Geological Highlights of the Thunder Bay Area

Field Trip for the Geological Society of Minnesota

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This document provides a brief summary of the primary geological features present in the vicinity of the City of Thunder Bay, along with descriptions of the geological features that can be observed at the locations that will be visited during the two days of this field trip.

**Introduction**

Thunder Bay is situated over the Precambrian age rocks of the Canadian Shield. These rocks were deposited over a period of several hundred million years, but all of them are more than 1 billion years old. In places, this ancient bedrock is overlain by much younger overburden deposits that were largely deposited near the end of the last period of glaciation approximately 10,000 years ago.

**Bedrock Geology**

The oldest bedrock is generally located to the north of the City. This area is dominated by rocks that form part of the oldest interior portion of the Canadian Shield, known as the Superior Province (see Figure 1). The Superior Province rocks in the Thunder Bay area are approximately 2.7 billion years old and consist of a complex mixture of deformed and metamorphosed volcanic and sedimentary rocks interspersed with granitic intrusions. Some of these rocks contain economically significant concentrations of precious and base metals, making the Superior Province one of the world’s most important mineral producing areas. In the Thunder Bay South Resident Geologist District, gold is currently being produced from the Hemlo Gold Mine (340 km east of Thunder Bay), while the Lac des Iles Mine (85 km north of Thunder Bay) is a significant producer of platinum group metals. The District also has a rich history of base metal production, with past-producing zinc-copper mines in the Manitouwadge and Schreiber areas, and a past-producing nickel-copper mine at Shebandowan.

At the time that the volcanic and sedimentary rocks of the Superior Province were being deformed and intruded by granite, it is likely that a high mountain range was present in the Thunder Bay area. However, after several hundred million years of erosion, approximately 1.9 billion years ago, the Thunder Bay area was located under water at the margins of an inland sea. At this time, new rocks of the Canadian Shield’s Southern Province began to form below the surface of this sea, on top of the older Superior Province “basement” rocks.

The earliest Southern Province rocks that formed in the Thunder Bay area are the flat-lying sedimentary strata of the Animikie Group. The Gunflint Formation (see Figure 2 geological map) is the lowermost (and oldest) sub-unit of the Animikie Group, and consists of a complex sequence of chemical (e.g., chert and carbonate) and clastic sedimentary (e.g., shale) rocks that formed at the bottom of the sea, interspersed with thin layers of volcanic tuff. Stromatolitic chert-carbonate horizons occur at a number of stratigraphic levels within the Gunflint Formation, including at locations near Kakabeka Falls, along the Current River in the City of Thunder Bay, and near Pass Lake. Rocks of the Gunflint Formation are exposed at throughout much of the City of Thunder Bay, and a thick cross-section can be observed in the gorge at Kakabeka Falls.

The upper boundary of the Gunflint Formation has recently been identified as a layer of impact debris that originated from the Sudbury meteorite impact event that occurred 1.85 billion years ago. This layer can be observed in outcrop at a number of locations, including the Terry Fox Lookout in MacGregor Township, and at Hillcrest Park in the City of Thunder Bay. Following the meteorite impact, a younger sedimentary unit known as the Rove Formation was deposited above the Gunflint and Sudbury Impact
Layer. The Rove Formation consists of a thick sequence of shale and sandstone (also with thin volcanic tuff layers) that dominates the area between the City of Thunder Bay and the international border at Pigeon River. Rove Formation rocks are also exposed in the southern portion of the Sibley Peninsula at Silver Islet.

![Map of Superior Province (subdivided into subprovinces), illustrating location relative to Southern Province.](image)

Figure 1. Map of Superior Province (subdivided into subprovinces), illustrating location relative to Southern Province.

Approximately 1.45 billion years ago, following a 300 million year hiatus in deposition, a new sedimentary rock unit known as the Sibley Group was deposited over top of all of the earlier formations during an estimated time period of about 100 million years. These rocks were deposited in a graben-type structure that that formed after the development of a number of north-trending faults in the area between Thunder Bay and Nipigon. Rocks of the Sibley Group are exposed to the east of Thunder Bay, along the Sibley Peninsula. The Pass Lake Formation forms the lowermost portion of the Sibley Group and consists of conglomerate (located at the base of the formation) and sandstone. The Pass Lake Formation is overlain by the Rossport Formation, which is dominated by siltstone, dolomite and dolomitic mudstone. This formation also contains sporadic horizons of stromatolitic chert-carbonate, including at Middlebrun Bay near the south end of the Sibley Peninsula.

Another hiatus in tectonic activity occurred during the period between 1.35 and 1.1 billion years ago. This tranquil period ended with the onset of the Midcontinent Rift event, which resulted in the development of numerous north-northeast trending faults, and the onset of a period of magmatic activity that is believed to have lasted for approximately 35 million years in the Thunder Bay area. The
faulting resulted in the development of a major graben structure in the area currently occupied by Lake Superior. Volcanic flows flooded over much of the area of the rift. However, owing to Thunder Bay’s location on the northern fringes of the rift, only igneous intrusive rocks are exposed in this area. These rocks occur largely as diabase sills and dikes. The diabase sills (see Figure 3 cross-section) form the cap rocks for the flat-topped mountains (or tablelands) that dominate the landscape in the area immediately south of the City of Thunder Bay.

Figure 2. Simplified bedrock geology of the Thunder Bay area.

During the waning phases of the Midcontinent Rift event, high temperature (hydrothermal) fluids continued to flow through the fault zones and fractures that opened up during rifting. These fluids contained dissolved minerals and metals that resulted in the formation of numerous veins within the faults and fractures. These veins are dominated by the minerals calcite and quartz, but in some localities, these veins contain accumulations of metallic minerals and/or amethyst. The most famous of the metallic mineral deposits was the Silver Islet Mine, located on a small island at the south end of the Sibley Peninsula. Many small-scale amethyst quarries are currently operating in the Thunder Bay District, with most of these deposits being concentrated in the Pearl area, approximately 45 km northeast of the City of Thunder Bay.
Overburden Geology

Approximately 11,000 years ago, glaciers began to retreat from the area surrounding Thunder Bay. However, ice re-advanced into the area from the northwest approximately 10,000 years ago, before retreating for good by approximately 500 years later. During these periods of glacial advance and retreat, a number of moraine deposits, including the Dog Lake, MacKenzie and Marks moraines were formed in the Thunder Bay area (Figure 4). As the ice retreated, Lake Kaministiquia was formed by glacial meltwater behind the Marks Moraine, while Lake Minong occupied an area slightly larger than present day Lake Superior. Approximately 9700 years ago, the Marks Moraine was breached, resulting in the deposition of extensive delta deposits in the Kaministiquia River valley beginning near Kakabeka Falls, which was then located at the shoreline of glacial Lake Mining.

The glacial delta deposits of the Kaministiquia River valley are an important source of aggregate, with numerous pits (e.g., in the Stanley area) having been developed in locations where abundant gravel is present. Many pits have also been developed in the moraine deposits, and in thick glacial outwash deposits located adjacent to the moraines in Gorham Township.

The Lake Minong shoreline runs through the upper part of the City, being particularly evident in Boulevard Park where river mouth bars and terraces of the Current River are seen. The Minong
shoreline in the city is strongly associated with Palaeo-Indian sites, the Cummins Site being the best-known. It is likely that as water levels fell, these early people moved down from the Arrow-Whitefish Lakes area into the Kaministiquia embayment. Little remains of the tools used by these people, other than a variety of knapped lithic tools made from Gunflint Formation chert.

Figure 4. Surficial Geology of the Thunder Bay area.
Day 1 Field Trip Stops – Geology of Thunder Bay and Kakabeka Falls

Stop TB1. Terry Fox Scenic Lookout

(UTM coordinates: NAD83; 340112E / 5372511N)

The road cut near the entrance to the Terry Fox Scenic Lookout provides an opportunity to view rocks of the Gunflint Formation, Rove Formation, and the Sudbury Impact layer, along with a Midcontinent Rift-related diabase sill. A stratigraphic section for this location is illustrated on Figure 6.

One of the most interesting features in this outcrop is a normal fault that displaces the stratigraphy by approximately 4 metres.
Figure 6. Photograph of the stratigraphic section at the Terry Fox Scenic Lookout. This photo was taken from an earlier cut face that was subsequently removed by blasting. The current face is less weathered, with poorer definition of the Sudbury Impact layer features.

Stop TB2. Hillcrest Park
(UTM coordinates: NAD83; 16U 0334689E / 5366961N)

On a clear day, the Sibley Peninsula and the Sleeping Giant can be seen across the waters of Thunder Bay (Figure 7). The 240 m high cliffs facing Thunder Bay are the highest in Ontario. The Sleeping Giant is capped by a diabase sill which has intruded Rove Formation shale and sandstone. Other prominent mesas and cuestas include Pie Island and Mount McKay and the other hills of the Nor’Wester range to
the south. All of these hills consist of Rove Formation sedimentary rocks capped by Logan sills. Isle Royale (Michigan), visible on the distant horizon, consists of Midcontinent Rift-related volcanic flows.

Raised beaches that represent the former water level of glacial Lake Minong are visible at a number of locations in the city, and westward toward Kakabeka Falls. The most prominent in this part of the city extends along Algoma Street. It is associated with the Nipissing Great Lakes stage (5500 years ago), approximately 20 m above present day Lake Superior.

**Figure 7.** Geological features visible on a clear day from the lookout at Hillcrest Park.

The large bell at this lookout rests upon what was previously known the “Upper Limestone” member of the Gunflint Formation. This unit has recently been re-interpreted as 1.85 billion year old carbonatized ejecta related to the Sudbury impact event. To view the ejecta, proceed down the concrete stairs, turn right and walk along the laneway. The ejecta layer here is characterized by brecciated fragments of the underlying Gunflint Formation and accretionary lapilli (Figure 8) that accumulated as “fall-out” from the impact event.

**Figure 8.** Sudbury Impact layer with spherules of accretionary lapilli.
After deposition, the Sudbury Impact layer (SIL) is believed to have been exposed to the atmosphere for approximately 15 million years before seawater transgressed back into the Animikie Basin and allowed for the deposition of the Rove Formation. During this time the SIL experienced extensive alteration that is interpreted to have been related to groundwater infiltration. This alteration included the development of karst cavities that were subsequently filled with agate stalactites. Many of these features are visible in the vicinity of the bell.

Stop TB3. Cummins Archaeological Site
(UTM coordinates: NAD83; 16U 0325670E / 5364042N)

The Cummins archaeological site is located along the former shoreline of glacial Lake Minong and is the most extensively studied Paleo-Indian site in the Thunder Bay region. Approximately 9500 years ago, this site was located near the mouth of the Neebing River and is characterized by several large sand and gravel bar deposits. Bedrock of the Gunflint Formation outcrops nearby. These outcrops include exposures of jasper, a major source of tool-making materials for the earliest Paleo-Indian peoples who migrated into this area following the retreat of glacial ice. The Cummins site is believed to have been a site that was used for an extended period of time as a quarrying and tool-making centre. The site has yielded thousands of discarded flakes, blocks and other tool-making debris, with relatively small relative numbers of finished tools having been recovered.

Figure 9. Map of the Cummins archaeological site (from Julig, McAndrews and Mahaney 1990 based on Phillips 1982). Field trip stop is at the west end of the fenced area.
Stop TB4. Highway 588 near Barrie Drive - Sudbury Ejecta
(UTM coordinates: NAD83; 16U 0307539E / 5357977N)

This is a location where recent road construction work has resulted in the placement of SIL rubble in to the roadside ditches adjacent to Highway 588. This is a collecting stop for those who are interested in obtaining samples of SIL ejecta. The rubble at this location also contains fragments of brecciated Gunflint Formation stromatolites.

Stop TB5. Kakabeka Falls
(UTM coordinates: NAD83; 16U 0305738E / 5364400N)
*This is a “no hammer” stop, as sample collection is prohibited in Kakabeka Falls Provincial Park

Figure 10. Kakabeka Falls.

Kakabeka Falls Provincial Park is dominated by a single, spectacular feature, Kakabeka Falls, which drops 39 m over sheer cliffs in Gunflint Formation sedimentary rocks. Kakabeka is an indigenous word meaning “steep cliffs.” The portage around the falls contains archaeological artifacts ranging in age from the Paleo-Indian to the fur trade periods.

The falls owes its existence to the thin, lowermost chert-carbonate bed of the Gunflint Formation which forms a resistant cap rock above softer underlying volcaniclastic shale and tuff. Looking down the gorge, one can observe a lapilli-tuff horizon as a distinctive lighter grey unit near the base of the black shale-dominated stratigraphy. Note that the thickness of the shale horizon at Kakabeka Falls is much greater than at other locations in the Thunder Bay region.
The outcrop on the northern edge of the parking lot contains layers of banded chert-carbonate within black, fissile shale. The alternating, dark grey chert and brown siderite-ankerite layers display slump and soft-sediment deformation features. Microscopic examination of banded chert-carbonates reveals delicate lamination in the chert, which resembles the “ribbon texture” of algal mats.

Stop TB6. Conmee Township Gravel Pit  
*(UTM coordinates: NAD83; 16U 0304716E / 5369390N)*

At this stop, we will be looking at a section of Superior lobe glacial drift. The exposed sequence consists of approximately 6 to 7 m of well sorted, steeply-dipping glaciofluvial sand and gravel overlain by 2 to 3 m of silty Superior lobe till. This feature represents a location at which the advancing Superior Lobe is likely to have stalled prior to reaching its maximum position further to the west, at the Marks Moraine. After meltwater deposited deltaic gravel at this location, the glacier resumed its advance, depositing subglacial till over top of the gravel that was not scraped away.

An interesting feature noted at this location during gravel extraction was the occurrence of a number of large angular to rounded boulders on the pit floor. Some of these boulders contain significant quantities of pyrite, sphalerite and magnetite. One of the boulders measured over 1 m in diameter and consisted of massive pyrite and magnetite with 10 to 15% sphalerite disseminated in pyrite-rich sections. Sphalerite (a zinc ore mineral) was also concentrated along fractures and adjacent to quartz veinlets throughout the rock. The boulders were extracted from the lower glaciofluvial unit and may not have been transported very far, suggesting that there is potential for the discovery of economic base metal mineralization nearby.

Stop TB7. Mud Lake Pillowed Volcanic Flows  
*(UTM coordinates: NAD83; 16U 0315060E / 5376760N)*

This stop provides an opportunity to view some of the very old (Archean) Superior Province rocks that dominate the area to the north of the City of Thunder Bay. These rocks are volcanic rocks of basaltic composition that have been metamorphosed to “greenschist” facies metamorphic grade (a relatively low pressure and temperature level of metamorphism). These rocks contain significant amounts of the dark green metamorphic mineral chlorite (hence the term greenschist). A significant proportion of the Superior Province is made up of linear belts of volcanic and sedimentary rocks that are commonly referred to as “Archean greenstone belts.” This name came about because dark green metamorphic minerals are almost always present in the basaltic volcanic rocks that tend to be the dominant rock type in these belts. The rocks at this location form part of the Shebandowan greenstone belt.
Figure 11. Pillowed volcanic rocks similar to those that can be seen at Mud Lake.

These volcanic rocks display structures called “pillows” that often develop when basaltic lavas erupt in an underwater environment. The dark-coloured pillow margins represent lava that cooled very quickly upon contact with water, forming rims of volcanic glass (due to metamorphic effects the original volcanic glass is no longer present). You will also note that the planar structures that are present in these rocks are steeply-inclined, unlike the near-horizontal bedding planes that we have observed in the Gunflint and Rove formations. This is because of the deformation, metamorphism and subsequent uplift and erosion that these rocks experienced during and after the tectonic events that accompanied the formation of the Superior Province.
Day 2 Field Trip Stops – Geology of the Sibley Peninsula

Stop S1. Pass Lake Corner Highway Rock Cut – Gunflint Unconformity

A long road cut on the southeast side of Highway 11-17 (immediately west of the intersection with Highway 587) provides an excellent cross-section through the Lower Gunflint Formation, immediately above the basal unconformity (see Figure 13). An Archean gabbro intrusion occurs immediately below the unconformity. This intrusion forms part of the ca. 2.7 billion year old Shebandowan greenstone belt, the same linear belt of metamorphosed and deformed volcanic, sedimentary and intrusive rocks observed yesterday near Mud Lake.

The Gunflint Formation rocks that can be seen at this location include the basal “Kakabeka” conglomerate, algal stromatolites and chert-carbonate grainstones. The algal stromatolites have been observed in a limited portion of the exposure immediately above the unconformity surface. The grainstones display cross-lamination features indicative of deposition in a near-shore environment.
Figure 13. Gunflint Formation unconformity in Highway 11-17 road cut near the intersection with Highway 587. The basal conglomerate can be seen adjacent to the scale card.

Stop S2. Devil’s Flowerpots
(UTM coordinates: NAD83; 16U 0370841E / 5382426N)

A quarry face exposure of black, fissile Rove Formation shale at this location displays a spectacular example of a large, flower pot-shaped concretion (Figure 14). Concretions form during diagenesis, following initial compaction and dewatering of the sediments. They represent a concentration of a cementing agent, such as silica or calcite that became focused during the migration of fluid through the sediments. They often nucleate around a piece of organic material or other foreign object. Because the cementing agent here is more resistant to weathering, these concretions stand out from the soft shale.

Groundwater and surficial water flow through the shale has led to the dissolution and subsequent precipitation of a variety of low-temperature minerals (probably mostly sulphates) that occur as white and yellow encrustations on the bedrock surface. One of the more unusual of these secondary minerals (yellow in colour) is known as magnesium aluminocopiaptite.
Stop S3.  Watson Lookout – Pass Lake Formation Cross-Section

(UTM coordinates: NAD83; 16U 0371737E / 5382460N)

A private access road extending up to a lookout provides an excellent 150 m long section exposing the disconformity between the Rove Formation shale and the overlying basal conglomerate and sandstones of the Pass Lake Formation. The conglomerate clast lithologies at this location are dominated by chert-carbonate clasts (Figure 15) that were derived from weathering and erosion of the Gunflint Formation. Other clasts that are present in the conglomerate include Archean age granite and quartz vein material derived from the older Superior Province basement rocks. The conglomerate is sharply overlain by mature, well-sorted, medium-grained sandstones that were deposited in a near-shore environment.
Stop S4. Kettle and Brohm Archaeological Sites  
(UKM coordinates: NAD83; 16U 0371241E / 5381279N and 371236E / 5380897N respectively)

As we discovered yesterday when visiting the Cummins site, local archaeological sites are closely tied to paleo-shorelines, especially those associated with Lake Minong. When flooded to Lake Minong levels, the Sibley Peninsula would have become a virtual island, most likely only connected to the mainland near Pass Lake by a spit between the sandstone cliffs. The location of the Kettle and Brohm archaeological sites may relate to the importance of this paleogeography in constricting the movement of caribou and other animals from the peninsula to the mainland.

Stop S5. Rossport Formation  
(UKM coordinates: NAD83; 16U 0372842E / 5377943N)

At this stop we will have an opportunity to view sandstone, siltstone, shale and dolomite of the Rossport Formation. The outcrop on the west side of the road consists of somewhat chaotic layering and appears to have several steeply dipping faults running through it. On the southern end of the outcrop the sandstone layers abruptly terminate against red siltstone. The shale horizons in the exposure have a distinctive purple colouration. The shale also has unusual mineralogy, as it is composed largely of potassium feldspar rather than clay minerals (as would be expected).

On the east side of the road, the sandstone that forms the top of the outcrop is underlain by a chaotic mixture of siltstone, shale and dolomite clasts within a pebbly silt matrix. This in turn overlies a thick layer of dolostone having an irregular upper surface that is interpreted to represent karst that was present at the time of sediment deposition.
**Stop S6. Sleeping Giant Scenic Viewpoint – Photo Opportunity**  
(*UTM coordinates: NAD83; 16U 0368140E / 5361707N*)

This scenic viewpoint provides an opportunity to view the “other side” of the Sleeping Giant from the shores of Marie Louise Lake, the largest lake on the Sibley Peninsula.

![View of the east side of the Sleeping Giant from the Marie Louise Lake scenic viewpoint.](image)

**Figure 16.** View of the east side of the Sleeping Giant from the Marie Louise Lake scenic viewpoint.

**Stop S7. Sleeping Giant Provincial Park Visitor Centre**  
(*UTM coordinates: NAD83; 16U 0366350E / 5353925N*)

The Sleeping Giant Provincial Park Visitor Centre is located at the Marie Louise Lake campground and features a number of interactive exhibits that provide information about the natural and cultural history of the Sibley Peninsula. These exhibits include a model of the Silver Islet Mine and a large polished block of stromatolitic chert carbonate from the Middlebrun Bay member of the Rossport Formation.
Stop S8. Silver Islet

Cliff Exposures (S8-1)
(UTM coordinates: NAD83; 16U 0366232E / 5355427N)

The cliff exposures along the portion of the Avenue shown on Figure 17 as Stop Location 1, reveal flat-lying, thinly bedded Rove Formation siltstones and shales (mudstones) that accumulated as turbidity current-deposited sediments in a submarine fan or ramp off of the continental shelf of the proto-North American Craton ca. 1840 million years ago. These sediments were likely shed off of eroding mountains hundreds of kilometres away and transported to an Animikie ocean basin via large rivers and deltaic complexes.

These sedimentary rocks are cut by a columnar-jointed, northeast-trending diabase dyke related to extension during Midcontinent Rifting ca. 1110 million years ago. This hard, intrusive igneous rock resists erosion, unlike the soft mudstones and siltstones. It forms dominant ridges, mesas, islands and long, prominent headlands extending out into Lake Superior.

Figure 17. Geological map of the Silver Islet area (Thunder Cape Sheet, Tanton 1924). Rove Formation sedimentary rocks are yellow; Sibley Group sedimentary rocks are blue and diabase dykes are red.
In the 1870s, Silver Islet was an active mining community that supported one of Canada’s most improbable mines. This stop affords us the opportunity to look across the waters of Lake Superior to the former site of the Silver Islet Mine, 1.8 km to the south. This tiny speck, barely rising above the waves, was once home to the most famous silver mine in the world. In 1868, native silver was discovered on the tiny outcrop just above the waves originally called Skull Rock. The silver ore occurred in veins that cropped out on the islet and extended below the surrounding waters of Lake Superior. The owners struggled for years to operate the mine while protecting it from battering storm waves and seepage of water into the mine workings. Over the mine’s 14-year history, it produced almost 3 million ounces of silver. The tiny original island, which originally measured only a few metres in diameter, was fortified with rock and cribbing, expanding its original size 16 times. At its peak, the little island supported 11 mine buildings and the workings descended almost 400 m below the lake. However, in 1884, the mine workings flooded when a coal shipment was delayed and the coal-fired pumps stopped working. Mining never resumed. Today, little remains on the island but the partly submerged foundations of cribbing and buildings (photo).

Figure 18. Aerial view of present-day Silver Islet with historic site plan.
Thunder Bay Geology References

The following reference documents were used in the preparation of this field trip guide and provide much more information about the geology of the Thunder Bay area.

Northern Ontario Geotours for Thunder Bay and Nipigon

https://www.mndm.gov.on.ca/sites/default/files/geotour_pdf_files/geotours_thunder_bay_e.pdf

https://www.mndm.gov.on.ca/sites/default/files/geotour_pdf_files/geotours_nipigon_e.pdf


