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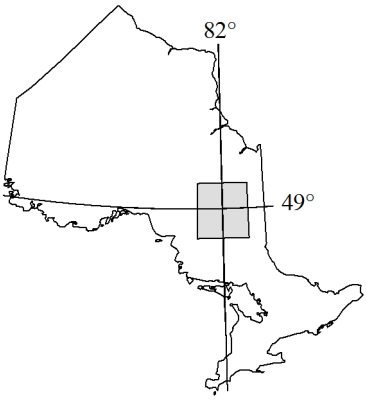
20. Project NE-17-003. Quaternary Geological Mapping of the Highway 11 Corridor, Northeastern Ontario: An Update



A.S. Marich[1]

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INTRODUCTION

This report outlines the results of the second season of field work conducted along the Highway 11 corridor of northeastern Ontario. This multi-year project is aimed at updating the Quaternary geology maps along the highway corridor between Iroquois Falls and Opasatika. To date, ground-based field work has been completed for 6 1:50 000 scale National Topographic System (NTS) map areas: Iroquois Falls (42 A/15), Abitibi (42 H/2), Cochrane (42 H/3), Smooth Rock Falls (42 H/5), Kapuskasing (42 G/8), and Opasatika (42 G/10) (Figure 20.1). This summary will discuss the field work completed within the Kapuskasing and Opasatika areas (Figure 20.2); note, in the text, these "areas" are referred to using the topographic map area name. Previous Quaternary geology mapping of the area was completed at a scale of 1:1 000 000 (Barnett, Henry and Babuin 1991) and 1:506 880 (Boissonneau 1965), and Northern Ontario Engineering Geology Terrain studies were produced at a scale of 1:100 000 (Lee and Scott 1989a, 1989b); however, a more detailed study of the surficial sediments in this area is required for land use planning, aggregate resource assessment and other geoscience-related studies. This project aims to delineate the distribution of the various Quaternary geological units as well as to determine the genesis of the landforms and sediments.

Field work was conducted between mid-May and the end of August 2017 and focussed on the examination of both natural and man-made exposures (e.g., river cuts, road cuts, pit excavations and roadside ditches), as well as soil probe and hand-auger cores. Access to the study area was via provincial highways, concession roads, active and abandoned forestry roads and recreational trails. Large portions of the study area are inaccessible by ground vehicle or by foot because they are largely occupied by wetlands with limited all-season access. In addition to ground-based work, helicopter-supported field work was conducted within map areas to the east (Abitibi, Iroquois Falls, Cochrane and Smooth Rock Falls NTS map areas) (*see* Figure 20.1). The helicopter work was undertaken to gain access to those areas that were inaccessible during the ground-based field work conducted in 2016 (*see* Marich 2016).

This project has also been undertaken to support an ongoing update to northern Ontario agricultural soils mapping being conducted by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). To aid these ongoing updates to the agricultural soils mapping, OMAFRA and the Ministry of Natural Resources and Forestry (MNRF) acquired high resolution digital elevation data. The resulting model, based on Light Detection and Ranging (LiDAR) remote sensing data, is a 50 cm raster of the land surface, a bare-earth model where the vegetation has been removed to show the surface topography. This model has been extremely helpful for the Quaternary geology mapping in delineating landforms at a much higher resolution than has ever been mapped in this part of Ontario (MNRF and OMAFRA 2017).

Summary of Field Work and Other Activities 2017,
Ontario Geological Survey, Open File Report 6333, p.20-1 to 20-12.

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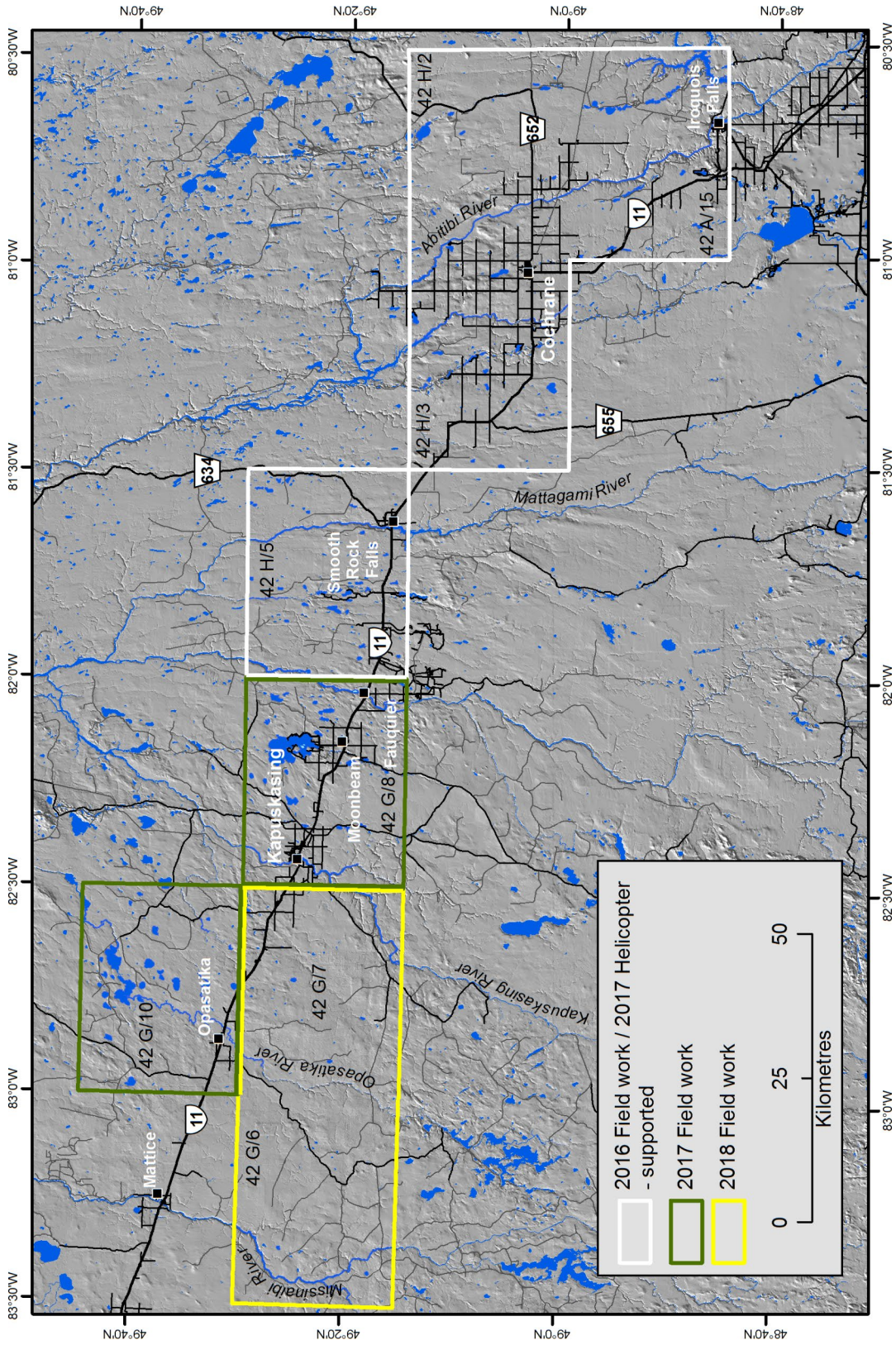

Figure 20.1. Study area map outlining the 3 areas of field work for 2016, 2017 and 2018, as well as the area of helicopter-supported field work in 2017. Lakes and drainage are shown in blue; roads are shown in black and dark grey. The high-resolution digital elevation surface is based on LiDAR remote sensing data from MNRF and OMAFRA (2017).

More than 2300 field observations were made, with 17 till and 17 esker sand samples collected. These samples will be investigated for pebble lithology, heavy mineral content, including gold grains, as well as kimberlite indicator minerals (KIM) and metamorphic/magmatic massive sulphide indicator minerals (MMSIM®[1]). In addition, fine-fraction geochemistry will also be completed on the silt and clay sized (−63 µm) fraction (*see* Figure 20.3 for sample locations). In support of the soil mapping initiative by OMAFRA, peat and mineral soil samples were collected at 135 locations throughout the current study area.

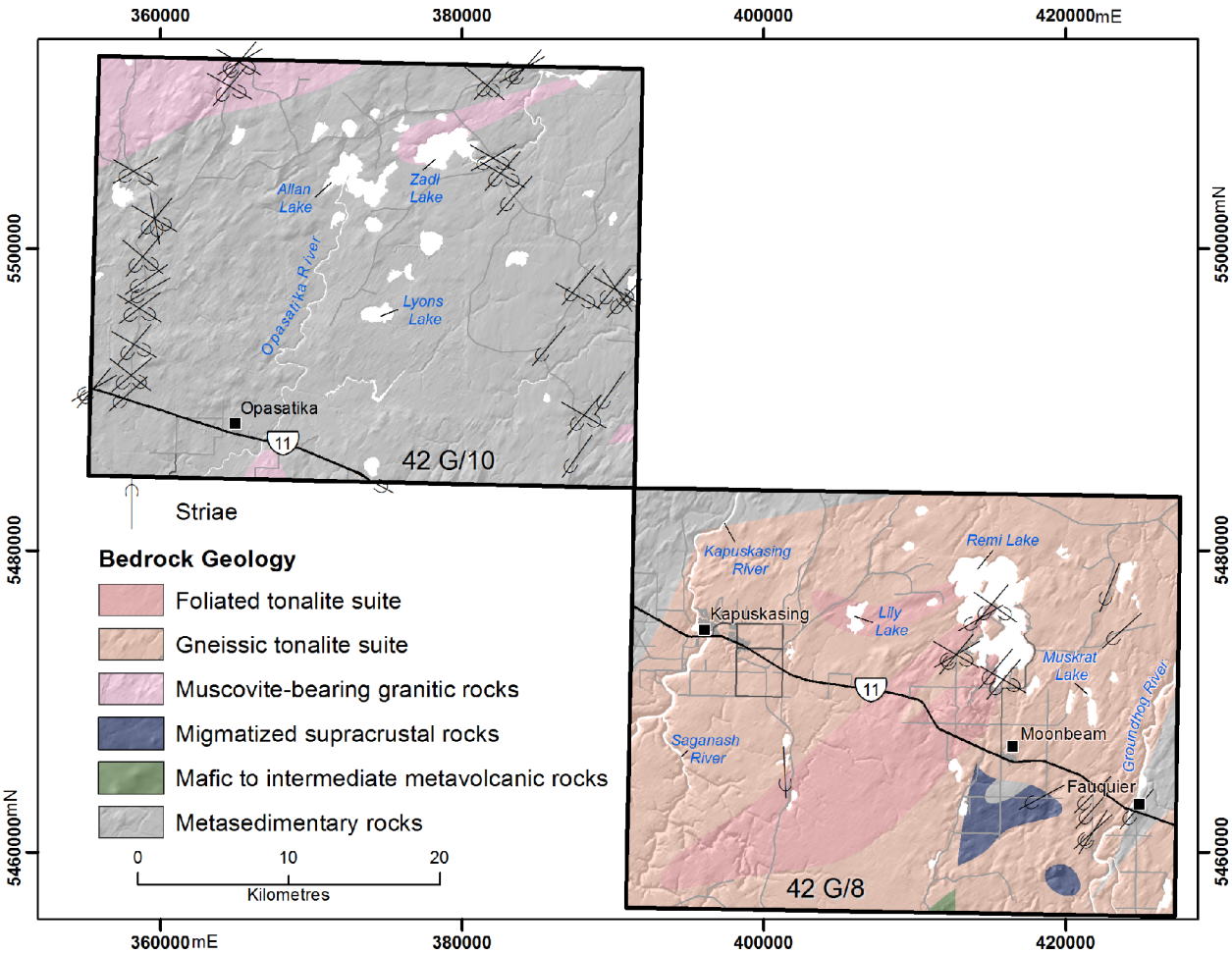

Figure 20.2. Simplified bedrock geology of the study area (*modified from* Ontario Geological Survey 2011). Note the NTS map areas are referred to in the text by area name rather than by the 1:50 000 scale NTS map numbers; thus 42 G/8 = Kapuskasing, 42 G/10 = Opasatika. This figure also includes locations of glacial striae measurements. The older ice flow direction is to the southeast, whereas the younger ice flow is to the southwest. The high-resolution digital elevation surface is based on LiDAR remote sensing data from MNRF and OMAFRA (2017). Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 17.

[1]*MMSIM is a registered trademark of Overburden Drilling Management Limited, Nepean, Ontario*.

BEDROCK GEOLOGY

Bedrock outcrops were observed sporadically throughout the study area. Drift thickness diminishes to the northwest along the Highway 11 corridor, with outcrops being identified more commonly within the Opasatika area. The study area is underlain by Archean bedrock of the Quetico Subprovince (Ontario Geological Survey 2011). Mesoarchean (3.4–2.5 Ga) metasedimentary rocks are the oldest identified and dominate the western half of the study area, extending west of Kapuskasing to west of the town of Opasatika. These rocks include paragneiss (Photo 20.1A) and migmatite, wacke, siltstone, arkose, slate, marble, chert and iron formation. Migmatized supracrustal rocks, consisting of metavolcanic rocks with minor metasedimentary rocks, mafic gneisses and granitic gneisses are located south of Moonbeam within the Kapuskasing map area (Ontario Geological Survey 2011) (Photo 20.1B). Mafic dikes were observed on some of the larger outcrops (Photo 20.1C).

Gneissic to foliated tonalitic to granodioritic rocks are the dominant rock type within the Kapuskasing area. There is a small isolated area mapped as mafic and ultramafic intrusive rocks (gabbros and anorthosites) south of Moonbeam along the southern margin of the Kapuskasing map area. Mica-bearing granitic rocks consisting of muscovite-biotite, cordierite-biotite granite and granodiorite-tonalite occur in the northwest part of the Opasatika map area (Photo 20.1D).

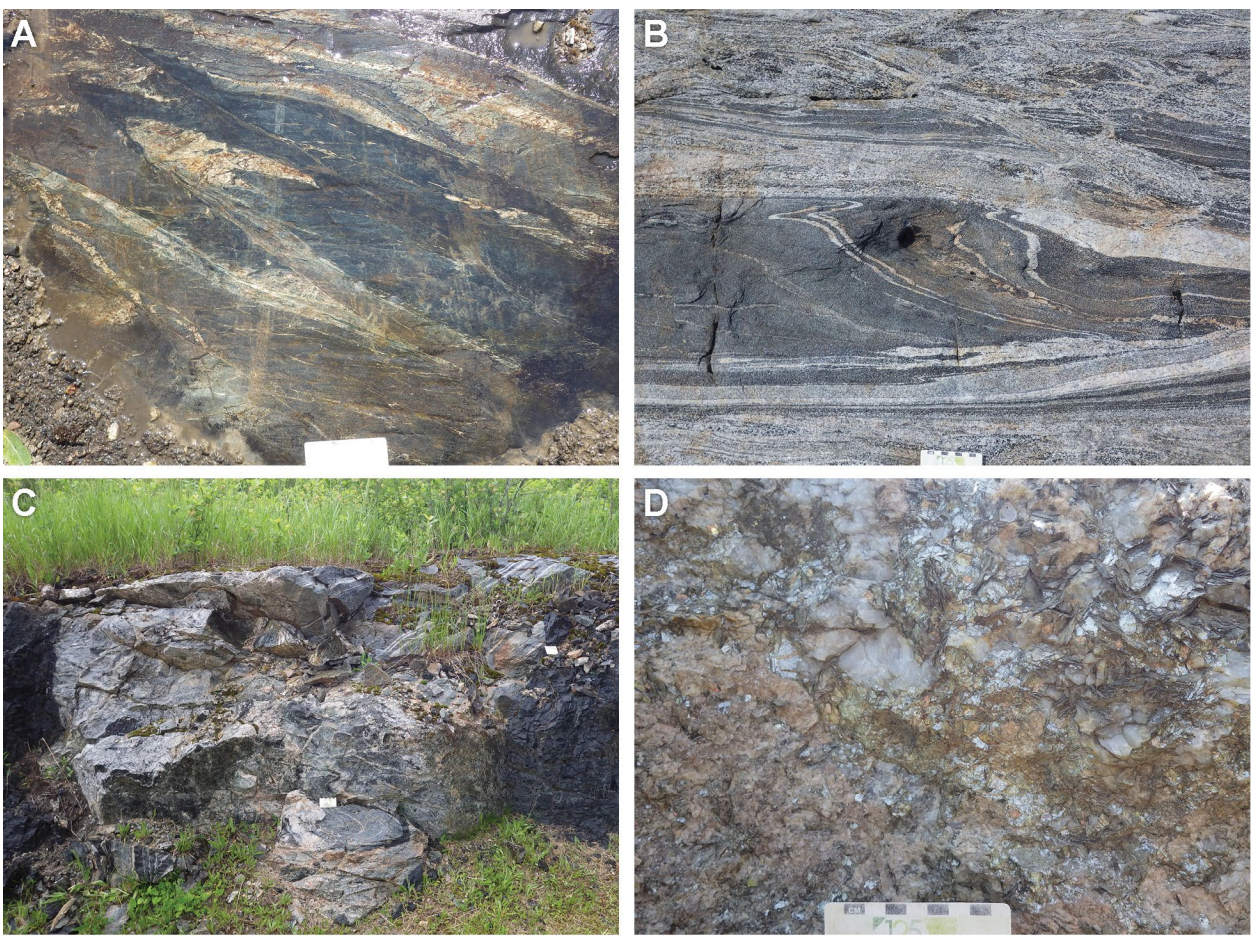

Photo 20.1. Examples of bedrock observed within the study area: **A**) paragneiss, **B**) gneiss, **C**) gneiss cut by a mafic dike and **D**) muscovite-bearing granitic rock.

QUATERNARY GEOLOGY

The landforms and sediments of northeastern Ontario were deposited by glaciers and associated geomorphic processes. The initial breakup and retreat of the Laurentide Ice Sheet began approximately 8500 ^{14}C years ago within the study area (Dyke 2004) and resulted in the formation of proglacial lakes, into which the Laurentide Ice Sheet readvanced on multiple occasions (e.g., Hughes 1965; Veillette 1994, Veillette et al. 2017; Evans 2011; Roy et al. 2011; Breckenridge et al. 2012). Glacial Lake Barlow and subsequently, glacial Lake Barlow–Ojibway, spanning 960 km west to east and 240 km north to south, occupied much of north-central Ontario and Quebec. Landforms and deposits of this lake dominate the regional landscape (Agterberg and Banerjee 1969). The lake existed for approximately 2000 years and its final drainage is thought to have been catastrophic, discharging northward during the final collapse of the ice sheet into the Tyrrell Sea (Veillette 1994; Roy et al. 2011).

The study area is located within the northern clay belt of Ontario and, as such, is dominated by wetlands with subdued topography and very low relief. Drift thickness within the study area varies from a few centimetres in areas adjacent to bedrock outcrops to approximately 40 m along esker ridges, based on limited water-well records. Areas where greatest relief was observed include esker ridges and gullies eroded by fluvial action. Iceberg keel marks cut into the surface materials in large swaths, most commonly to the south of Highway 11. These features vary in length and width, with widths ranging from a couple of metres to about half a kilometre, and lengths from a couple of metres to several kilometres. These keel marks are easily identifiable on the LiDAR digital terrain model, even those only a few metres long. The orientation of these keel marks can appear to be random at first look, but regionally their predominant direction is southeast, suggesting a dominant wind direction towards the southeast. This wind direction is reflected in the orientation of parabolic dunes located to the east within the Burntbush area (Gao 2013) and to the south near Timmins (Boissonneau 1965, 1966). The following sections describe the sedimentary units from oldest to youngest.

The oldest sediment observed within the study area consists of a pale grey, silty sand diamicton, regionally identified as the Matheson Till. The till contains 5 to 10% granules to pebble-sized gravel of predominantly Precambrian rock types. It has low matrix carbonate content and does not effervesce when subjected to 10% HCl. The low carbonate content and prevalence of Precambrian rock types suggests that Matheson Till is a locally derived till. A thorough understanding of the provenance and geochemical signature of till can be useful when attempting to assess the mineral resource potential of the area. The ice flow associated with this oldest till unit was to the south or southeast, and has been recorded in the bedrock striation record which will be discussed below. It is important to distinguish between the various ice flow directions, and their associated sedimentary deposits, when undertaking drift prospecting in order to target the appropriate locations for potential mineral deposits. This till was identified only during the helicopter-based field work undertaken within map areas to the east, and not, as of yet, within the Opasatika or Kapuskasing areas. Sample sites of Matheson Till were commonly at the base of river cuts, where the till was exposed beneath several metres of younger glaciolacustrine sediment, or adjacent to bedrock outcrops, where the stratigraphic sequence is compressed.

Glaciofluvial deposits associated with eskers were observed within the Kapuskasing area (Figure 20.3). The esker systems are generally oriented southward to southwestward but do not form a continuous ridge along their lengths because portions of the esker ridges are completely blanketed by lake sediments. Faces cut into eskers that were upwards of 20 m higher than the surrounding landscape were observed at several sand and gravel pits; however, most exposures are less than 5 m high. Several metres of fine-textured glaciolacustrine sediments and/or Cochrane Till were observed capping most of the glaciofluvial deposits of the region (Photo 20.2A). Both the glaciolacustrine sediments and Cochrane till are described below. Because Cochrane Till drapes these eskers, their formation predates the Cochrane Till deposition. This, along with the general south- to southwest orientation of the esker ridges, and their continuity beyond the

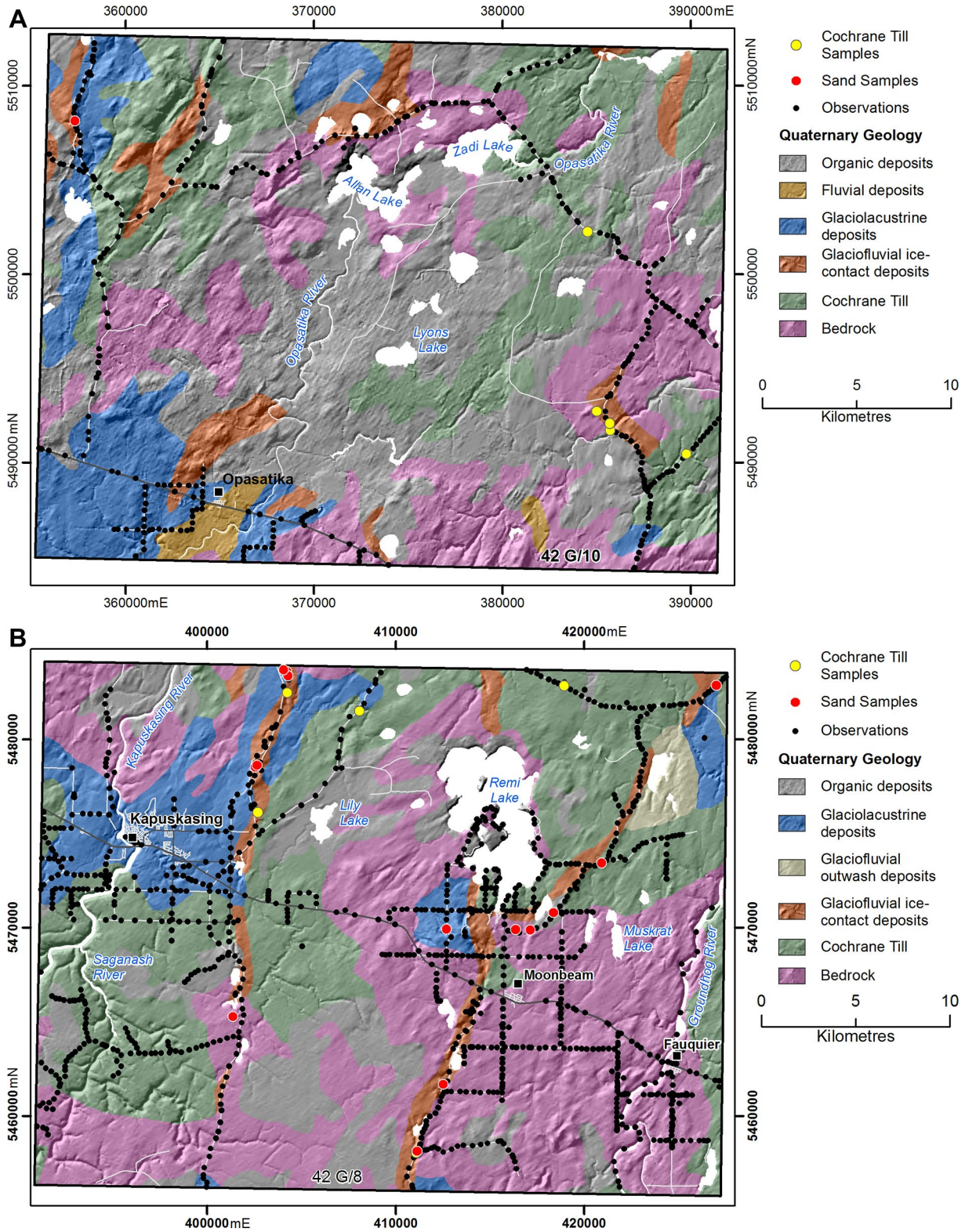

Figure 20.3. Simplified Quaternary geology of the **A**) Opasatika and **B**) Kapuskasing study areas (*modified from* Barnett, Henry and Babuin 1991). Map includes field (black dots) and sample locations. Locations where Cochrane Till was sampled are identified with yellow dots; locations where esker sands were sampled are identified with red dots. The high-resolution digital elevation surface is based on LiDAR remote sensing data from MNRF and OMAFRA (2017). The UTM co-ordinates are provided using NAD83 in Zone 17.

limit of Cochrane Till, suggests that the eskers are associated with the glacial ice responsible for the deposition of Matheson Till (Barnett, Henry and Babuin 1991). Esker sediments consist primarily of variably textured sands with minor gravel (Photo 20.2B). It has been suggested by Veillette et al. (2017) and others that the source material for these sand-dominated eskers are the Lower Cretaceous, unlithified deposits (silica sands, kaolin, silt, and lignite) of the Mattagami Formation located north of the study area. Paleoflow directions measured from sedimentary beds indicate a general south to southwest flow within the esker deposits. The clast content, albeit fairly low, consists of local Precambrian lithologies as well as far-travelled Paleozoic lithologies of the Hudson and James Bay Lowlands. Of note, is the presence of cobbles from the Proterozoic Omarolluk Formation (omars); the source of these cobbles is likely the Belcher Islands in southeastern Hudson Bay. The dark grey greywacke cobbles contain deep circular cavities resulting from preferential dissolution of carbonate concretions (Prest, Donaldson and Mooers 2000). Many of these eskers and the associated glaciofluvial sediments are being extracted as a local source of aggregate. Current operations are stockpiling sands and crushed gravel for use in road construction and maintenance.

The youngest sediments identified in the study area are associated with the Cochrane advance, the final advance of the Laurentide Ice Sheet into the study area and beyond, at approximately 8200 ^{14}C years ago (Hughes 1965; Evans 2011). Multiple interbeds of Cochrane Till and laminated to varved glaciolacustrine clays and silts suggest that on at least one occasion, if not multiple occasions, during the Holocene, the Laurentide Ice Sheet advanced into the glacial Lake Barlow–Ojibway basin (e.g., Hughes

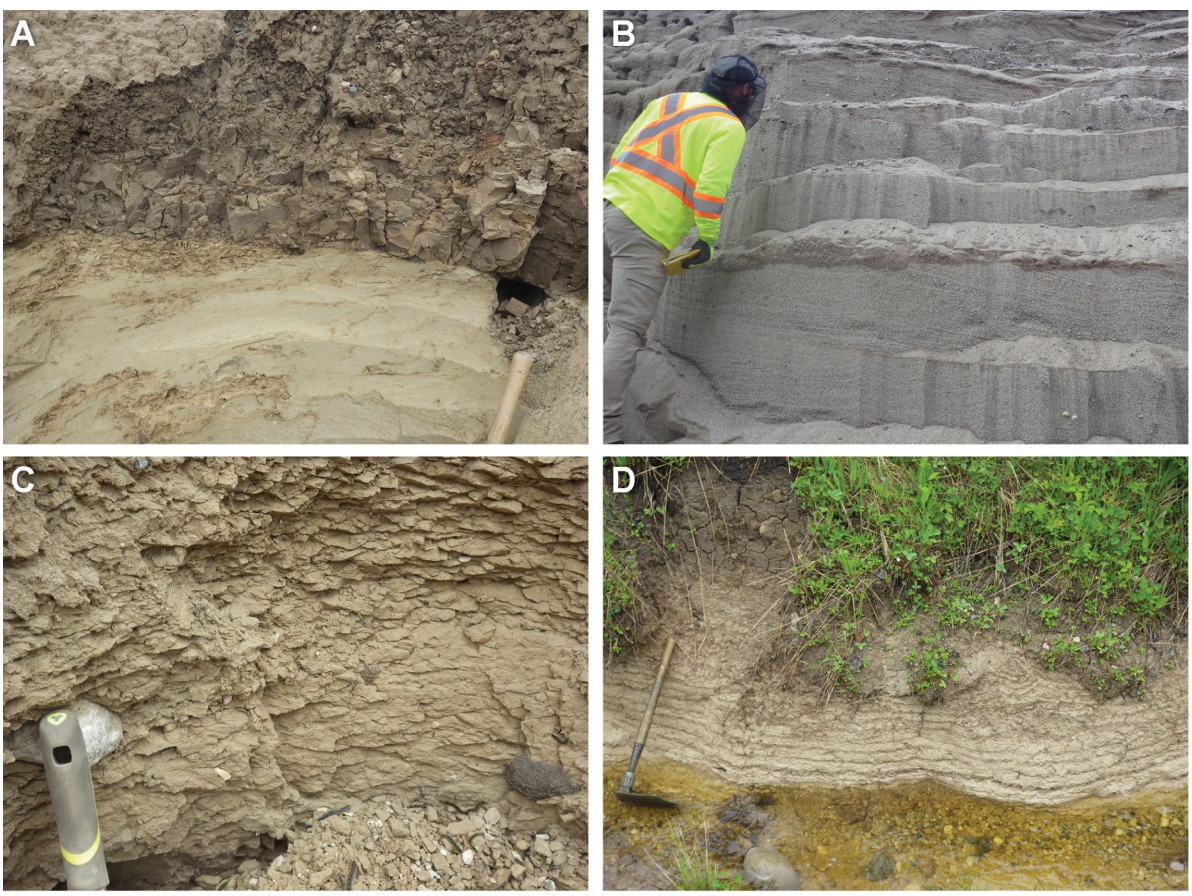

Photo 20.2. **A**) Cochrane Till overlying fine-textured esker sands; approximately 20 cm of the shovel handle is shown in the photograph. **B**) Interbedded sands and pebbly sands within an esker deposit. **C**) An example of a possible subglacial facies of Cochrane Till, a fissile sandy silt and clast-poor diamicton; trowel handle is approximately 10 cm long. **D**) Ditch cut showing rhythmically laminated glaciolacustrine sediments (varves). Dark brown beds are clay and pale tan beds are silt. Shovel handle is approximately 40 cm long.

1965; Veillette 1994). The Cochrane Till is fine textured with minor (<5%) granules to cobble-sized clasts, with most clasts being granule to 1 to 2 cm in diameter (Photo 20.2C). The till is variably compact, blocky in structure, in some cases exhibits strong fissility and is commonly capped by glaciolacustrine clays and silts. The Cochrane advance has been associated with ice flow to the southwest, based on the orientation of streamlined landforms and the youngest set of glacial striae (this study and Veillette 1994; Veillette et al. 2017). The Cochrane Till was most commonly observed north of Highway 11 within the Kapuskasing and Opasatika areas where drift generally thins.

South and southeast of Fauquier, in the Kapuskasing area, are a series of narrow, linear crag-and-tail features oriented approximately southwestward (*see* Figure 20.2). The tails of these landforms are composed of a very stony diamicton (Photo 20.3). The matrix of this diamicton is similar to that of the Cochrane Till but is much stonier, at approximately 10 to 15%, and clasts are predominantly local Precambrian rock types. These features may be the result of deformation of sediment around a bedrock obstruction and the down-ice streamlining of pre-existing sediment. The low-lying areas between these landforms are draped with fine-textured glaciolacustrine sediments.

Deep water glaciolacustrine sediments consisting of massive to laminated silt and clay as well as varved sediments occupy much of the Highway 11 corridor. These silts and clays are commonly greater than 1 m thick and in some places are upwards of 10 m thick. Varved silts and clays are observed throughout the study area and are often interbedded with massive clayey silt to silty clay. The varves consist of distinct dark grey clay (winter) beds and pale tan silt (summer) beds (Photo 20.2D). Thin beds containing ice-rafted debris were commonly observed. Within the ice-rafted debris, red granules were commonly observed. It is suggested that these granules are derived from the Silurian Kenogami River Formation, a red mudstone that outcrops to the north on the Albany River (Bajc, Lee and Yeung 2014; Gao, Lee and Yeung 2015).

Photo 20.3. Coarse-textured diamicton observed within crag-and-tail landforms south of Fauquier in the Kapuskasing area; shovel handle is approximately 40 cm long.

Sand deposits associated with both shallow glaciolacustrine (beach/nearshore) and subaqueous fans were identified south of Remi Lake. Road cuts through these sediments showed a sequence of fine-textured glaciolacustrine sediments and Cochrane Till overlying fine- to very fine-textured sands. These sands exhibit ripple and cross-bedding structures, including heavy mineral and fine detrital organic accumulations along these bedding structures. The landform associated with these sediments is a broad flat plain which is highly dissected with gullies up to 5 to 10 m deep.

Ice Flow Indicators

Ice flow indicators were observed throughout the study area. In areas of thin drift, where polished bedrock was exposed, striae are common. The striae were most commonly preserved on outcrops of fine-textured rock types (e.g., metasedimentary rocks) or on fine-textured veins and/or dikes within coarse-textured rock types. Two main ice flow directions are recorded in the striation data set (*see* Figure 20.2) (Photo 20.4A),

Photo 20.4. A) Crosscutting sets of glacial striae. An older set, oriented to the southeast, is shown by the marker in the bottom right corner of the photograph (ice flow is towards the upper right corner of the photograph), and a younger set, oriented to the southwest, is parallel to the long axis of the compass (ice flow is towards the bottom of the photograph). **B**) A gneissic bedrock outcrop showing the classic stoss and lee form. In this case, ice flow would have been from the left side of the photograph to the right side as shown by the black arrow.

an older flow to the southeast, which has been associated with the ice mass that deposited the Matheson Till, and a younger flow to the southwest, which records the latest ice flow associated with the Cochrane Till (Veillette et al. 2017). These measurements correlate well to observations recorded by Veillette and others within the northern clay belt (Veillette et al. 2017). Many outcrops exhibited sets of crosscutting striae showing these 2 ice flow directions.

In addition to striation measurements, the orientation of larger features, such as flutings and crag-and-tail landforms, were used to interpret ice flow. Photo 20.4B shows a classic stoss and lee form, where the bedrock is gently sloping and polished on the up-ice side, and steeply dipping and less polished in the down-ice, or lee side. The orientation of these features can be used to help interpret the local ice flow direction.

HELICOPTER-SUPPORTED FIELD WORK

In mid-July, field work was conducted within the Iroquois Falls, Abitibi, Cochrane and Smooth Rock Falls areas using a helicopter. The work targeted areas that were previously inaccessible using trucks and all-terrain vehicles. Landing sites included winter logging roads, old forest plots and any clearing where sediment was observed. An additional 1700 aerial and ground observations were made during the helicopter-supported field work. Numerous photographs, which will aid in the landform and sediment interpretations, were also acquired as part of the survey. This work was also helpful in gaining a better understanding of the regional geomorphology of the study area. Photo 20.5 shows an example of an esker ridge and associated kettle lakes.

FUTURE WORK

Field work will continue to the west within the Val-Rita (42 G/7) and Rock River (42 G/6) areas in 2018. If time and resources allow, areas with limited access within the Kapuskasing and Opasatika areas will be visited by helicopter.

Photo 20.5. Photograph showing a sinuous esker ridge flanked by kettle lakes.

Updated 1:50 000 scale Quaternary geology maps will be created for each of the 8 NTS map areas once all field work and laboratory analyses are completed.

ACKNOWLEDGMENTS

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REFERENCES

Agterberg, F.P. and Banerjee, I. 1969. Stochastic model for the deposition of varves in glacial Lake Barlow–Ojibway, Ontario, Canada; Canadian Journal of Earth Sciences, v.6, p.625-652.

Bajc, A.F., Lee, V.L. and Yeung, K.H. 2014. Field studies in support of terrain mapping and aggregate resource assessment, James Bay Lowland, Ontario; *in* Summary of Field Work and Other Activities, 2014, Ontario Geological Survey, Open File Report 6300, p.23-1 to 23-9.

Barnett, P.J., Henry, A.P. and Babuin, D. 1991. Quaternary geology of Ontario, east-central sheet; Ontario Geological Survey, Map 2555, scale 1:1 000 000.

Boissonneau, A.N. 1965. Algoma–Cochrane, surficial geology; Ontario Department of Lands and Forests, Map S365, scale 1:506 880.

——— 1966. Glacial history of northeastern Ontario I. The Cochrane–Hearst area; Canadian Journal of Earth Sciences, v.3, p.550-578.Breckenridge, A., Lowell, T.V., Stroup, J.S. and Evans, G. 2012. A review and analysis of varve thickness records from glacial Lake Ojibway (Ontario and Quebec, Canada); Quaternary International, v.260, p.43-54.

Dyke, A.S. 2004. An outline of North American deglaciation with emphasis on central and northern Canada; *in* Quaternary glaciations—Extent and chronology, Part II: North America; Developments in Quaternary Sciences, v.2, p.373-424.

Evans, G.L. 2011. Ice margin and sediment fluctuations recorded in the varve stratigraphy of Lake Ojibway; unpublished MSc thesis, University of Cincinnati, Cincinnati, Ohio, 53p.

Gao, C. 2013. Quaternary geology, Burntbush area, northeastern Ontario: Ontario Geological Survey, Preliminary Map P.3770, scale 1:100 000.

Gao, C., Lee, V.L. and Yeung, K.H. 2015. Field studies in support of remote predictive mapping in the Missisa Lake area, Far North of Ontario; *in* Summary of Field Work and Other Activities, 2015, Ontario Geological Survey, Open File Report 6313, p.27-1 to 27-12.

Hughes, O.L. 1965. Surficial geology of part of the Cochrane District, Ontario, Canada; *in* International Studies on the Quaternary, 7th International Quaternary Association (INQUA) Congress, Geological Society of America, Special Paper 84, p.535-565.

Lee, H.A. and Scott, S.A. 1989a. Northern Ontario Engineering Geology Terrain Study, Guilfoyle Lake, data base map; Ontario Geological Survey, Map 5088, scale 1:100 000.

——— 1989b. Northern Ontario Engineering Geology Terrain Study, Kapuskasing, data base map; Ontario Geological Survey, Map 5090, scale 1:100 000.

Marich, A.S. 2016. Quaternary geological mapping along the Highway 11 corridor, northeastern Ontario; *in* Summary of Field Work and Other Activities, 2016; Ontario Geological Survey, Open File Report 6323, p.23-1 to 23-7.

Ministry of Natural Resources and Forestry and Ministry of Agriculture, Food and Rural Affairs 2017. Lidar-digital terrain model, Cochrane LiDAR DTM (2016–17), 50 cm raster; Land Information Ontario (LIO) Data Set, available on Land Information Ontario.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

Prest, V.K., Donaldson, J.A. and Mooers, H.D. 2000. The omar story: The role of omars in assessing glacial history of west-central North America; Géographie physique et Quaternaire, v.54, p.257-270.

Roy, M., Dell'Oste, F., Veillette, J.J., de Vernal, A., Hélie, J.-F. and Parent, M. 2011. Insights on the events surrounding the final drainage of Lake Ojibway based on James Bay stratigraphic sequences; Quaternary Science Reviews, v.30, p.682-692.

Veillette, J.J. 1994. Evolution and paleohydrology of glacial lakes Barlow and Ojibway; Quaternary Science Reviews, v.13, p.945-971.

Veillette, J.J., Roy, M., Paulen, R.C., Ménard, M. and St-Jacques, G. 2017. Uncovering the hidden part of a large ice stream of the Laurentide Ice Sheet, northern Ontario, Canada; Quaternary Science Reviews, v.155, p.136-158.