneath sand.

Grand Sable Banks consists of a basal layer of fine-grained sediments, overlain by interbedded sand and silt, then by alluvial sand and gravel (fig. 8). Active sand dunes cap the banks. Grand Sable Banks preserves past lake levels. As lake levels rise, the bluffs and dunes along the lakeshore become more active or reactivated. When lake levels lower, vegetation begins to stabilize the landscape. This cycle has occurred at least a dozen times in the last 5,000 years. Grand Sable Lake formed when the Great Lakes' level was higher, overran the shoreline bluffs, eroding sand and depositing sand downcurrent toward Lonesome Point. This flowing sand dammed Sable Creek. Today, the core of Grand Sable Banks contains a paleovalley, paleosols, and springs flow from the base of the banks (fig. 9).

Pictured Rocks National Lakeshore protects myriad unique ecosystems and habitat. The endangered Pitchers thistle plant takes 10 years to mature and produce seeds. This particular plant, native only to the Great Lakes region, (Lakes Superior and Michigan) grows in the sandy substrate at Pictured Rocks along with one other known population on Lake Superior, at Sault Ste. Marie. These are the only known population in the Lake Superior area. Pine islands inhabit old dune ridges. After they formed, the climate became drier, vegetation died, and the dunes were reactivated. Several rare plant species grow at the springs along the base of Grand Sable Banks.

Figure 6. Large arch carved by collapse along the cliffs at Pictured Rocks National Lakeshore. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 7. Stump prairies inland of the lakeshore formed by sterilized soils as a result of 1880s logging practices. View is to the northwest. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 8. Grand Sable Banks. View is to the northeast. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 9. Seeps at the base of Grand Sable Banks. View is to the northeast. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Recommendations

1. Access the “onegeology” global portal interface.
2. Visit the National Fossil Day (October 13) website prepared in partnership between the NPS and American Geological Institute.
3. Investigate research using light dating (optically stimulated luminescence) studies to determine the time of sand burial in an effort to determine the lake level history. Such studies already exist for sands at Sable Creek.
4. Use progressive aerial photographs to document and monitor shoreline changes as a result of the breakwater at Grand Marais. Currently photographs exist for every 3 to 5 years in the past few decades.

Action Items

1. GRI report author will obtain copy of Bill Blewett’s (Shippensburg State University) new book on Pictured Rocks (currently in review)
2. GRI team will obtain a copy of the USGS upcoming 2011 publication on the rift geology.
3. GRI report author will obtain a copy of Schetzel’s 2009 book.
4. GRI report author will obtain a copy of LeBarge’s Lake Superior book.
5. GRI report author will find research from (Indiana) Sleeping Bear Dunes National Lakeshore regarding past lake levels.
6. GRI report author will obtain a copy of Rob Young’s report on coastal features at Pictured Rocks; a copy of the 2002 Friends of the Pleistocene guidebook (Walt Loope co-leader); a

copy of John Dorr and Donald Eschman's Geology of Michigan Report; and a copy of Bill Blewett's 1987 publication.

7. GRI report author will obtain information about C^{14} dating in the park.
8. GRI report author will obtain the following reference, Karrow, P.F., Dreimanis, A. and P.J. Barnett. 2000. A proposed diachronic revision of Late Quaternary time-stratigraphic classification in the eastern and northern Great Lakes area. Quaternary Research 54:1–12.
9. GRI report author will obtain a copy of Farrand and Drexler (1985).

References

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Farrand, W.R. and C.W. Drexler. 1985. Late Wisconsinan and Holocene history of the Lake Superior Basin. in Karrow, P.F. and P.E. Calkin (eds.) Quaternary Evolution of the Great Lakes. Geological Association of Canada Special Paper 30, pp. 18-32.

Table 2. Scoping Meeting Participants

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