MINERAL RESOURCES BRANCH

Bedrock, Glacial, Economic and Environmental Geology of the Halifax Regional Municipality

Guidebook for EdGEO Field Excursion
August 23, 2004

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August 23, 2004

T. A. Goodwin
Project Geochemist
Nova Scotia Department of Natural Resources

Itinerary

Monday August 23, 2004

Leader: Terry Goodwin, NSDNR

Time	Event
1:00 pm	Depart from Bedford Institute of Oceanography
1:20 pm	Stop 1 Dunbrack/Northwest Arm Interchange
1:40 pm	Stop 2 Walmart, Bayer's Lake Industrial Park
2:10 pm	Stop 3 Kearney Lake Road
3:00 pm	Stop 4 Blue Acres Industrial Park, Hammonds Plains
3:20 pm	Stop 5 Waterstone Subdivision, Lucasville
4:45 pm	Stop 6 First Lake Drive, Lower Sackville
5:30 pm	Return to Bedford Institute of Oceanography

Acknowledgments

Special thanks to summer assistant Nicole Boudreau for her help in the field and for her many hours of typing the field trip guide. Also, thanks to Doug MacDonald (NSDNR) and Barb MacDonald (NSDNR) for rapid editing and layout of the field trip guide. Finally, to Mike Cherry (NSDNR) for allowing me the time and resources to help "teach the teachers".

Safety Procedures

For personal and group safety, all participants of this field trip are encouraged to read and heed the following safety procedures. Also note that several of the stop descriptions contain precautionary statements relative to that particular stop. It is ALWAYS a good idea to have a trained First Aider with you and to carry an adequate first aid kit on any field trip since accidents happen even with proper precautionary measures. Thank you for your co-operation and please use common sense in making this a safe and enjoyable field trip.

1. PICKS AND HAMMERS: Do not indiscriminately hammer, and use downward blows. Either shield your eyes or wear protective glasses or goggles when hammering, especially since we will be examining very hard, fine-grained, hydrothermally altered rocks at many of our stops. Be aware of persons standing around you when hammering. Note that only rock hammers are suitable for breaking samples. A carpenter's hammer may splinter and send metal chips flying.

2. SUITABLE CLOTHING: Participants should have adequate footwear and protection against both wet and cold, including a hat, gloves, and boots. Adequate clothing is important if you are involved in an accident. The spring/summer weather in Nova Scotia is unpredictable and can vary from beautiful to pitiful with little notice.

3. HARD HATS: Most professional geologists do not wear hard hats outside of mines and quarries. They are recommended anywhere there are cliff faces or overhangs. Hard hats will be provided on request but we may not have enough for everyone.

4. STOPS ALONG HIGHWAYS: Road cuts often expose good sections and, hence, make good field trip stops, but they can be very dangerous. You must exercise caution, as you will be paying attention to the rocks and not the traffic. Some simple rules are: (1) be sure to park as far off the pavement as possible, especially on 100 series highways where traffic is travelling in excess of 100 km/hr; (2) if possible, park on the side of the road that has the section you wish to view; (3) do not venture onto the pavement unless you are crossing the road and only cross the road when the group crosses as we want to avoid a situation where participants are straggling back and forth across roads.

5. CLIFFS AND FALLING ROCKS: Falling rocks are a major hazard on field trips. Avoid unstable or overhanging cliffs. Don't climb a cliff when others are below you.

6. ABANDONED SHAFTS AND PITS: Mainland Nova Scotia is littered with old gold mines that have been abandoned since the early 20th Century. All have numerous deep shafts and pits, many of which are unstable. Stay in a group and do not venture too close to shafts or old trenches. These can be slumped and overgrown near the surface and therefore look shallow, but they are extremely dangerous.

7. FIRST AID: Kits will be in the lead vehicle. Terry Goodwin is a certified First Aider and participants with valid First Aid certificates are encouraged to identify themselves at the beginning of the field trip.

8. IN THE UNLIKELY EVENT OF AN EMERGENCY DIAL 911.

Bedrock Geology

Mainland Nova Scotia, south of the Cobequid-Chedabucto Fault Zone, is referred to as the Meguma Zone. The southwestern portion of the Meguma Zone consists predominantly of Cambrian to Ordovician sedimentary rocks and Devonian granitic rocks (Fig. 1). Overlying these Paleozoic rocks are sequences of sedimentary and volcanic rocks of Carboniferous and Triassic age.

The Cambro-Ordovician Meguma Group rocks are interpreted as a continuous sequence of deep-water turbidites. The metasedimentary sequence consists of the basal Goldenville Formation, characterized dominantly by metasandstone (commonly referred to as greywacke, wacke or quartzite), with lesser amounts of interbedded slate and calcareous units. The overlying Halifax Formation consists of slates of various colours and lesser amounts of metasandstone, metasiltstone, and calcareous units.

The Meguma Zone was deformed during the middle Devonian Acadian Orogeny (400 ± 10 Ma; note Ma = million years ago) into regional scale, tight, upright, northeast-trending folds and is characterized regionally by greenschist to amphibolite facies metamorphism that accompanied the middle to late stages of Acadian deformation.

The regional metamorphic grade throughout the Meguma Zone is variable, but systematic, and ranges from chlorite and biotite facies in the central region up to andalusite-staurolite-cordierite facies and sillimanite facies in the eastern and southwestern ends.

Widespread intrusion (South Mountain Batholith) of the Meguma Zone metasedimentary rocks by post-tectonic peraluminous granite (ca. 370 Ma) resulted in an extensive, superimposed thermal contact aureole reflected by the presence of abundant cordierite porphyroblasts in the metasedimentary country rocks within 100 to 500 m of contacts. The contact metamorphism overprints regional metamorphic mineral assemblages.

The intrusive sequence within the granitic rocks consists of, from oldest to youngest, tonalite, biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite, two-mica leucomonzogranite, leucogranite, aplite, and pegmatite with monzogranite and granodiorite being the most common. All of the granitic units contain the major minerals quartz, plagioclase, alkali feldspar, biotite, and muscovite in varying proportions. Most granodiorites, monzogranites, and coarse-grained leucomonzogranites are medium- to coarse-grained, megacrystic and commonly have metasedimentary xenoliths. In contrast, fine-grained leucomonzogranites and leucogranites are predominantly equigranular or porphyritic, muscovite-rich, and are associated with pegmatites and rare xenoliths.

Gold has been identified throughout the entire Meguma Group stratigraphy. Most of the gold, however, has been produced from auriferous quartz veins in the basal Goldenville Formation. The various granite phases of the South Mountain Batholith are also mineralized. For example, tin and uranium have been found in granite at East Kemptville and Millet Brook, respectively.

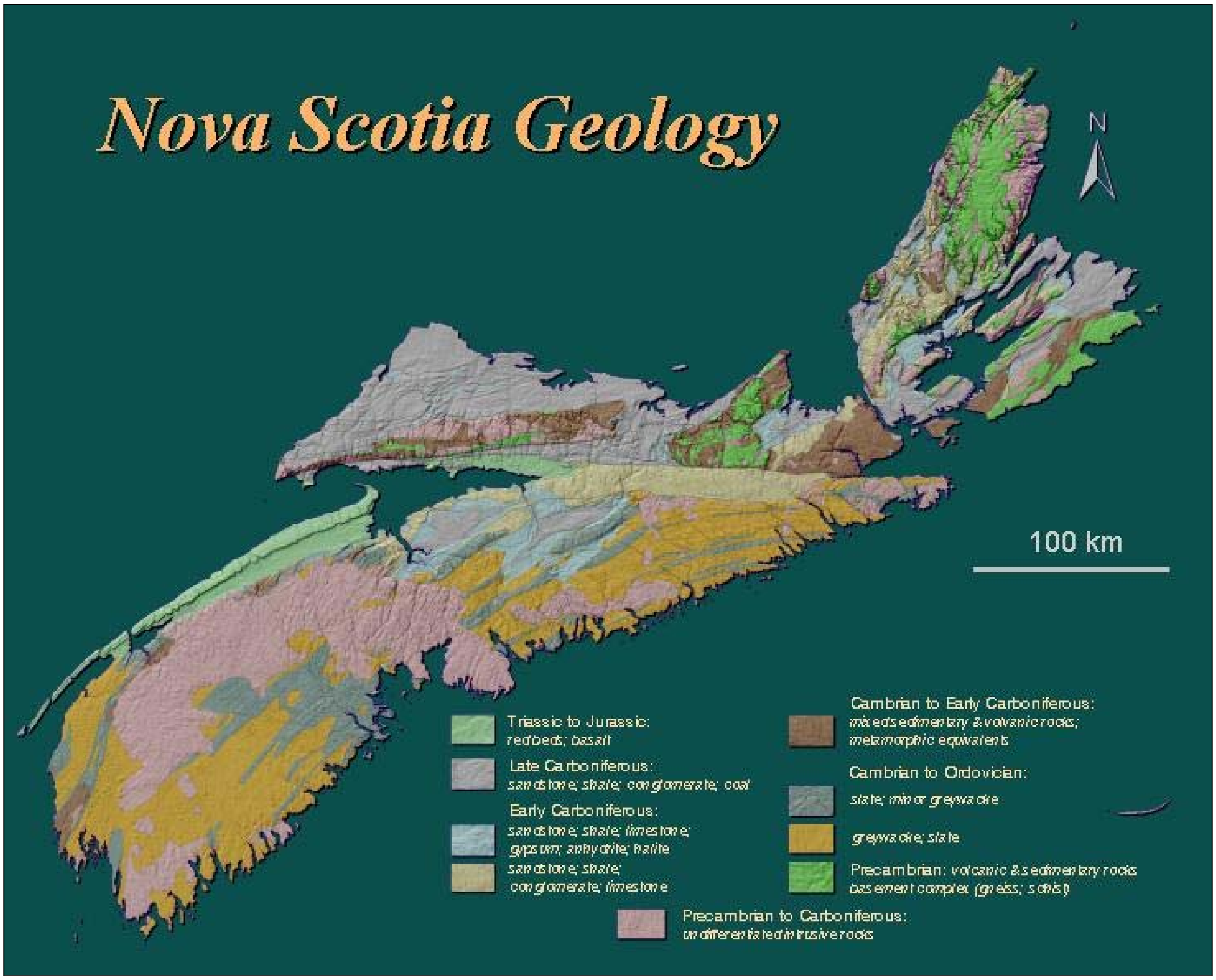

Figure 1. Simplified bedrock geology of Nova Scotia.

Surficial Geology

Most of the surficial glacial deposits and associated landforms throughout Nova Scotia were formed during the Wisconsinan glaciation in the last 70 000 years. Superimposed till sheets and various multiple-flow directional indicators reveal that Nova Scotia is characterized by a relatively complex ice flow history.

The oldest ice flow patterns mapped in the area are toward the east and southeast, and are responsible for the formation of the Hartlen Till, a very compact, grey, silty till characterized by abundant local metasediment and granite clasts associated with the Caledonia Phase (75-40 ka; note ka = thousand years ago).

This was followed by south and southwest ice flow of the Escuminac Phase (22-18 ka) and the deposition of the Lawrencetown Till. The Lawrencetown Till is derived from Carboniferous redbeds of northern Nova Scotia and Prince Edward Island, along with distinct erratics from the Cobequid Highlands. Soils developed on the Lawrencetown Till make excellent agricultural lands.

During the Scotian Phase (18-15 ka), an ice divide was situated over Nova Scotia and the resulting ice flow varied from northwestward in northern Nova Scotia to south and south-southeast in southern Nova Scotia, and produced the Beaver River Till. Beaver River Till can be subdivided into three distinct lithological/textural facies: (1) granite, (2) slate and (3) metasandstone facies. Beaver River Till is derived almost exclusively from local bedrock sources, as shown by the abundance of local clasts (> 80%) and by the angularity of the clasts and boulders.

The Chignecto Phase (13-12.5 ka) was characterized by shifting ice flow associated with small ice caps, the remnants of waning stages of the Scotian Phase glacier.

Gold, arsenic, and other elements are commonly geochemically enriched in soil and till down-ice from known gold occurrences, resulting from mechanical dispersion (erosion, transportation, and deposition) by advancing glacial ice. Dispersal distances vary in Nova Scotia from hundreds of meters to several kilometres down-ice from the source.

Overview of the Field Trip Stops

There will be six stops in this field trip (Fig. 2):

Stop No.	Location	Key Words/Concepts
1	Dunbrack/Northwest Arm Interchange	bedrock – slates, bedding glacial – grooves, striations environmental – acid rock drainage
2	Walmart, Bayer’s Lake Industrial Park	bedrock – metasediments, granite, contact, xenoliths
3a	Kearney Lake Road Lafarge Quarry	bedrock – metasediments economic – aggregate quarry
3b	Kearney Lake Road Inter Supply Quarry	bedrock - metasediment glacial – overburden profile economic – aggregate use
4	Blue Acres Industrial Park	bedrock – metasediment, tree roots glacial – stoss/lee, striations, grooves, crescentic features, plucking environmental – weathering
5a	Waterstone Subdivision, Lucasville	bedrock – slate (sulphide rich), pyrite, pyrrhotite, bedding glacial – striations environmental – acid rock drainage, sulphide oxidation
5b	Waterstone Subdivision, Lucasville	environmental – acid rock drainage, iron precipitate
5c	Waterstone Subdivision, Lucasville	bedrock – slate (sulphide poor), bedding, cleavage
5d	Waterstone Subdivision, Lucasville	environmental –acid rock drainage, manganese
6	First Lake Drive, Lower Sackville	glacial – Lawrencetown till

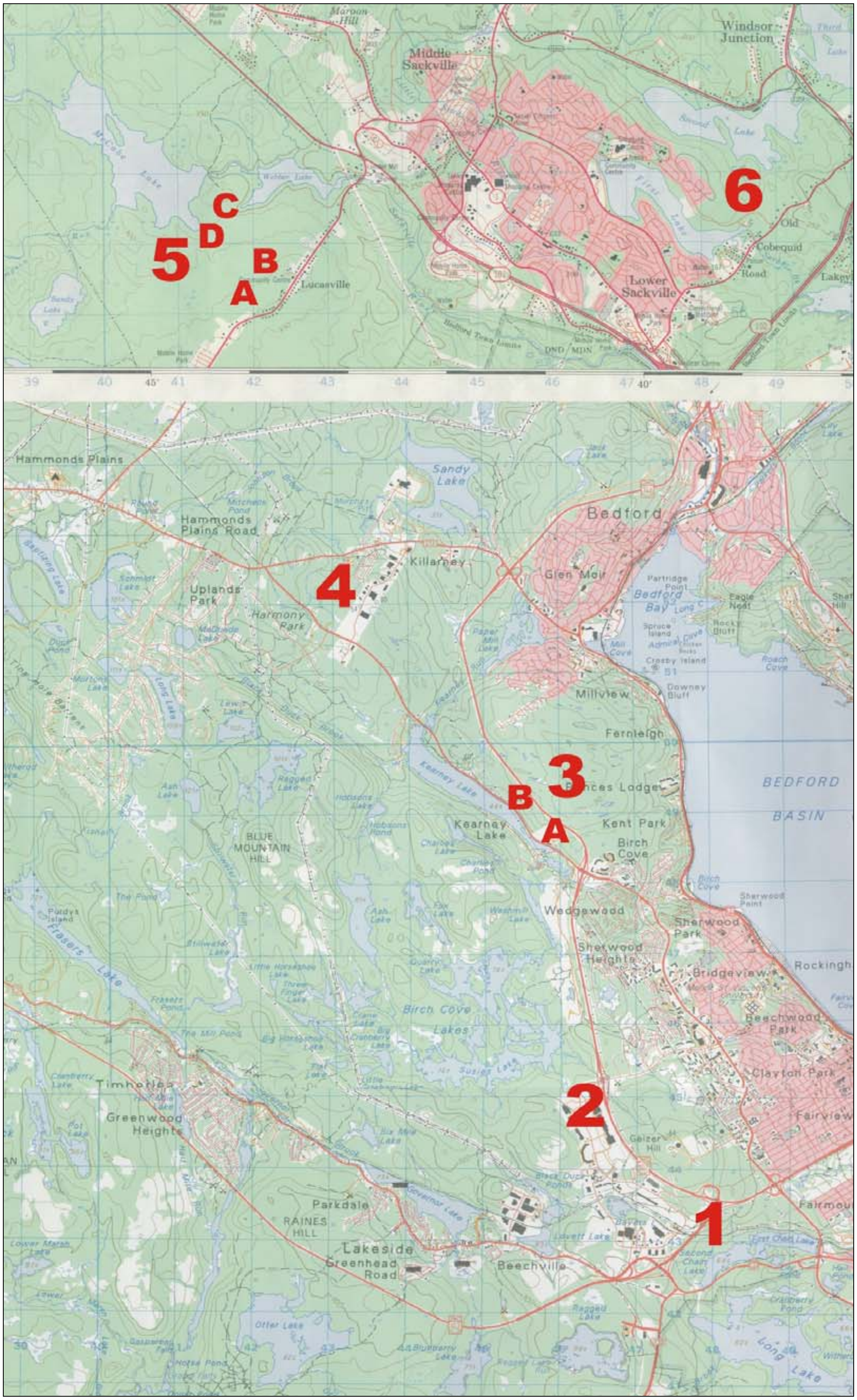

Figure 2. Field trip stop locations.

Field Trip Stops

Directions

We will begin the field trip on the off ramp of Exit 1D from Highway 102 south.

Stop 1

Highway 102 Dunbrack/Northwest Arm Interchange (Exit 1D), Halifax.

Safety Warning

This area often experiences heavy traffic; therefore; please use caution when crossing the road.

Overview

This outcrop features glacially polished interbedded metasiltstone and slate of the Cambro-Ordovician Halifax Formation (Fig. 3). Striations and grooves can be observed where the glacier moved over bedrock. They are essentially 'scratch marks' which, when measured, can be used as ice flow indicators. In this case, there are two directions of flow with the younger azimuth at 120 ° and the older at 155 °. This outcrop also presents a good example of bedding in slate; its features include soft sediment deformation and younging direction indicators. The rusty appearance of some of the rocks indicates the presence of (weathered) sulphides; these sulphides increase the probability that this outcrop may be producing acid rock drainage.

Directions to Stop 2

Proceed along the off ramp and turn left at the stop sign. Get back onto Highway 102 by taking exit 1H and head north for about 3.2 km. Take Exit 2A and turn left at the first set of lights you encounter. Continue for about 700 m into the Bayer's Lake Business Park and turn left at the set of lights into the Walmart parking lot. Stop 2 is located behind Walmart (on the Costco side).

Stop 2

Bayer's Lake Industrial Park**,** Walmart, Clayton Park

Safety Warning

Do not stand too close to the outcrop and watch for falling rocks; hard hats are recommended.

Overview

Here one can see a knife-sharp contact between intrusive granite and Cambro-Ordovician metasandstone of the Meguma Group (Goldenville Formation). The granites are classified as medium-grained granodiorites containing up to 12-15 % biotite. The metasedimentary rocks are characterized by a highly fractured and rusty appearance. Away from the contact, the granodiorite gets coarser grained implying (at this site) proximity to a chill margin. Also note the large roof pendants and small xenoliths (inclusions of Meguma Group rocks) in granodiorite. The increasing number of xenoliths at this site relative to other areas of the intrusion is further evidence of proximity to a margin or to the roof of the intrusion.

Figure 3. Glacially striated and polished outcrop of interbedded metasiltstone and slate of the Cambro-Ordovician Halifax Formation.

Figure 4. Contact between intrusive granodiorite (light colour) and Cambro-Ordovician metasediments (dark colour) of the Meguma Group (Goldenville Formation).

Directions to Stop 3a

From the parking lot, head back out the way you entered and turn right at the lights. Travel about 600 m and turn left just after the overpass to get back onto Highway 102 north. Travel another 2.5 km and take Exit 2 (Kearney Lake Road). Turn left at the stop sign and proceed for about 700 m to the Lafarge Quarry.

Stop 3a

Lafarge Quarry, Halifax

Safety Warning

Please pull well off to the right to keep out of the way of oncoming traffic.

Overview

This former quarry (Fig. 5) in Goldenville Formation (Meguma Group) metasandstone produced aggregate for the local market from 1968 until it closed in 1994. The quarry operator was Standard Paving Maritime but the quarry was subsequently bought by the site's current owner, LaFarge . The quarry produced approximately three million tonnes of material that was mostly used in the construction of highways, but also produced rip rap (large boulders for retaining walls) and aggregate for Inter Supply, a concrete firm formerly located at stop 3b.

To put this quarry into perspective, the Halifax metro area uses three million tonnes of crushed stone annually. Here are some interesting facts on aggregate production and use in Nova Scotia.

Aggregate

- most widely used construction material today.
- primary uses include road base, asphalt, concrete, and fill.
- critical materials in development of infrastructure (roads, bridges, sidewalks, underground services).
- more than three million tonnes of crushed stone used in Metro each year (almost a tandem truck load for every man, woman and child, each year).
- in Metro, more than one third of the province's aggregate is consumed in an area representing less than 1 % of the province's land mass.
- most materials come from three quarries: Conrad Brothers (Dartmouth), Rocky Lake (Waverley), and Gateway Materials (Kearney Lake).
- natural gravel is rarely used in the area, except for specialty applications (coloured gravel is brought to the city from the Cobequid Highlands). Why? (1) Almost no glacial gravel deposits in area and (2) natural gravel is rarely used for high-quality stone because of quality problems (won't pass latest specifications).
- natural sand is trucked to the city from as far away as Coldbrook and Bridgetown in the Annapolis Valley (> 100 km); used in concrete and for traction on ice.
- marine sand and gravel was a main source of aggregate in the past; materials came from beaches and dredging; shipped from as far away as Mahone Bay; evidence = shells in older concrete in the city.

Figure 5. Former aggregate quarry located on the Kearney Lake Road (Kearney Lake in the foreground).

- more than 300 tonnes of aggregate go into the construction of a new home.
- approximately 24 000 tonnes used in the construction of 1 km of new, paved, two-lane highway.
- trucking costs are the most expensive component in the price of landed aggregate. For example, using an average transport distance of 22 kilometres from the quarry gate in the Metro area, Nova Scotia Department of Transportation and Public Works gravel trucking rates are $2.89 / tonne. If local quarries are no longer accessible in the future and the stone had to be hauled an average distance of, say 100 km, the rate goes up to $8.92 / tonne. This may not seem very high, but that extra $6 / tonne on the 3 million tonnes used in the area means $18 million dollars more to get the same amount of stone from distant sources. The 300 tonnes of stone used in the house would mean an additional $1800 dollars required for its construction. The 24 000 tonnes of aggregate used in the highway would mean an additional $144,000. These costs should be a strong incentive for home owners and tax payers to support local aggregate sources.

Directions to Stop 3b

Continue along Kearney Lake Road for about 600 m from Stop 3a and pull off to the right hand side of the road.

Stop 3b

Inter Supply Quarry, Kearney Lake Road, Halifax.

Safety Warning

Again, this is a busy road so pull well off to the right hand side. We will be crossing the road to the lake edge after the discussion of the overburden profile, so please cross as a group and exercise extreme caution.

Overview

This is an example of a typical overburden profile (Fig. 6). The A (organic), B (soil), and C (till) horizons can be distinguished from one another by comparing the difference in colour and texture. For example, the A horizon is black as it is composed mainly of decaying organic matter. In contrast, the till has been locally derived from Goldenville metasandstone; this is reflected in both the colour and the composition of its matrix, pebbles, and boulders.

Across the road, note: (i) rip rap (discussed at Stop 3a) has been used to line the edge of Kearney Lake Road closest to the lake, (ii) fine-grained aggregate has been used for building the road base, in the asphalt and the storm sewer pipe, and (iii) across the lake medium-sized boulders have been used for the construction of retaining walls.

Directions to Stop 4

Proceed along Kearney Lake Road for approximately 3.3 km; turn right onto Bluewater Road, and into the Atlantic Acres Industrial Park. Follow this road for about 400 m and turn left into the Iron Mountain parking lot.

Stop 4

Blue Acres Industrial Park, Bluewater Drive, Iron Mountain Parking Lot.

Overview

This outcrop (Fig. 7) is composed of metasandstone (with minor interbedded metasiltstone) of the Goldenville Formation and represents a ‘whale back’ glacial feature. Ice flow indicators such as striations, grooves, crescentic features, and stoss/lee sculpting features with a plucked (down ice) end are present in the outcrop. Two ice flow directions can be observed with a dominant 150° direction and a younger one at 175°. Also note the non-glacial features on the outcrop that are similar in appearance to grooves, but that are generally wider and curvilinear; these features are interpreted to be tree root casts (inset, Fig. 7). Differential rates of oxidation are visible on the outcrop. The more recently exposed section of the outcrop (south side) looks very fresh and polished, and retains even subtle features such as fine striations and thinly laminated beds. Conversely, the northern half of the outcrop is characterized by advanced stages of weathering (oxidation) and lacks evidence of preserved subtle features noted on the south half of the outcrop.

Figure 6. Overburden profile along Kearney Lake Road. Inset: rip-rap boulders along Kearney Lake Road.

Directions to Stop 5a

Turn left out of the parking lot and travel approximately 700 m down Bluewater Road to the stop sign. Turn left on to Hammonds Plains Road and proceed for about 4.4 km. Turn right at the set of lights onto Lucasville Road. Travel for 3 km and turn left into the Waterstone subdivision. Stop 5A is located 400 m down Waterstone Run at lot 179.

Stop 5a

Waterstone Run, Waterstone Subdivision, Lucasville

Overview

The Halifax Formation can be subdivided into two distinct, slate-dominated units: (1) the lower Cunard Unit and (2) the overlying Glen Brook unit.

The Cunard unit (Fig. 8) is predominantly a black, finely laminated slate with thin, interbedded grey metasiltstone and metasandstone, as seen here at stop 5a. This unit is generally characterized mineralogically by its significant pyrite (as coarse cubes) and fine- to coarse-grained, weakly magnetic pyrrhotite associated with the metasiltstone beds. When these sulphide minerals oxidize, they form a red rusty coating that characterizes the Cunard unit.

Figure 7. Glacially sculpted outcrop located in the Blue Acres Industrial Park, Hammonds Plains. Ice flowed from bottom left to top right. Inset: interpreted root casts.

On an aeromagnetic map the Cunard unit is represented as a strong magnetically responsive unit (relative to the rest of the bedrock) because of the presence of pyrrhotite. These magnetically responsive beds are excellent marker units and can be traced along strike for many tens of kilometres, and are interrupted only by granitic intrusions or major faults.

Also note on the outcrop the presence of striations. These striations have an azimuth of 125° 305 ° and are similar in orientation to the youngest ice flow direction noted at Stop 1.

Directions to 5b

Proceed along Waterstone Run for approximately 900 m; stop 5b is on the right hand side of the road.

Stop 5b

Waterstone Run, Waterstone Subdivision, Lucasville.

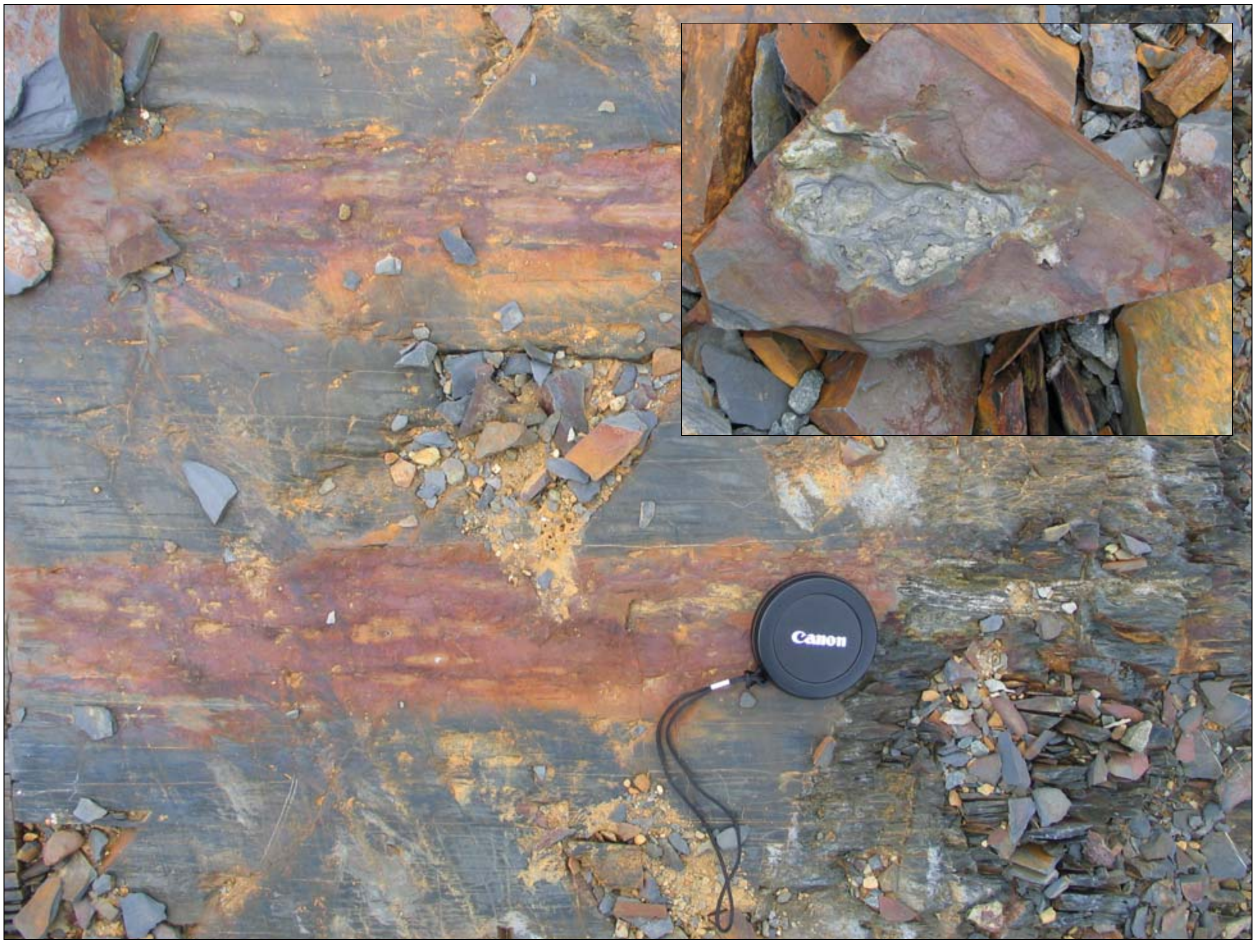

Figure 8. Outcrop of sulphide bearing Halifax Formation (Cunard Unit) slate and metasiltstone.
Inset: fresh sulphide in hand sample.

Overview

In the ditch is evidence of the oxidation of sulphide minerals and probable acid rock drainage (Fig. 9) seen at stop 5a. The ditch here is characterized by the presence of red iron precipitate in the water and presumably low pH (acidic) water. The local residents have water softeners and filters because the well water in the area leaves a red rusty stain on their porcelain fixtures and discolours laundry. The iron-rich waters from ditches in the subdivision drain directly into McCabe Lake and Webber Lake, which are part of the Sackville River system.

Acid rock drainage occurs when exposed sulphides break down, resulting in low pH waters further characterized by their high dissolved mineral content, both of which negatively affect water quality. Sites of recent acid rock drainage issues include the Halifax International Airport, Highway 107 at West Petpeswick Lake, and the Little Sackville River.

Directions to 5c

Continue along Waterstone Run for about 300 m and turn left onto Stonewick Crescent. Proceed for 900 m; stop 5c is located on the right hand side of the road.

Stop 5c

Waterstone Division, Stonewick Crescent, Lucasville.

Overview

The Glen Brook unit, which overlies the Cunard unit at stop 5a, is a pale green to grey, banded, well-cleaved slate with interbedded metasiltstone (and thin metasandstone) beds. This unit (Fig. 10) lacks the sulphides (pyrite and pyrrhotite) and thus the rusty appearance that characterize the Cunard unit. Compare and contrast hand samples of the Cunard and Glen Brook Units.

This area (stops 5a, 5b, 5c, and 5d) is a good example of the potential difference in the susceptibility of different rock types (based on their mineral composition) to acid rock drainage and of the potential impacts on drinking water quality and the environment.

Directions to 5d

Turn around and head back out of the subdivision for about 100 m; stop 5d is on the right hand side of the road.

Figure 9. Water in a ditch characterized by red iron precipitate (presumably from the oxidation of sulphide).

Stop 5d
Waterstone Division, Stonewick Crescent.

Overview
In this section, waters drain from a drainage ditch (approximately 100 m down gradient) into McCabe Lake. Note the difference in the colour (Fig. 11) of the water (darker and slightly black) from that of stop 5b. Also note the lack of precipitated iron.

These waters originate from the Glen Brook unit at stop 5c. The dark colour of the water may be the result of the presence of manganese in the Glen Brook unit.

The lack of sulphides in the Glen Brook unit would suggest these waters are less acidic than those seen at Sop 5b. Again, note that these waters also flow directly into McCabe Lake.

Directions to Stop 6
Turn left onto Lucasville Road from Waterstone Run. Travel about 4.1 km and turn right onto Sackville Drive at the stop sign. Continue for about 1.5 km and turn left at the intersection next

Figure 10. Sulphide-poor outcrop of the Halifax Formation (Glen Brook unit).

to Kent Building Supplies onto Beaverbank Road. Travel another 700 m to the next set of lights (next to the Petrocan) and turn right onto Glendale Drive. Travel 1.3 km down Glendale to the second set of lights and turn left onto Metropolitan. Follow this road for about 300 m to the set of lights and turn right onto First Lake Drive. Continue for about 2.3 km and pull off to the right hand side of the road.

Stop 6

First Lake Drive, Lower Sackville.

Overview

Lawrencetown Till (Fig. 12) is, generally, moderately compact clay till that can grade into a red-brown compact sand-silt till. It forms a till blanket (ground moraine) and is often characterized by the presence of large drumlins. This till blanket averages around 8 m in thickness while drumlins attain thickness of up to 25 m.

The Lawrencetown Till can be identified by its red colour, high clay content, and by the presence of a high number of 'foreign' pebbles (originating from Carboniferous basins and the Cobequid Mountains).

Figure 11. Water in a ditch characterized by its dark colour (presumably from the presence of manganese). Notice the difference in the colour of the water in this ditch with the water in Figure 9.

Figure 12. An example (from the Halifax Lateral of the gas pipeline) of typically red Lawrencetown Till.

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