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Paleoproterozoic Glacial, Microbially Induced, and Tidal Deposits of the Huronian Supergroup, Elliot Lake Region, Northeastern Ontario: A Geological Guidebook

2023

ONTARIO GEOLOGICAL SURVEY

Open File Report 6396

Paleoproterozoic Glacial, Microbially Induced, and Tidal Deposits of the Huronian Supergroup, Elliot Lake Region, Northeastern Ontario: A Geological Guidebook

by

P.L. Corcoran and C.M. Hill-Svehla

2023

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PREFACE

This geological field trip guidebook was prepared initially for use with a field trip (trip number FT08) for the joint annual meeting of the Geological Association of Canada, the Mineralogical Association of Canada and the Society for Geology Applied to Mineral Deposits (GAC–MAC–SGA) in Sudbury, Ontario, May 25–27, 2023.

Sudbury is one of the world's premier nickel-copper mining districts, a significant platinum group element (PGE) producer, and one of the oldest, largest, and best-exposed meteorite impact sites on Earth. As the world's largest integrated mining technology cluster, Sudbury has a vibrant mineral exploration and mining community that includes several major producers, numerous junior exploration companies, dozens of mining supply and service companies, 3 post-secondary educational institutions and associated exploration and mining centres, and several Ontario government mining and mineral ministry offices, making Sudbury one of the best places in the world to host a multidisciplinary meeting of this type. The City of Greater Sudbury, the largest city by landmass in Ontario, lies amidst glacially shaped ridges, green boreal forests, and contains 330 lakes over 10 hectares in size and 112 lakes over 100 hectares in size. The success of more than 40 continuous years of environmental reclamation efforts has led to numerous national and international awards, including a Government of Canada *Environmental Achievement Award*, a United States *Chevron Conservation Award*, and a United Nations *Local Government Honours Award.* And, as part of Sudbury's continuing regreening efforts, the milestone 10 millionth tree was planted in July 2022.

The theme of the GAC–MAC–SGA meeting—"Discovering Ancient to Modern Earth"—reflects the location of the meeting at the intersection of the Archean Superior Province and Proterozoic Southern and Grenville provinces, and Paleozoic–Quaternary cover sequences. The hybrid conference included a technical program of oral and poster presentations in Symposia, Special Sessions and Regular Sessions covering the complete spectrum of geoscience disciplines, which were complemented by 10 field trips, 6 workshops and 1 short course.

The meeting was hosted by the Harquail School of Earth Sciences and the Mineral Exploration Research Centre (MERC) at Laurentian University.

Abstract

The Huronian Supergroup is located within the geological Southern Province and is exposed from the Sault Ste. Marie area in the west to the Cobalt Embayment in the northeast and to just north of Lake Huron in the south. The Southern Province is in contact with the Superior Province along its northern margin and with the Grenville Province along its southeastern margin. The Huronian Supergroup is up to 12 km thick and was deposited between 2.45 and 2.22 billion years ago, as determined from the ages of felsic volcanic rocks near the base of the stratigraphy and gabbro (diabase) intrusions that cut the entire succession. The supergroup is composed of 5 groups and 13 sedimentary formations that were deposited in transform rift to passive margin tectonic settings. The lower Huronian Supergroup developed during a rifting stage under reduced atmospheric conditions, whereas the upper Huronian Supergroup formed along a passive margin in an oxygenated atmosphere. Tripartite cycles containing conglomerate overlain by fine-grained strata (mudstone–siltstone or mudstone–siltstone–limestone–dolostone) and capped by sandstone reflect deposition during glacial advance and retreat associated with tectonic disturbances. The Paleoproterozoic rocks are very well exposed and shallowly dipping in the Elliot Lake region.

The Matinenda Formation is composed of uranium- and pyrite-bearing sandstone and pebble conglomerate, and it was mined heavily between the late 1950s to the early 1990s. These economic deposits are responsible for the presence of the town of Elliot Lake. This field trip guidebook describes 10 stops in the Elliot Lake area, 1 stop near Wharncliffe, 1 stop near Spanish, and 1 stop in Espanola. Of the 13 sedimentary formations of the Huronian Supergroup, this field trip visits 10, over a two-day period. The visited formations provide excellent examples of microbial mat chips, microbially induced sedimentary structures (MISS), soft-sediment deformation structures (SSDS), and tidal structures (e.g., flaser and lenticular bedding, herringbone cross-stratification, wave ripples). This excursion also provides evidence for 1 of the oldest glaciations recorded in the rock record in the form of dropstones, varves, and ice-rafted slabs. The road-accessible stops included in this guidebook were selected to illustrate the evidence for critical atmospheric, biological and surficial processes that occurred during Earth's early evolution.

Paleoproterozoic Glacial, Microbially Induced, and Tidal Deposits of the Huronian Supergroup, Elliot Lake Region, Northeastern Ontario: A Geological Guidebook

P.L. Corcoran[1] and C.M. Hill-Svehla[2]

Ontario Geological Survey
Open File Report 6396
2023

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Introduction

The Huronian Supergroup of the geological Southern Province is exposed along the northern shoreline of Lake Huron in Canada. The Paleoproterozoic, sedimentary-dominated succession is up to 12 km thick and represents deposition during a transform rift to passive margin transition (Ojakangas et al. 2001; Young et al. 2001; Long 2004, 2009). The well-preserved deposits provide excellent examples of ancient glacial and early biological influence, as well as evidence for a reducing atmosphere followed up-section by strata that accumulated during oxygenated conditions.

This geological guidebook was prepared to assist participants and subsequent users of this guidebook in understanding the rocks of the Paleoproterozoic Huronian Supergroup in the Elliot Lake region. The trip leaders are very experienced in the sedimentology of the Huronian Supergroup. Professor Corcoran has supervised 1 MSc and 2 PhD students whose theses focused on 3 geological formations exposed in and around Elliot Lake. Results of these theses have been published in 5 journal articles. Professor Corcoran has taught the geology of the Huronian Supergroup in Whitefish Falls, Espanola and Elliot Lake to undergraduate students for almost 2 decades. Professor McCausland (coleader) has also taught Huronian Supergroup geology to undergraduate students in the Whitefish Falls region.

SAFETY

All outcrops are accessible by vehicle and several stops are located on busy roads. Care should always be exercised when parking, exiting vehicles and crossing the roads. Use of safety vests is mandatory to improve visibility to motorists, these will be provided. Seat belts must be worn at all times. There will be a large first aid kit in each vehicle, but it is recommended that anyone using this field guide should bring their own first aid supplies. Cell phone service coverage at some stops is poor, especially north of Elliot Lake and Iron Bridge. Safety glasses must be worn if participants wish to hammer the rocks. Some outcrops are not to be hammered—a leader will inform participants if this is the case. Weather during the month of May is quite variable. Be prepared for warm, cold and wet conditions.

Regional Geology and Geological Setting

The Paleoproterozoic Huronian Supergroup is a succession of primarily siliciclastic rocks that comprise part of the geological Southern Province of Ontario, Canada (Figure 1). The Huronian Supergroup is exposed along the north shore of Lake Huron and extends northeast into the Cobalt Embayment (Figure 1). Maximum U/Pb ages of 2450 $^{+25}/_{-10}$ Ma (Krogh, Davis and Corfu 1984) and 2452.5±6.2 Ma (Ketchum et al. 2013) were determined from a rhyolite unit near the base of the succession. Gabbro intrusions that cut the entire stratigraphy provide a minimum age limit of 2219.4±3.5 Ma (Corfu and Andrews 1986). Detrital zircon U/Pb geochronology of the 2 uppermost formations of the Huronian Supergroup constrains their deposition to sometime after 2315±5 Ma (Hill, Davis and Corcoran 2018).

A transform-rift to passive margin model has been adopted for the tectonic setting of the Huronian Supergroup by recent authors (Figure 2; Ojakangas et al. 2001; Young et al. 2001; Long 2004, 2009). The supergroup is composed of 4 formal and 1 informal group, respectively: Elliot Lake, Hough Lake, Quirke Lake, Cobalt, and Flack Lake (Figure 3). Of these groups, 3 are characterized by tripartite divisions containing basal glaciogenic deposits overlain by fine-grained siltstone, mudstone and/or carbonate deposits, and capped by thick, cross-bedded sandstones of fluvial origin (McDowell 1957; Card, Innes and Debicki 1977; Long 2009; Young 2004, 2014). These tripartite cycles are inferred to have been controlled by glacio-eustacy and/or tectonic uplift and subsidence (Card, Innes and Debicki 1977; Young et al. 2001). Similar Paleoproterozoic glaciogenic deposits have been identified in Quebec and Nunavut (Canada), Michigan (USA), the Transvaal basin (South Africa), the Hamersley basin (Australia), the North Karelia and Kainuu belts (Finland), southern Karelia (Russia), and other locations (Melezhik et al. 2012).

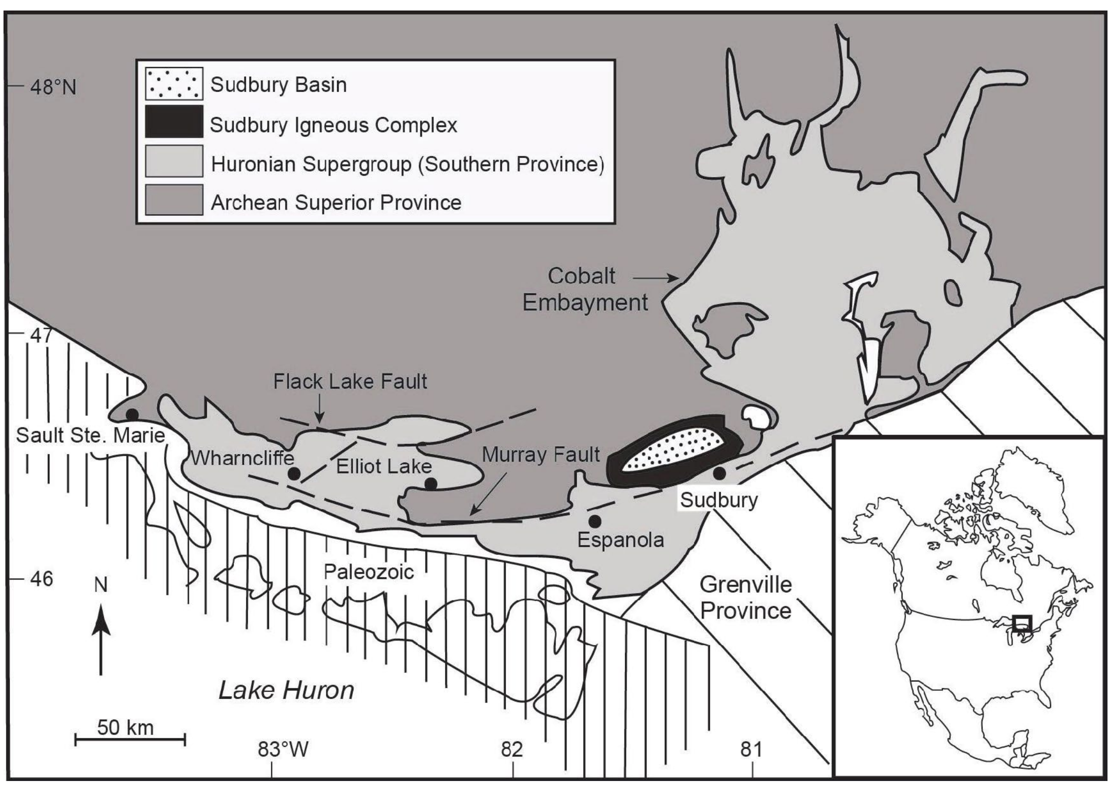

Figure 1. Location of the Huronian Supergroup in North America. The succession stretches from the Sault Ste. Marie region in the west to the Cobalt Embayment northeast of Sudbury. The field stops are located in and around Elliot Lake, with 1 stop in Espanola and 1 stop near the community of Wharncliffe. *Modified from* Hill (2019) and Young et al. (2001).

The Huronian Supergroup contains evidence of the transition from a reducing to oxygenated atmosphere. Low atmospheric oxygen is supported by sulphur isotopes in pyrite (Zhou et al. 2017), and the presence of detrital uranium-bearing minerals in the Matinenda Formation (Elliot Lake Group) and Mississagi Formation (Hough Lake Group) (Long 2009). Red beds in the Gowganda and Lorrain formations (Cobalt Group), and the Gordon Lake and Bar River formations (Flack Lake Group), in addition to evaporite minerals in the Gordon Lake Formation, indicate that the atmosphere was oxygenated during deposition of the upper half of the stratigraphy (Wood 1973; Chandler 1988). Stromatolites and microbial mat fragments in the Espanola and Gordon Lake formations indicate at least locally oxygenic conditions (Hoffman et al. 1980; Hill et al. 2016; Al-Hashim 2016; Hill and Corcoran 2018). Table 1 contains details regarding the interpreted processes and depositional settings of the 13 sedimentary formations of the Huronian Supergroup.

Rocks of the Huronian Supergroup were deformed during the Penokean Orogeny, which occurred *circa* 1875–1825 Ma (Van Schmus 1976; Schulz and Cannon 2007). The deposits north of the Murray Fault (in the Elliot Lake region) have been subjected to lower greenschist grade metamorphism.

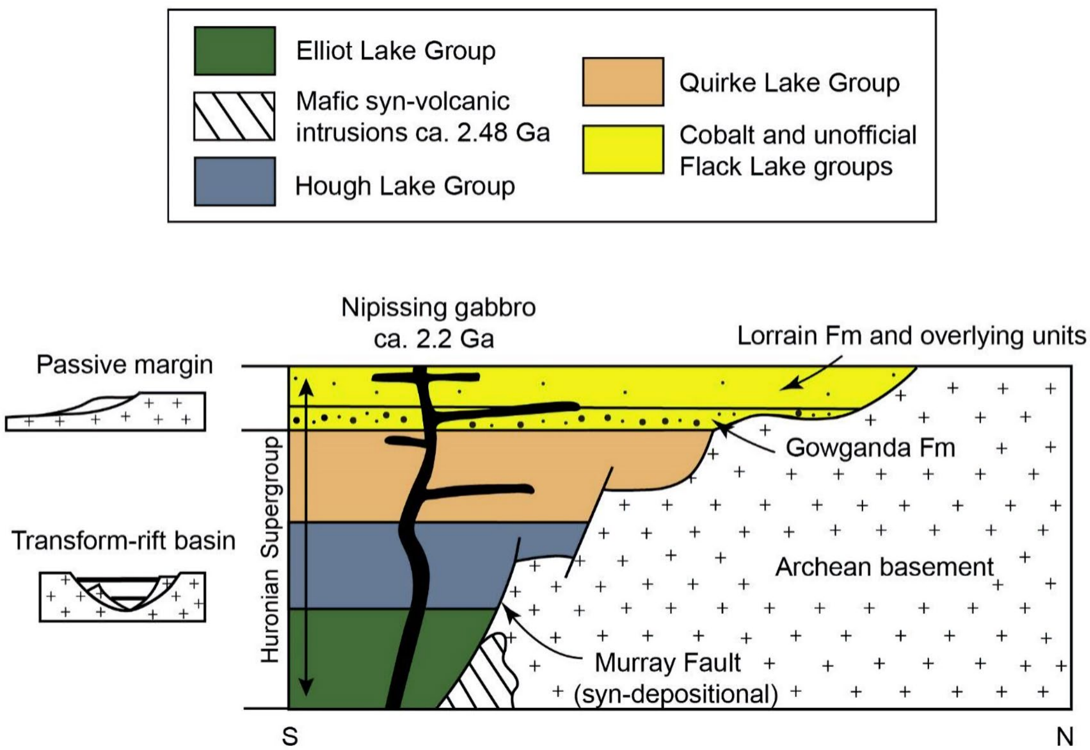

Figure 2. Interpreted basin configuration of the Huronian Supergroup displaying the Elliot Lake, Hough Lake, and Quirke Lake groups deposited in a transform-rift basin, and the Cobalt Group and the Flack Lake (unofficial) Group were deposited along a passive margin. Figure *from* Hill (2019) which is *modified from* Young et al. (2001).

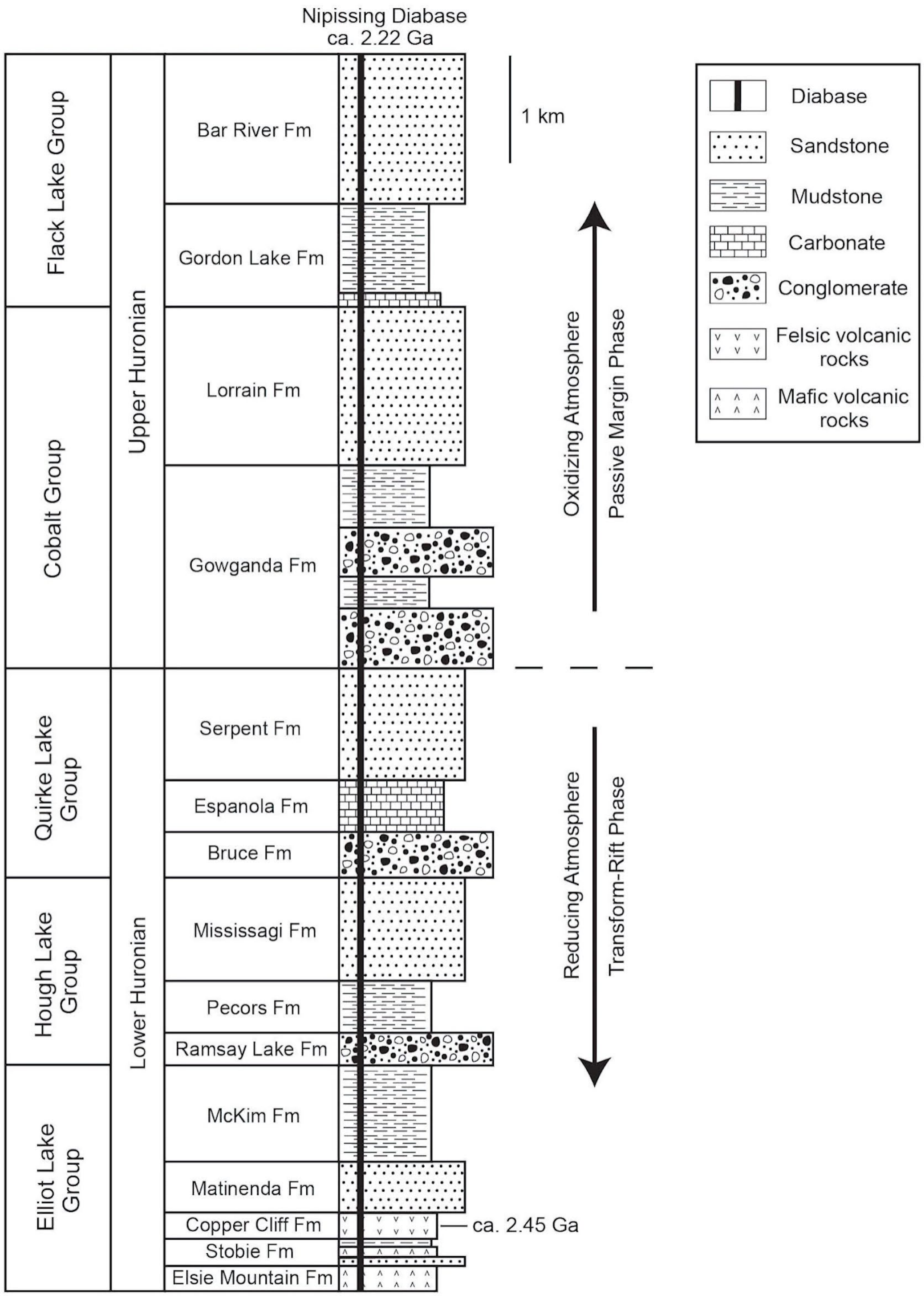

Figure 3. Generalized stratigraphic section of the Huronian Supergroup illustrating the 1 informal (Flack Lake) and 4 formal groups. Note the inferred division between the lower and upper Huronian Supergroup formations that marks a change from transform-rift deposits in a reducing atmosphere to passive margin deposits in an oxidizing atmosphere. *From* Hill et al. (2016).

Table 1. Main characteristics of the sedimentary formations of the Huronian Supergroup *from* Hill (2019) and references therein.

Formation	Characteristics	Interpretation	References
Bar River	Cross-bedded, rippled quartz arenite and minor mudstone; MISS and desiccation and/or synaeresis cracks	Beach, nearshore to shallow marine, sand shoal, tidal channel deposits	Wood (1973); Card, Innes and Debicki (1977); Aranha (2015)
Gordon Lake	Interbedded sandstone, mudstone, and intraformational conglomerate, local basal carbonate; microbial mats, MISS, desiccation and/or synaeresis cracks	Tidal flat to shallow marine deposits; possible deep marine	Wood (1973); Hofmann, Pearson and Wilson (1980); Hill et al. (2016); Hill and Corcoran (2018)
Lorrain	Arkosic to quartz-rich, rippled and cross-bedded sandstone with minor mudstone and quartz-jasper conglomerate	Mainly braided river deposits; possible shallow marine	Young (1973); Chandler (1986); Long (2004)
Gowganda	Laminated paraconglomerate and mudstone with dropstones; interbedded sandstone and mudstone	Continental ice sheet deposits and deep-water deposits	Young and Nesbitt (1985); Long and Leslie (1986)
Serpent	Cross-bedded arkosic sandstone, local conglomerate, minor siltstone	Braided river deposits	Fedo, Young and Nesbitt (1997); Long (2009)
Espanola	Limestone and/or dolostone, siltstone, and calcareous siltstone; microbial mats, desiccation and/or synaeresis cracks, clastic dikes	Deltaic, lacustrine, and tidally influenced shallow marine deposits	Bernstein and Young (1990); Al-Hashim (2016)
Bruce	Clast-rich, matrix-supported, sandy paraconglomerate	Floating ice shelf deposits	Young (1981)
Mississagi	Cross-bedded arkosic to subarkosic sandstone, local conglomerate and mudstone intervals	Shallow braided river deposits	Long (1978, 2009)
Pecors	Laminated mudstone and wackes; local dropstones	Prodeltaic deposits	Long (2009)
Ramsay Lake	Sandy, clast-rich paraconglomerate with minor sandstone and siltstone	Subglacial melt-out deposits	Card, Innes and Debicki (1977); Long (2009)
McKim	Laminated mudstone with minor sandstone and siltstone; Bouma sequences	Turbidity current and prodeltaic suspension deposits	Card, Innes and Debicki (1977); Long (2009)
Matinenda	Pyritic-, quartz-, and uranium-bearing pebble conglomerate; cross-bedded arkosic sandstone	Alluvial fans and braided river deposits	Fralick and Miall (1982); Long (2009)
Livingstone Creek	Cross-bedded arkosic sandstone, uranium- and pyrite-bearing polymictic conglomerate, siltstone, and wacke	Alluvial fans and braided river deposits	Young et al. (2001)

Abbreviation*: MISS, microbially induced sedimentary structures.*

Road Logs

Note: Caution should be taken when parking vehicles on the shoulders of the road or highways and when examining outcrops located along the field trip route. All Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 17.

DAY 1. OVERALL DESCRIPTION

The field stop locations on Day 1 are displayed in Figures 4 and 5. The first day of the field trip travels from Sudbury west to Wharncliffe, Ontario where glaciogenic rocks of the Gowganda Formation are exposed. From Stop 1.1, the field trip goes to Flack Lake where evidence for tidal processes and ancient life is exposed in the Gordon Lake Formation (Stops 1.2 and 1.3). From Stop 1.3, the field trip follows Highway 639 south toward Elliot Lake, stopping to examine tidal signatures and hematite staining in the Bar River Formation, as well as the claystone layer from which a U/Pb detrital age was determined (Stops 1.4 and 1.5). From Stop 1.5, an outcrop on Panel Mine Road that exposes the contact between the glaciogenic Ramsay Lake Formation and Pecors Formation rhythmites is visited (Stop 1.6).

0.0 km	Start at the front of the Science 2 Building at Laurentian University.
221 km	From University Road, turn west on Ramsey Lake Road, then north on Regional Road 80 and merge onto Highway 17 heading west. Drive west to Iron Bridge, turn north on Highway 546, then west onto Highway 554, and south on Highway 129. The outcrop is just south of the intersection between Highways 129 and 554.

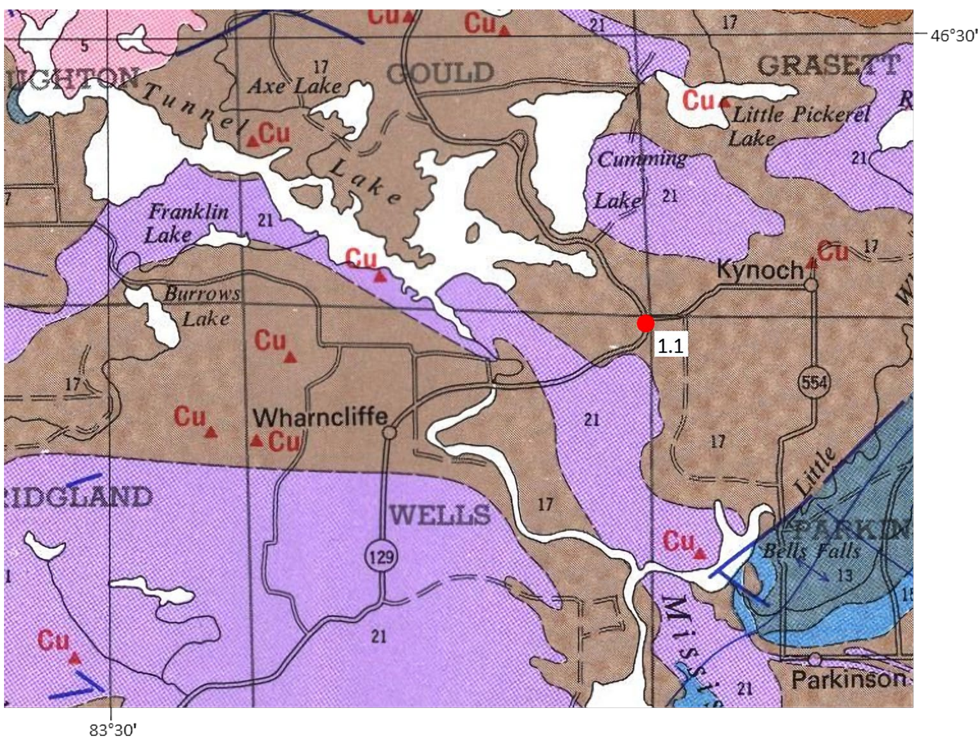

Figure 4. Location of Stop 1.1 near Wharncliffe, Ontario. Geological map *from* Giblin, Leahy and Robertson (1979). Brown unit is the Gowganda Formation, purple unit is Nipissing gabbro.

Stop 1.1. Dropstones in rhythmites of the Gowganda Formation

UTM 321089E 5145135N

Potential hazards: Steep and slippery slope; loose rocks; vertical outcrop

This stop is a spectacular example of rhythmites of the Gowganda Formation (Photo 1A). The laminated siltstone and claystone couplets are laterally continuous and range from 1 to 32 mm thick. Pebble- to cobble-size dropstones disrupt the couplets and are mainly granitic. The dropstones are interpreted to have been deposited during melting of floating ice derived from glaciers. Howe et al. (2016) conducted time series analysis of the couplet thickness records and discovered periodicities in the range of 2.2 to 2.9 couplets per cycle. These are similar to those of modern climatic cycles, such as the quasi-biennial oscillation (QBO) and the El Niño Southern Oscillation (ENSO). The results suggest that the couplets represent annual deposits, and therefore varves (Photo 1B).

Photo 1. Rhythmites of the Gowganda Formation near Wharncliffe, Ontario. **A)** A dropstone disrupting siltstone-claystone couplets. **B)** View of the vertical cliff face with laterally continuous couplets interpreted as varves. Professor P.L. Corcoran serves as scale.

221 km	Return to vehicles and drive back to the intersection at Highway 129 and 554.
300 km	Head east on Highway 554, then turn north on Highway 546, following it all the way to the junction with Highway 639. Head south on Highway 639 and stop along the shoulder near the entrance to Laurentian Lodge.

Stop 1.2. MISS, microbial mat structures, and tidal deposits of the Gordon Lake Formation

UTM 362995E 5163267N

Potential hazards: Stay off road shoulder; high-visibility vests required

This excellent three-dimensional exposure of the Gordon Lake Formation displays many key features consistent with a mixed intertidal flat to shallow marine environment. The rocks at this outcrop mainly contain interlaminated to interbedded mudstone and fine-grained sandstone. Upper and lower bed contacts are predominantly sharp and rippled. The beds are laterally discontinuous over 5 to 10 m, and are characterized by lenticular and flaser bedding, wavy to ripple-cross laminae, shrinkage cracks, and wave and interference ripples (Hill-Svehla and Corcoran 2022). Microbial-induced sedimentary structures (MISS) at this locality include sandcracks, microbial sand and silt chips, large mat chips and iron patches (Photos 2A and 2B; Hill et al. 2016). Minor intraformational granular to pebbly sandstone beds are interpreted as storm deposits (Photo 2C).

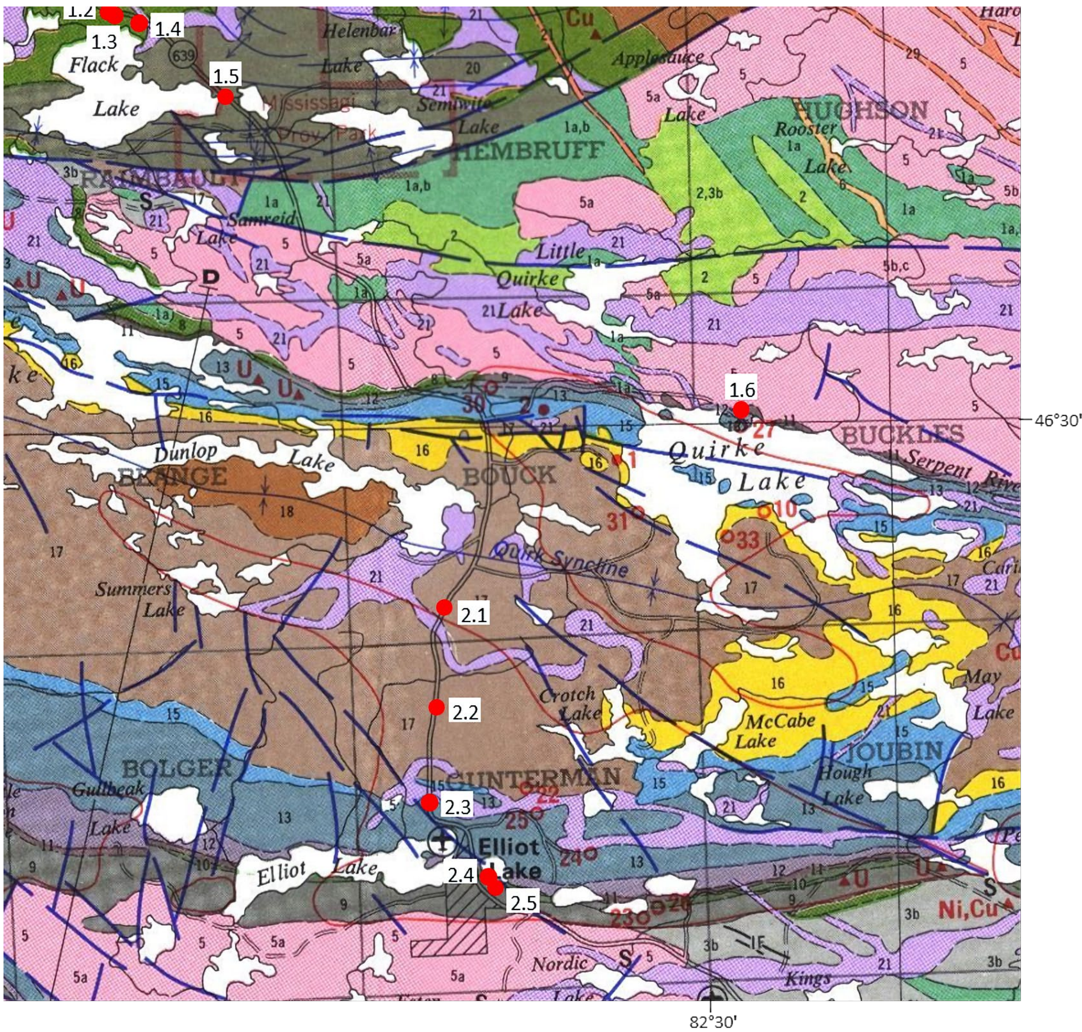

Figure 5. Locations of Stops 1.2 to 1.6 and 2.1 to 2.5 near Elliot Lake, Ontario. Geological map *from* Giblin et al. (1979).

300 km Return to vehicles and drive south on Highway 639.

300.6 km Stop along the shoulder at a safe location near the outcrop at the top of a small hill.

Stop 1.3. Microbial mat structure in the Gordon Lake Formation

UTM 363047E 5163221N

Potential hazards: Stay off road shoulder; high-visibility vests required

This outcrop provides a rare example of a Paleoproterozoic microbial mat destruction feature. The large, uncurled mat chip has a mottled texture (Photo 2D), which reflects mat growth prior to erosion. Note how the edges of the mat chip are sharp and irregular, indicating tearing by water or wind prior to burial.

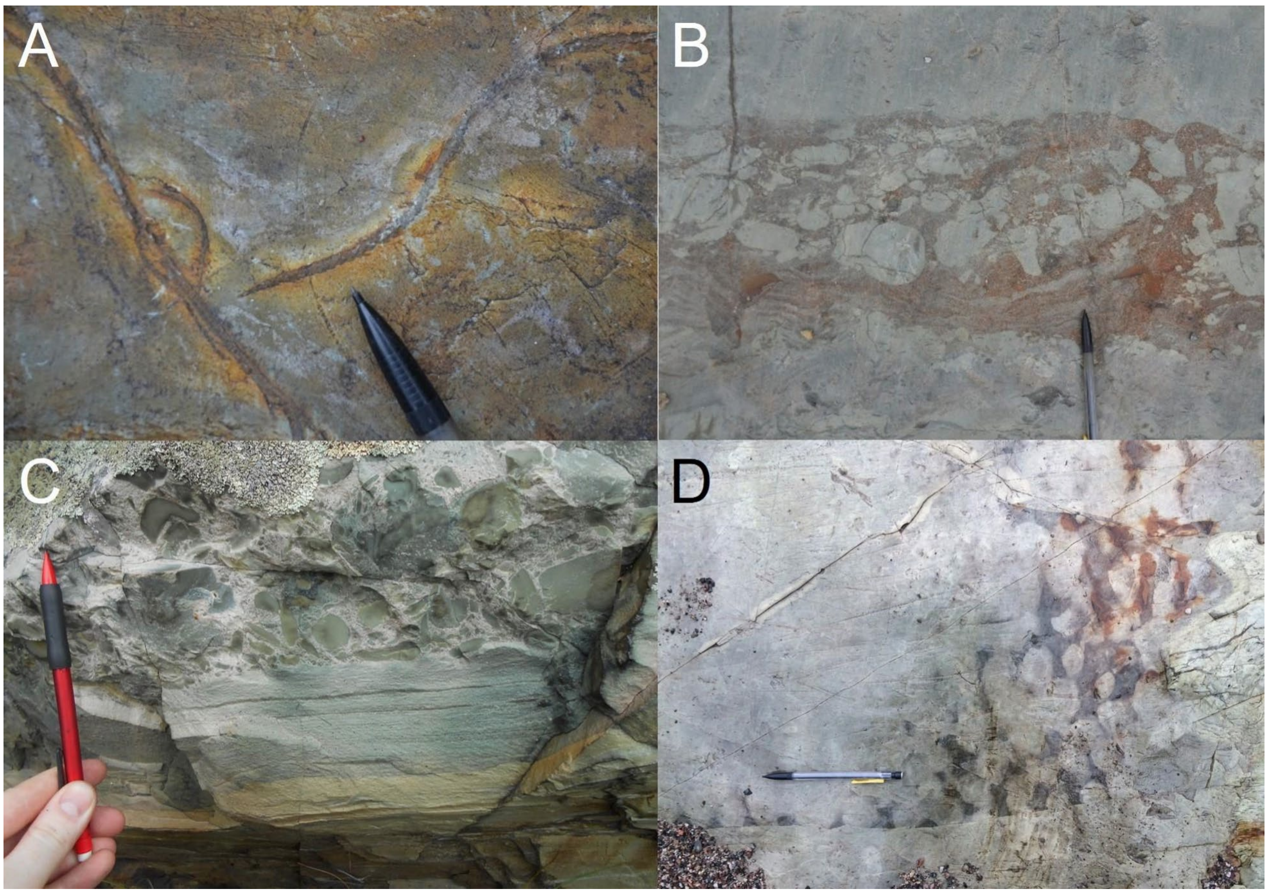

Photo 2. Characteristics of the Gordon Lake Formation at Stops 1.2 and 1.3. **A)** Curved, corrugated sand cracks interpreted as microbial-induced sedimentary structures (MISS). **B)** Microbial sand and silt chips preserved in fine-grained sandstone. **C)** Intraformational conglomerate at the base of a fining-upward bed (top not shown). Note that this photo was taken in Lady Evelyn–Smoothwater Provincial Park west of Temagami (approximately 200 km east of Elliot Lake), but similar deposits are exposed at Stop 2.1. **D)** Large torn mat chip in a fine-grained sandstone bed. Pen for scale is approximately 9 cm long.

300.6 km	Return to vehicles and drive south on Highway 639.
302.6 km	Stop along the shoulder at a safe location near the outcrop at the top of a small hill.

Stop 1.4. Cross-beds and claystone layer in the Bar River Formation

UTM 365260E 5162002N

Potential hazards: Stay off road shoulder; high-visibility vests required

Excellent exposures of the Bar River Formation sandstone, pebbly sandstone, and claystone are located on both the east and west sides of the road. The quartzite contains planar and trough cross-beds, overturned cross-beds, ripples, and horizontal bedding (Photo 3A). Herringbone cross-beds are also common in this formation (Photo 3B) and support a tidal influence. The 22 cm thick claystone layer that is well exposed in the outcrop on the western side of the road was sampled for geochronology. The average age of the youngest zircon grains constrains the age of deposition to after 2315±5 Ma, but prior to intrusion of the gabbro (Nipissing) sills and dikes approximately 95 million years later (Hill, Davis and Corcoran 2018). The western outcrop also displays friable pebbly sandstone.

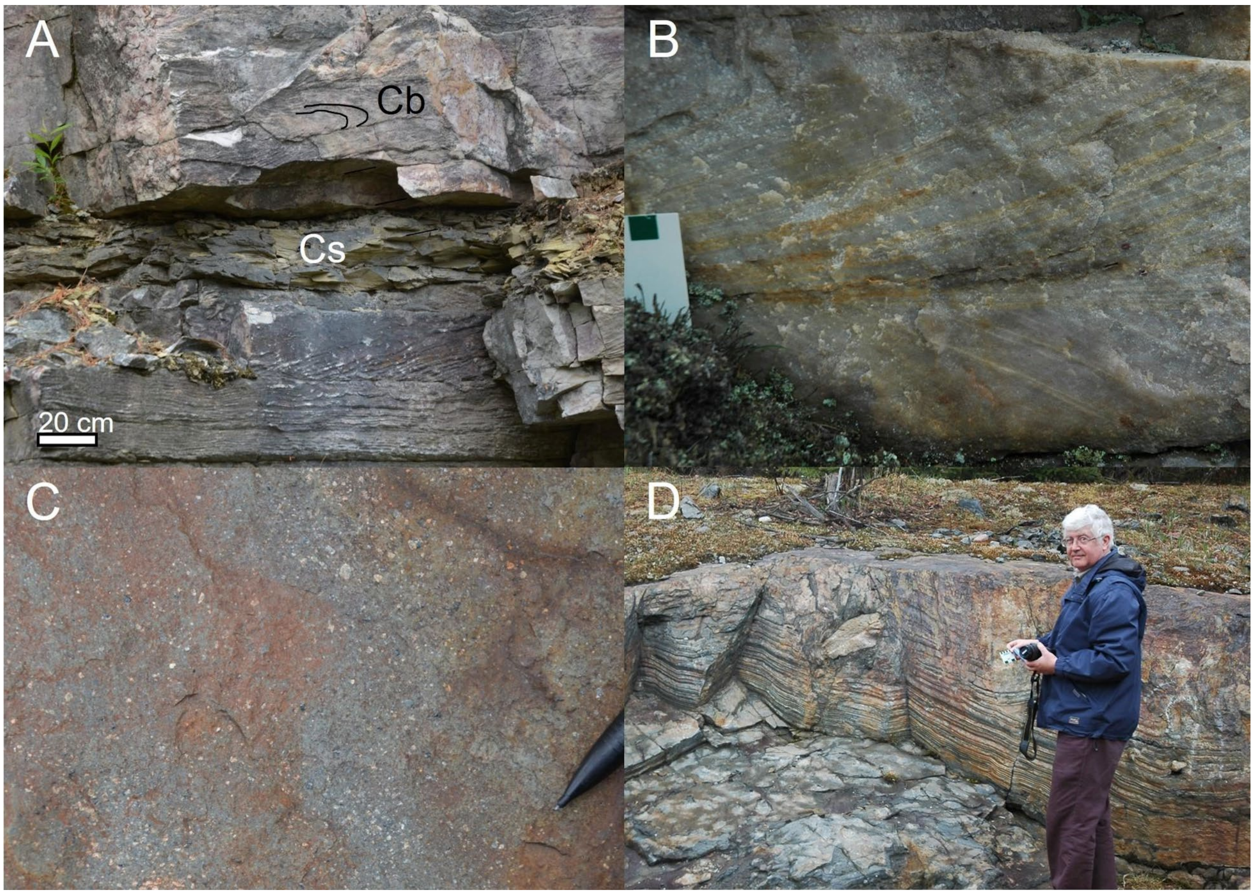

Photo 3. Characteristics of the Bar River Formation and the contact between the Ramsay Lake and Pecors formations (Stops 1.4 to 1.6). **A)** Claystone (Cs) horizon over- and underlying quartz arenite of the Bar River Formation. Note the overturned cross-beds (Cb), ripples and horizontal bedding. **B)** Herringbone cross-stratification in the Bar River Formation. **C)** Bedding plane in the Bar River Formation displaying hematite staining and pyrite grains. **D**) Sharp and irregular contact between the Ramsay Lake mixtite and the overlying Pecors Formation rhythmites. Note the dropstone in the middle of the photo. Professor F.J. Longstaffe serves as scale.

302.6 km	Return to vehicles and drive south on Highway 639.
305 km	Stop along the shoulder at a safe location near the outcrop at the top of the hill.

Stop 1.5. Pyrite patches in hematite-stained Bar River Formation

UTM 366885E 5160391N

Potential hazards: Stay off road shoulder; high-visibility vests required

The outcrops along the eastern and western sides of the road at this locality contain trough and planar cross-beds, ripples and shrinkage cracks on bed surfaces. Pyrite patches, identified in the troughs of interference ripples (Photo 3C), were interpreted by Aranha (2015) and Hill et al. (2016) to represent the locations of former microbial mats. The lower layers of mats are generally anoxic due to the decay of organic matter, and this would have promoted the formation of pyrite. Purple, iron-rich laminae alternating with white, quartz-rich laminae could indicate changing hydrological conditions from calm to higher energy water, which would have hindered the growth of the mats.

305 km	Return to vehicles and drive south on Highway 639 for 12.5 km.
317.5 km	Turn east onto Panel Mine Road.
323.1 km	Stop along the shoulder at a safe location near the outcrop.

Stop 1.6. Dropstones in rhythmites of the Pecors Formation

UTM 378706E 5151761N

Potential hazards: Stay off road shoulder; high-visibility vests required

This outcrop presents a spectacular example of the sharp but undulating contacts between mixtites of the Ramsay Lake Formation and siltstone and mudstone couplets of the Pecors Formation (Photo 3D). The conglomerate is mainly composed of potassium feldspar–poor granitoid clasts, felsic volcanic clasts, and mafic intrusive and/or extrusive clasts in a dark gray sandstone matrix. The overlying couplets of the Pecors Formation are easily identifiable because the siltstone laminae have a more positive relief compared to the clay-rich mudstone laminae. Dropstones disrupt the laminae, thereby supporting a varve interpretation for the couplets. The dropstones are interpreted to have been derived from melting of ice-rafted debris following and during deposition of the fine-grained couplets.

Return to vehicles, drive west on Panel Mine Road then south on Highway 108 to the Hampton Inn in Elliot Lake.

DAY 2. OVERALL DESCRIPTION

The field stop locations on Day 2 are displayed in Figures 5 and 6. The second day of the field trip begins in the town of Elliot Lake. After travelling north on Highway 108, the glaciogenic Gowganda Formation paraconglomerate and stratified orthoconglomerate at Stops 2.1 and 2.2 are observed. From Stop 2.2, the field trip drives south on Highway 108 to examine the characteristics and contacts of the fluvial Mississagi Formation, glaciogenic Bruce Formation, and calcareous Espanola Formation (Stop 2.3). For Stops 2.4 and 2.5, the field trip returns to the town of Elliot Lake where the history of uranium mining in the Elliot Lake region, as well as the Matinenda Formation, from which the uranium was mined, is briefly discussed. From Elliot Lake, the field trip moves south on Highway 108 and then east to near Denvic Lake (Stop 2.6) to view sandstone and conglomerate deposits of the Mississagi Formation. The final field trip stop is in Espanola, Ontario, where an example of the Espanola Formation siltstone-limestone deposits is viewed (Stop 2.7).

0.0 km	Start at the front of the Hampton Inn Elliot Lake. Drive north on Highway 108 for 8.7 km.
8.7 km	Park along the side of the road.

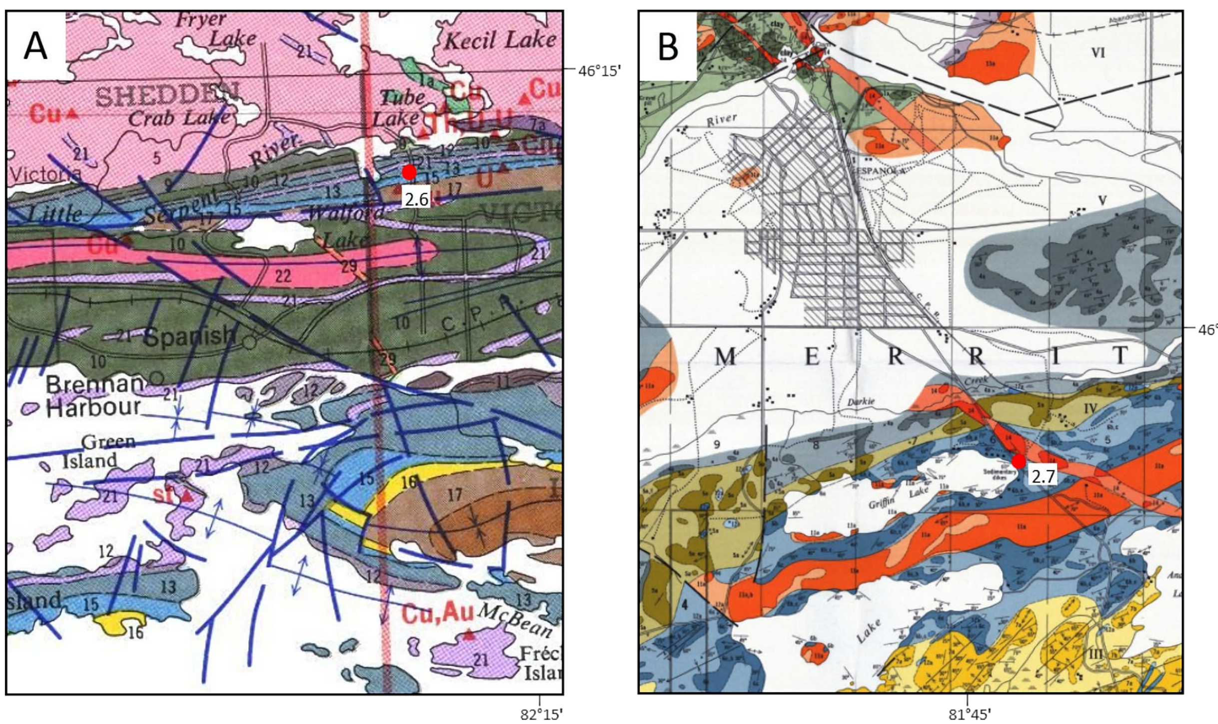

Figure 6. Locations of Stops 2.6 and 2.7. **A)** Near Tube Lake (Denvic Lake). Geological map *from* Giblin et al. (1979). **B)** Near Espanola, Ontario. Geological map *from* Card (1984).

Stop 2.1. Gowganda Formation paraconglomerate (mixtite)

UTM 372285E 5145917N

Potential hazards: Stay off road shoulder; high-visibility vests required

The outcrop on the east side of Highway 108 displays the characteristics of the Gowganda Formation paraconglomerate (tillite or mixtite). No bedding is evident at this locality. The mixtite is polymictic and poorly sorted with clasts ranging from granule- to boulder-size. One large granitic boulder protrudes from the outcrop (Photo 4A). The matrix is a dark gray claystone. The lack of interbedded sandstone and orthoconglomerate suggests that these deposits are consistent with a subaqueous debris flow origin, rather than having been deposited as till.

8.7 km	Return to vehicles and drive south on Highway 108 for 2.9 km.
11.6 km	Park along the side of the road.

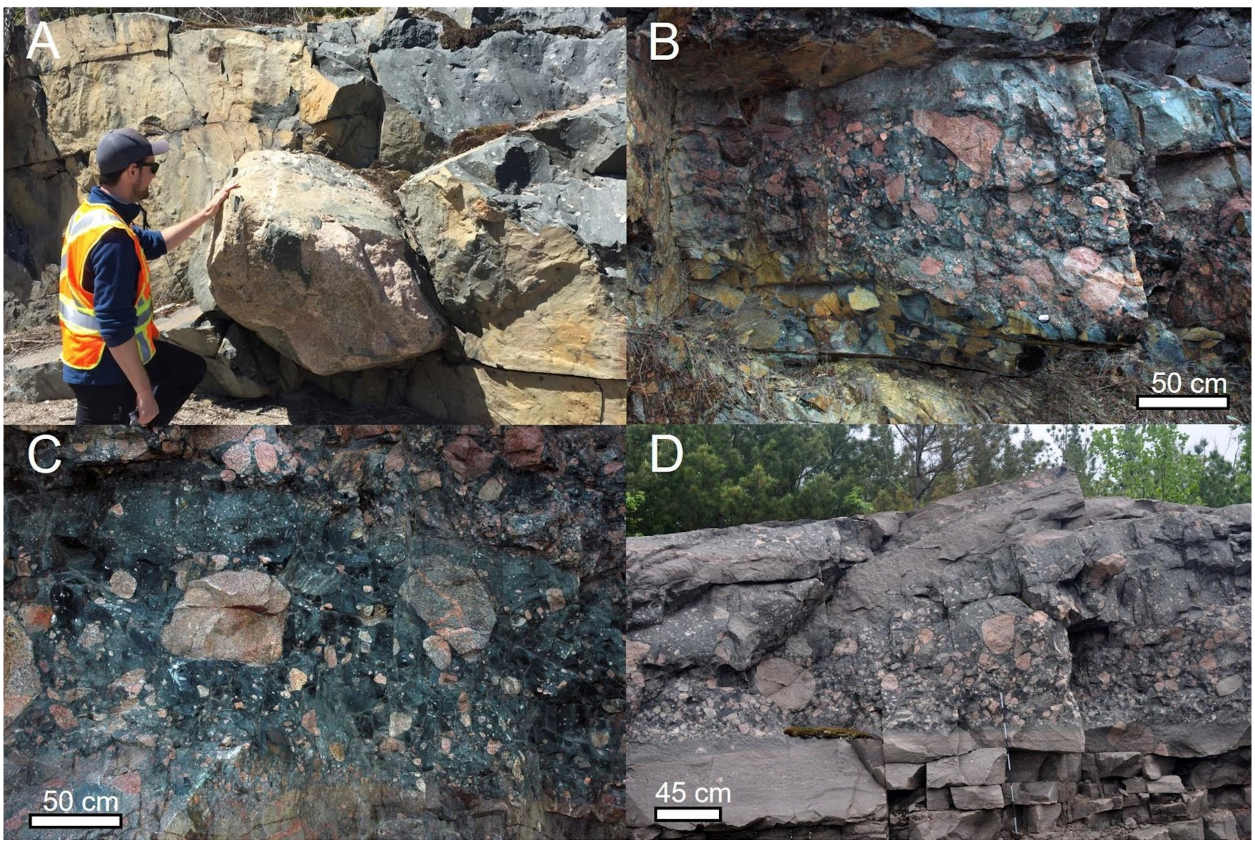

Photo 4. Characteristics of the Gowganda Formation at Stops 2.1 and 2.2. **A)** Poorly sorted paraconglomerate at Stop 2.1 with an outsized boulder protruding from the outcrop. Person serves as scale. **B)** Poorly sorted, polymictic orthoconglomerate bed at Stop 2.2 typical of hyperconcentrated flow deposits. **C)** Paraconglomerate (mixtite) underlying an orthoconglomerate bed at Stop 2.2. **D)** Interbedded sandstone and orthoconglomerate at Stop 2.2. Note the sandstone “slab” near the top of the outcrop, interpreted to have formed as a jökulhlaup. Photos 4B, 4C and 4D courtesy of D.G.F. Long.

Stop 2.2. Stratified Gowganda Formation

UTM 371835E 5143224N

Potential hazards: Stay off road shoulder; high-visibility vests required; vertical outcrop

This is an excellent exposure of stratified, polymictic, ortho- and paraconglomerate of the Gowganda Formation. At the south end of the outcrop, on the west side of Highway 108, there is a contact between massive conglomerate and laminated strata. Note the laminated mudstone with outsized clasts, which are interpreted as glacially rafted dropstones. Stratified orthoconglomerate resembles hyperconcentrated flow deposits (Photo 4B), and mixtite (paraconglomerate) contains grains ranging from mud to boulder size (Photos 4C and 4D). Some conglomerate units display normal and reverse grading, which suggests debris flow deposition. The laminated units are laterally continuous throughout the outcrop, except where they dip at an angle to the main bedding (Photo 4D). One of these interpreted ice-rafted slabs is evident near the top of the outcrop and it may have formed as a jökulhlaup (D.G.F. Long, personal communication). The units in this outcrop are considered to have been deposited proximal to a retreating glacial margin.

11.6 km Return to vehicles and drive south on Highway 108 for 2.0 km.

13.6 km Park along the west side of the road on the southern crest of the hill.

Stop 2.3. Contact between the Mississagi, Bruce and Espanola formations

UTM 371670E 5141230N

Potential hazards: Stay off road shoulder; high-visibility vests required

This series of well-exposed outcrops displays 2 contacts between 3 formations. Younging direction is to the north. Massive sandstone of the Mississagi Formation is overlain by mixtites of the Bruce Formation. The Bruce Formation is gradationally overlain by dolostone of the Espanola Formation. The beds in the latter are well-defined as a result of differential weathering of carbonate and siltstone (Photo 5A). The beds are 2 to 5 cm thick with wavy upper and lower contacts and are internally laminated. Small-scale faults and folds are considered synsedimentary because they are confined within stratigraphic horizons and are over and underlain by undisturbed strata (Photo 5A; Al-Hashim, 2016). Clastic dikes, typical of the Espanola Formation, are evident at this locality (Photo 5B). Garnet and scapolite are consistent with contact metamorphism related to intrusion of a gabbroic dike to the south.

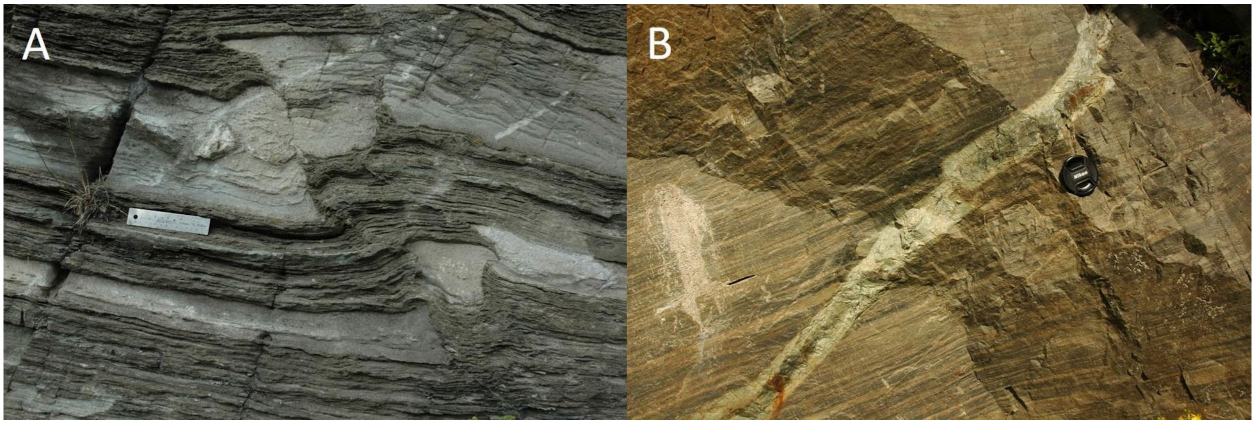

Photo 5. Characteristics of the Espanola Formation at Stop 2.3. **A)** Carbonate-rich (low relief) and carbonate-poor (high relief) beds in the Espanola Formation. Note how the beds are cut by a small-scale fault, folded, and displaced. **B)** Alternating siltstone and dolostone beds and laminae in the Espanola Formation with a clastic dike cutting through the stratigraphy. Photos courtesy of M.H. Al-Hashim.

13.6 km	Return to vehicles and drive south on Highway 108 for 4.2 km.
17.8 km	Turn into the parking lot of the Miners' Memorial Park.

Stop 2.4. Miners' Memorial Park

UTM 372989E 5138651N

This stop has no outcrop, but cliffs of the thickly bedded Matinenda Formation can be seen at a distance along the eastern side of Horne Lake. In the parking lot, the names of the mine workers who died from workplace accidents or occupational illnesses are engraved on the memorial. Polished rock pillars have information engraved on them concerning mine productions in the Elliot Lake area over the years.

17.8 km	Return to vehicles and drive south on Highway 108 for 0.7 km.
18.5 km	Turn north onto Manitoba Road and park in the parking lot in front of Seidel's store. The outcrop is in front of Huron Lodge (treed area).

Stop 2.5. Matinenda Formation granular sandstone

UTM 373344E 5138152N

Potential hazards: Vertical outcrop

This outcrop is composed of medium- and coarse-grained arkosic sandstone and granular sandstone. Large scale ripples, trough cross-beds and planar beds are evident. This formation was a significant source of uranium and spurred the development of multiple mines in the Elliot Lake region. Most of the uranium was contained in the pyrite-rich, quartz pebble conglomerate units, which are not seen at this locality. The placer deposits are interpreted to have formed in fluvial and alluvial fan settings.

18.5 km	Return to vehicles and head back to Highway 108, then drive south to the junction with Highway 17.
45 km	Turn left (east) onto Highway 17 and drive 22 km to the intersection with Waterfalls Road in the community of Spanish.
67 km	Turn north on Waterfalls Road and drive 3 km, then pull over on the shoulder of the road. The outcrop (Stop 2.6) is on a hill on the west side of Waterfalls Road.

Stop 2.6. Breccia-conglomerate of the Mississagi Formation

UTM 400097E 5120234N

Potential hazards: Slippery when wet

The rocks at this outcrop belong to the Lauzon member of the Mississagi Formation (Long 1977). The exposure displays resedimented conglomerate and massive and planar laminated sandstone. Clasts ranging from granule to boulder size are mainly composed of angular and subangular, laminated or massive, green mudstone to siltstone, resembling the beds of the Pecors Formation at Stop 1.6 (Photo 6A). Other clasts are composed of mixtite resembling the Ramsay Lake Formation (Photo 6B), minor granite (Photo 6A), black chert and quartz. At least one fining-upward sequence is visible at this outcrop. The planar laminated sandstone contains minor ripples, as well as trough crossbedding toward the top of succession (south end of outcrop). The rocks are interpreted as sediment gravity flow deposits that developed as subaqueous fans or fan head canyons. Long (1977) interpreted that the subaqueous fans formed in response to contemporaneous movement along a proto-Murray fault system. The fining upward sequences here and at other localities where the Lauzon member is preserved, suggest that channelized proximal subaqueous fans gradually became infilled. Gravity flow deposition was followed by deposition from traction currents in a shallow subaqueous environment.

67 km	Return to vehicles and head back to Highway 17, then drive east for 43 km to the junction of Highways 17 and 6.
110 km	Turn south onto Highway 17 and drive 12 km to the Clear Lake beach parking area.
122 km	From the vehicles, walk approximately 30 m north along a small trail that parallels Highway 6.

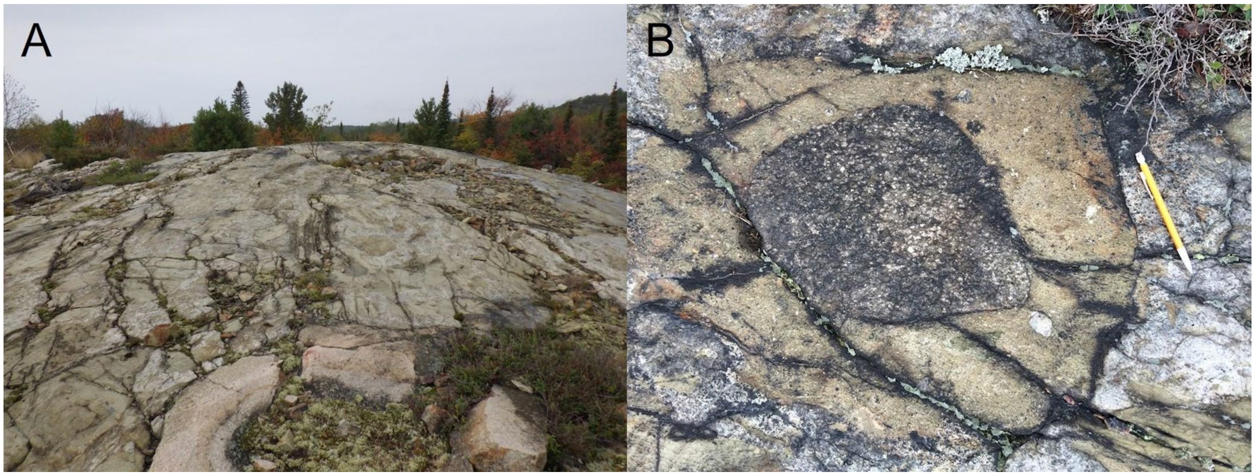

Photo 6. Characteristics of the Mississagi Formation at Stop 2.6. **A)** Breccia-conglomerate facies of Long (1977) displaying a large granite boulder (approximately 3.5 by 2 m) and smaller green mudstone, siltstone and sandstone clasts. The green clasts are mainly angular but rounded quartz pebbles and granules characterize the matrix. **B)** A subangular mixtite clast, itself containing a granite and quartz clasts, surrounded by a quartz-rich matrix. Photos courtesy of D.G.F. Long. Pen for scale is approximately 9 cm long.

Stop 2.7. Clastic dike in Espanola limestone

UTM 442406E 5120910N

This locality displays a remarkable example of a clastic dike cutting the interlaminated to interbedded siltstone-carbonate lithofacies of Al-Hashim (2016) (Photo 7A). The beds are 2 to 5 cm thick with wavy upper and lower contacts. The carbonate beds are very thinly laminated and contain the mineral scapolite. The siltstone beds are massive to faintly laminated. Load structures are evident and small-scale faults displace the beds (Photo 7B). The clastic dike is 0.5 m thick and is composed of sandstone near the margins and conglomerate in the centre (internal sorting). The dike is inferred to have developed during faulting and liquefaction of sediment, followed by forceful injection (Al-Hashim and Corcoran 2021).

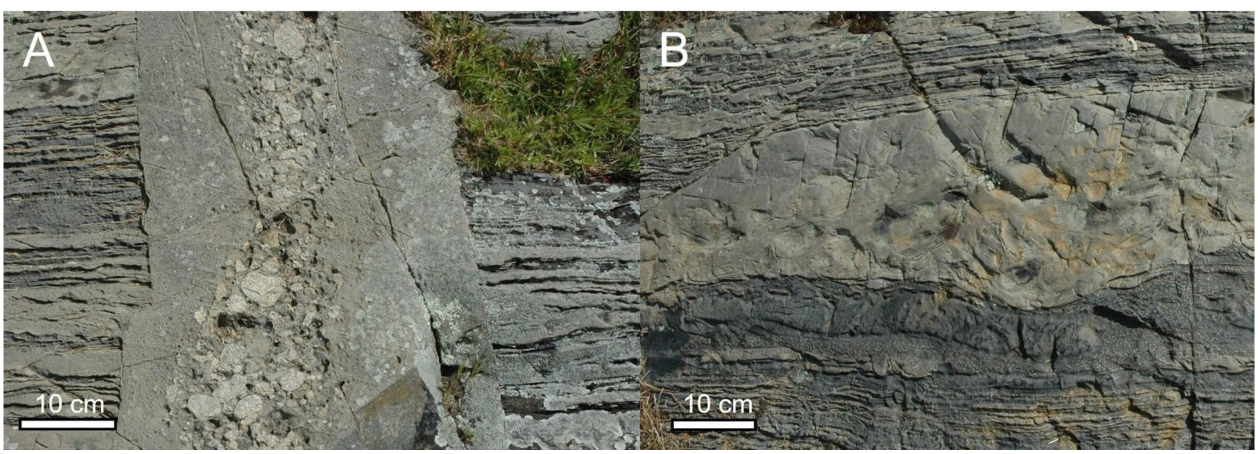

Photo 7. Characteristics of the Espanola Formation at Stop 2.7: **A)** clastic dike cutting the interlaminated to interbedded siltstone-carbonate lithofacies; and **B)** load structures in a siltstone horizon and scapolite (white mineral) in a carbonate horizon. Photos courtesy of M.H. Al-Hashim.

122 km Return to vehicles and drive back to Laurentian University in Sudbury, Ontario.

End of Road Log.

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Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton(short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 9**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy) / ton (short)	1 ounce (troy) / ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights / ton (short)	1 pennyweight / ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors in ***bold*** *type are exact. The conversion factors have been taken from or have been derived from factors given in the* Metric Practice Guide for the Canadian Mining and Metallurgical Industries*, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.*

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