Geochemistry and mineralogy of glacial sediments, north of Fury and Hecla Strait, northwestern Baffin Island, Nunavut

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The Fury and Hecla Geoscience Project (FHGP) is being led by the Canada-Nunavut Geoscience Office in collaboration with Crown-Indigenous Relations and Northern Affairs Canada, and researchers and students from Laurentian University, McGill University and Université du Québec à Montréal. The multiyear project involves mapping and sampling of Archean, Proterozoic and Paleozoic rocks, and Quaternary surficial deposits and features. The study area comprises all or parts of nine 1:250 000 scale National Topographic System (NTS) map areas north and south of Fury and Hecla Strait on Baffin Island and Melville Peninsula, respectively (NTS 37C, F, 47C–H and 48A).


Abstract

The objective of this project is to reconstruct the glacial history and evaluate the mineral potential of the area on the north coast of Fury and Hecla Strait, northwestern Baffin Island, from the study of glacial sediments. Following till sampling conducted in 2018, laboratory work was performed on the samples, including geochemical, heavy minerals and sedimentological analyses. Till compositions were classified between five characteristic lithology groups and compared with the geochemistry of different pebble lithologies. The geochemical and mineralogical data will provide additional baseline data to guide future mineral exploration and infrastructure studies (permafrost and geotechnical) in the region. The region displays mineral exploration potential for uranium, iron and diamonds. A minor, but still uncertain, potential is that for white and clear corundum grains; their presence in till is reported here but further investigation is required to assess their significance.

Résumé

Ce projet a pour objectif de permettre la reconstitution de l’histoire glaciaire de cette région, située sur la côte nord du détroit de Fury et Hecla, au nord-ouest de l’île de Baffin, à partir de l’étude de sédiments de cette même époque, tout en évaluant son potentiel minier. Des échantillons de till recueillis en 2018 ont été analysés en laboratoire afin d’établir leurs caractéristiques géochimiques et sédimentologiques et leur teneur en minéraux lourds. Les tills ont été répartis selon cinq groupes lithologiques caractéristiques et comparés aux paramètres géochimiques de divers types lithologiques de galets. Les données géochimiques et minéralogiques fourniront des données de référence supplémentaires susceptibles d’aider à mieux orienter les travaux d’exploration minérale futurs ainsi que les études liées aux infrastructures (pergélisol et géotechnique) dans la région. Cette dernière semble prometteuse en matière d’exploration minérale et pourrait receler de l’uranium, du fer et des diamants. Il y a même une possibilité, bien que moindre et incertaine, que la région puisse receler des grains de corindon clair et blanc; leur présence dans le till a été notée mais des recherches supplémentaires s’imposent afin de déterminer leur importance.

Introduction

The objective of the surficial geology component of the Fury and Hecla Geoscience Project is to reconstruct the glacial history and evaluate the mineral potential from the study of glacial sediments from the area located north of Fury and Hecla Strait, northwestern Baffin Island (Figure 1). Following till sampling conducted in 2018, laboratory work was performed, including geochemical, heavy minerals and sedimentological analyses. Tremblay and Godbout (2018) mapped ice-flow indicators using Landsat and SPOT satellite imagery, aerial photographs,
Figure 1: Selected glacial geomorphology features, ice-flow lines and glaciodynamic zones of the study area, northwestern Baffin Island (modified from Tremblay and Godbout, 2018). Digital elevation model (DEM) from the 0.5 m horizontal resolution, high-resolution digital elevation model (HRDEM; Natural Resources Canada, 2018) developed from ArcticDEM dataset (Porter et al., 2018) and from a Canadian digital elevation model (CDEM; Natural Resources Canada, 2015).
multibeam bathymetry and digital elevation models (DEM), which together with previous surficial mapping studies helped to reconstruct the ice-flow history of the study area (Figure 1). The geochemical and mineralogical data from till samples collected for this project will provide additional baseline data to guide future mineral exploration and infrastructure studies (permafrost and geotechnical) in the region.

**Location**

The study area is located on northwestern Baffin Island, 130 km northwest of the hamlet of Igloolik and north of Fury and Hecla Strait, Nunavut (Figure 1). Maximum elevation in the study area is 603 m asl.

**Geological setting**

The bedrock geology of the study area consists of basement lithologies of the Archean and Paleoproterozoic (PP) Rae domain (mostly felsic orthogneiss, mafic–ultramafic intrusive complex and felsic intrusive bodies) unconformably overlain by Mesoproterozoic rocks of the Fury and Hecla Group (quartzitic sandstone, sandstone, mudstone, carbonate and volcanic rocks). Neoproterozoic mafic dykes and sills intrude older Precambrian rocks. Paleozoic carbonate rocks and sandstones overlie basement rocks on Crown Prince Frederik Island and in the northwestern and northeastern sector of the study area (Figure 2a; Chandler, 1980; de Kemp and Scott, 1998; Steenkamp et al., 2018). Refer to Tremblay and Godbout (2018) for a detailed overview of the physiography, surficial geology and bedrock geology of the area.

Mineral exploration in the study area was conducted by Noranda Exploration Company Ltd. and Dejour Mines Limited from 1977 to 1981 for uranium (Cusveller, 1999; NunavutGeoscience.ca, 2015) and by De Beers Canada Exploration Inc. in 2002 for diamonds (Government of Nunavut et al., 2002). The study area is known to host uranium mineralization in the bedrock adjacent to the northern contact between the Archean basement and the rocks of the Fury and Hecla Group (Figure 2e; NunavutGeoscience.ca, 2015). Two Geological Survey of Canada (GSC) till samples containing kimberlite indicator minerals (KIMs) were reported by de Kemp and Scott (1998; Figure 2f) and DiLabio and Knight (1998). Tremblay and Godbout (2018, Figure 7c) documented an erratic clast of massive, hematitic (specularite), banded iron formation found in surficial sediments (Figure 2f), indicating iron deposit potential in the study area.

A synthesis of the ice-flow chronology for the study area based on striations, macroforms and glacial dispersion evidence is presented in Tremblay and Godbout (2018; Figure 1). During the last glacial cycle (Dyke et al., 2003), the main regional ice flow was influenced by the presence of ice streams flowing toward the Gulf of Boothia, in Bernier Bay (Bernier Bay ice stream) and in Fury and Hecla Strait (Fury and Hecla Strait ice stream). A local ice divide persisted on the Saputing Lake–Gifford River plateau (Gifford-Saputing ice divide). Glaciodynamic units were mapped in Tremblay and Godbout (2018; Figure 1), including cold-based zones (CB; corresponding to areas where signs of glacial erosion are virtually absent from the landscape), intermediate cold-based zones (IB; representing a transition zone) and warm-based zones (WB; displaying increasing signs of glacial activity, such as streamlined outcrops and bedrock hills, linear glacial erosion corridors and macroforms).

**Methods**

**Sample collection**

In July and August 2018, till was sampled at 45 sites and submitted for sedimentological, geochemical and heavy minerals analyses. Till samples were collected with a shovel from frost boils, between 0 and 40 cm from the surface. Till sample weight was about 2 kg for geochemical and sedimentological samples and about 9 kg for heavy mineral samples. This paper presents the results of the analyses of these samples.

**Till geochemistry and sedimentology analyses**

Forty-five till samples (~2 kg) were collected for sedimentological and geochemical analyses. The samples were processed at the GSC Sedimentology Laboratory (Ottawa, Ontario). Each sample was air dried and then split, with a portion dry-sieved to recover the <63 µm fraction for geochemical analysis. Another portion was used for grain-size analysis, and for the determination of inorganic carbon content, loss-on-ignition (LOI) and Munsell colour. Lastly, a third portion was saved for archival purposes.

The till sample grain-size distribution (sand, silt, clay) was determined using a Beckman Coulter, Inc. LS 13 320 laser particle sizing analyzer on the <63 µm fraction (see Girard et al., 2004, for details on laboratory protocols). The grain size of fractions between 63 µm and 2 mm was determined by wet sieving on the >45 µm and <2 mm fraction, followed by dynamic digital image processing using a HORIBA, Ltd.’s CAMSIZER particle size and shape analysis system. Inorganic carbon content and LOI were measured with a LECO Corporation CR412 carbon analyzer. Munsell colour determination was completed using X-Rite, Incorporated’s SP64 portable sphere spectrophotometer. In this study, the colour of till is expressed with CIELAB parameters (Tremblay et al., 2020): L* is the lightness value
Figure 2: Sedimentology, geochemistry and heavy minerals results from till sampling program, north of Fury and Hecla Strait, northwestern Baffin Island. a) bedrock geology and grain size; b) CIELAB colour parameters (a* and L*). Geochemical results are from the <63 µm fraction (blue full and black outline circles are samples from this study) and from the <2 µm fraction (orange full and red outline circles with white dots are from Utting et al., 2008 and without white dots are from de Kemp and Scott, 1998). Heavy minerals results are from this study, unless otherwise noted. Background bedrock geology modified from Steenkamp et al. (2018), south of thick grey line and north of Fury and Hecla Group; elsewhere, it is from de Kemp and Scott (1998), except for banded iron formation (BIF), which is from Lebeau et al. (2020).
Figure 2 (continued): Sedimentology, geochemistry and heavy minerals results from till sampling program, north of Fury and Hecla Strait, northwestern Baffin Island. c) SiO$_2$ and Ca; d) Mg and Sr; e) U and La. See page 52 for description of geochemical plots and background geology.
Figure 2 (continued): Sedimentology, geochemistry and heavy minerals results from till sampling program, north of Fury and Hecla Strait, northwestern Baffin Island: f) Ti and Fe; g) Zn and Pb; h) Ni and Cu. See page 52 for description of geochemical plots and background geology.
Figure 2 (continued): Sedimentology, geochemistry and heavy minerals results from till sampling program, north of Fury and Hecla Strait, northwestern Baffin Island: i) V and Cr; j) Au and gold grains normalized to 10 kg table feed; k) sulphide grains from nonferromagnetic heavy mineral concentrate (NFHMC). See page 52 for description of geochemical plots and background geology.
Carbonate content was analyzed by titration with UIC Inc.’s CM5015 CO₂ coulometer with CM5230 acidification module on the <63 µm fraction, on a (maximum) 2 g sample. A split of the <63 µm fraction was sent to Bureau Veritas Minerals (Vancouver, British Columbia) for geochemical analysis. Refer to McClenaghan et al. (in press) for a description of laboratory protocols. A 30 g split was digested with modified aqua regia and analyzed by inductively coupled plasma–mass spectrometry (ICP-MS) for 65 elements, including gold, base metals, platinum and rare-earth elements. Another 2 g split was analyzed using a lithium metaborate/lithium tetraborate fusion and digestion in nitric acid followed by inductively coupled plasma–emission spectrometry (ICP-ES) for major oxides and ICP-MS for trace elements. Analytical accuracy and precision were monitored by including GSC CANMET-certified standards (TILL-2 and TILL-4) inserted into the sample batch at the GSC Sedimentology Lab and additional quality control samples inserted by Bureau Veritas Minerals (laboratory duplicates of samples, blanks, reference standards and analytical duplicates). For some till samples, the <2 µm fraction was geochemically analyzed using the methods described above.

Whole rock X-ray fluorescence (XRF) analysis was performed at CSG Inc. in Montreal (Quebec) on clasts visually selected from the >4 mm pebble fraction of till samples TIAT18-172 and -173. The samples were crushed with a
mortar and pestle. X-ray fluorescence geochemical analysis was conducted using a Vanta handheld XRF analyzer from Olympus Corporation using 30, 60 and 60 seconds for the 40, 10 and 50 kilovolt (kV) beams, respectively.

The <2 µm till samples from de Kemp and Scott (1998) and Utting et al. (2008) were analyzed with ICP-ES and ICP-MS respectively, after aqua-regia acid dissolution.

Heavy mineral analysis

Forty-two bulk till samples (9 kg average total weight) were collected to produce heavy mineral concentrates (HMC) for the recovery of indicator minerals, including KIMs, sulphides, platinum group minerals, gold, gemstones and other minerals of interest using methods described in Plouffe et al. (2013). Samples were sent to Overburden Drilling Management Limited (ODM; Ottawa, Ontario) for heavy mineral analysis. A standard pre-analysis treatment was applied to all samples, which included initial sieving of pebbles (>2 mm; the 4–8 mm fraction was separated for lithological counting) and preconcentration of heavy minerals on a shaking table. The table concentrate was panned to recover gold grains and metallic indicator minerals, which were counted, described and returned to the preconcentrate. The heavy mineral preconcentrate was then further refined using heavy liquid separation (methylene iodide, specific gravity of 3.2) and ferromagnetic separation. The >0.25 mm fraction of the nonferromagnetic heavy mineral concentrate (NFHMC) was examined with a binocular microscope and various distinctive mineral species including KIMs and metamorphic massive-sulphide indicator minerals (MMSIMs), which included gahnite, red rutile, pyrite, chalcopyrite and arsenopyrite (Averill, 2001), were visually identified. The mineralogical picking was performed on three different size fractions (0.25–0.5 mm, 0.5–1 mm, 1–2 mm) of the NFHMC. Following further preparation, binocular microscope identifications of MMSIMs and KIMs were undertaken and supported in specific cases by scanning electron microscope (SEM) analysis. The indicator mineral abundances in the NFHMC reported by ODM were subsequently normalized to 10 kg of <2.0 mm material (table feed) prior to the interpretation of the data.

Results and discussion

Maps with grain size, colour, geochemistry (on the <63 µm fraction of samples from this study and the <2 µm fraction of samples from de Kemp and Scott, 1998, and Utting et al., 2008) and select HMC minerals are shown on Figure 2. Complete data are presented in Tremblay et al. (2020). Both the <63 µm and <2 µm fraction till geochemistry analyses are presented in Figure 2, however, the following interpretation will focus solely on the <63 µm fraction analysis, because of the partitioning effect between both grain sizes (Shilts, 1993). Data classification of geochemical results for each size fraction were plotted as proportional circles on Figure 2 using Jenks natural breaks classification method. Based on the lithological content in the >2 cm pebble fraction of the till samples (see Figure 2 in Tremblay and Godbout, 2018, and Tremblay et al., 2020), it is possible to distinguish between tills with distinct geochemical and sedimentological characteristics. Figure 2a shows the distribution of till samples and their characteristic pebble lithology classification. The samples for each characteristic lithology group are clustered over corresponding bedrock lithologies. Table 1 lists the average values of selected geochemical and heavy minerals data for each main pebble lithology group. Table 2 lists the main sedimentological characteristics and the geochemistry mean values for each group. It is noteworthy that most till samples classified as Archean mafic–ultramafic rocks, Archean to Paleoproterozoic metasedimentary rocks, and felsic gneiss and granite were collected in IB or CB settings, therefore, enhanced weathering conditions might play a role in grain size, colour or the distribution of certain geochemical elements. Also, glacial transport distances for till are expected to have been relatively low in IB and CB settings. Additionally, specific economically relevant parameters are presented in the following section.

Table 1: Averages of select sedimentological and geochemical data for characteristic lithology groups from the till samples, north of Fury and Hecla Strait, northwestern Baffin Island. Refer to text for more details on the CIELAB colour classification system: a* is a red-green colour value (red [–100], grey [0], green [100]); b* is a blue-yellow colour value (blue [–100], grey [0], yellow [100]); and L* is a lightness value (black [0], white [100]). Clay is defined as <4 µm for grain-size analysis. Colour intensity shown is a proportional scale between minimum and maximum values for each data column, except for the value in white text as it is a high value outlier excluded from classification for clarity. In the case of the CIELAB colour, the colour tone reflects the general information conveyed by the parameters, and not the exact colour of the sediment. Abbreviation: PP, Paleoproterozoic.

<table>
<thead>
<tr>
<th>Characteristic lithology group (till)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>C (inorganic) (%)</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archean mafic–ultramafic rocks</td>
<td>72.6</td>
<td>20.6</td>
<td>6.8</td>
<td>0.10</td>
<td>56.3</td>
<td>4.6</td>
<td>18.6</td>
</tr>
<tr>
<td>Archean to PP metasedimentary rocks</td>
<td>72.1</td>
<td>23.5</td>
<td>4.4</td>
<td>0.25</td>
<td>59.7</td>
<td>3.5</td>
<td>16.0</td>
</tr>
<tr>
<td>Felsic gneiss and granite</td>
<td>78.0</td>
<td>18.6</td>
<td>3.4</td>
<td>0.09</td>
<td>55.0</td>
<td>5.2</td>
<td>16.3</td>
</tr>
<tr>
<td>Fury and Hecla Group sedimentary rocks</td>
<td>71.5</td>
<td>23.2</td>
<td>5.3</td>
<td>0.10</td>
<td>58.3</td>
<td>7.1</td>
<td>14.3</td>
</tr>
<tr>
<td>Felsic gneiss and granite / Paleozoic carbonate rocks</td>
<td>47.5</td>
<td>38.3</td>
<td>14.2</td>
<td>6.9</td>
<td>68.2</td>
<td>3.5</td>
<td>19.1</td>
</tr>
</tbody>
</table>
### Table 2: Average of select geochemical and heavy mineral data for characteristic lithology groups or lithologies, by medium (till or pebbles), north of Fury and Hecla Strait, northwestern Baffin Island. The two lower sets of rows refer to the ratio between different main lithology groups or lithologies versus the felsic gneiss and granite till group or the average granite and gneissic rocks lithology values. Till geochemical data were derived from aqua-regia digestion followed by inductively coupled plasma–emission spectrometry (ICP-ES) and –mass spectrometry (ICP-MS) on the <63 µm fraction, and pebble geochemical data were derived from the analysis of the bulk crushed fraction with X-ray fluorescence. Green colour intensity is a proportional scale between minimum and maximum values for each data column, except for the values in white text as they are the highest value outliers excluded from the green colour classification for clarity. In the two lower sets of rows, red indicates the high values and blue indicates the low values for each element. Abbreviations: Ccp, chalcopyrite; PP, Paleoproterozoic; Py, pyrite; VG, visible gold.

| Medium | VG (total grains) | Au (ppb) | Ccp (%) | Py (%) | SO₂ (%) | SiO₂ (%) | Ca (%) | Mg (%) | Sr (%) | Fe (%) | Cr (%) | V (%) | Ti (%) | Ni (%) | Pb (%) | Cu (%) | Zn (%) | U (%) | La (%) | P (%) |
|--------|------------------|----------|---------|--------|---------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| **Characteristic lithology group** | | | | | | | | | | | | | | | | | | | | |
| Archean mafic-ultramafic rocks | 1.0 | 0.6 | 0.00 | 0.57 | 0.046 | 58 | 0.66 | 1.1 | 28 | 3.6 | 46 | 83 | 0.19 | 32 | 9 | 46 | 68 | 3.9 | 52 | 0.15 |
| Archean to PP metasedimentary rocks | 2.2 | 2.1 | 0.00 | 0.22 | 0.017 | 65 | 0.60 | 1.0 | 11 | 2.3 | 70 | 39 | 0.12 | 37 | 14 | 32 | 51 | 2.3 | 44 | 0.07 |
| **Till** | | | | | | | | | | | | | | | | | | | | |
| Felsic gneiss and granite | 0.1 | 0.5 | 0.01 | 0.08 | 0.041 | 64 | 0.29 | 0.6 | 10 | 1.9 | 28 | 29 | 0.11 | 18 | 8 | 12 | 40 | 2.5 | 42 | 0.08 |
| Fury and Hecla Group sedimentary rocks | 0.5 | 1.0 | 0.02 | 0.35 | 0.013 | 80 | 0.09 | 0.3 | 13 | 1.6 | 25 | 23 | 0.03 | 19 | 4 | 17 | 14 | 1.2 | 17 | 0.03 |
| Felsic gneiss and granite / Paleozoic carbonate rocks | 0.0 | 0.5 | 0.00 | 32 | 0.093 | 30 | 11 | 6.6 | 38 | 1.5 | 32 | 26 | 0.07 | 19 | 8 | 15 | 24 | 0.6 | 24 | 0.04 |
| **Lithology** | | | | | | | | | | | | | | | | | | | | |
| Mafic-ultramafic rocks | 0.24 | 0.4 | 7.5 | 5.2 | 85.0 | 128.5 | 0.35 | 81 | 42 | 73 | 44 | 6.5 | 49 | 0.022 |
| Granodiorite | 0.44 | 0.3 | 26.0 | 1.3 | <0.1 | 0.10 | <1 | 127 | 9 | 32 | 7.0 | 31 | 0.018 |
| Hornblende syenite | 0.38 | 0.4 | 24.0 | 2.3 | <0.1 | 0.90 | 13 | 136 | 20 | 36 | 7.0 | 44 | 0.026 |
| Gneiss | 0.60 | 0.4 | 20.5 | 2.0 | <0.1 | 0.14 | 16 | 205 | 14 | 44 | 4.5 | 12 | 0.025 |
| Vein and pegmatite | 0.13 | 0.0 | 14.5 | 1.1 | <0.1 | 0.03 | <1 | 46 | 10 | 11 | 4.5 | 19 | 0.026 |
| Granite and gneissic rocks (average) | 0.39 | 0.3 | 21.3 | 1.7 | <0.1 | 0.12 | 7 | 128 | 13 | 31 | 5.8 | 26 | 0.021 |
| Purple sandstone and siltstone | 0.01 | 0.3 | 3.5 | 1.6 | <0.1 | 0.12 | 7 | 56 | 10 | 6 | 4.5 | 33 | 0.023 |
| Oxidized conglomeratic sandstone | 0.02 | 0.4 | <1 | 0.7 | <0.1 | 0.06 | <1 | 47 | 4 | 4 | 3.0 | 34 | 0.022 |
| Oxidized quartz arenite | 0.03 | 0.3 | <1 | 0.7 | <0.1 | 0.03 | <1 | 55 | <0.1 | 3 | 5.0 | 31 | 0.022 |
| Fury and Hecla Group sedimentary rocks (average) | 0.02 | 0.34 | 1.4 | 0.99 | <0.1 | 0.07 | 2.33 | 46.38 | 4.50 | 4.33 | 4.17 | 32.50 | 0.022 |
| **Characteristic lithology group, versus felsic gneiss and granite** | | | | | | | | | | | | | | | | | | | | |
| Till | Archean mafic-ultramafic rocks | 2.28 | 1.71 | 2.87 | 1.86 | 1.67 | 2.84 | 1.74 | 1.82 | 1.13 | 4.00 | 1.69 | 1.59 | 1.23 | 1.77 |
| Fury and Hecla Group sedimentary rocks | 0.32 | 0.42 | 1.37 | 0.85 | 0.91 | 0.79 | 0.29 | 1.06 | 0.47 | 1.46 | 0.34 | 0.48 | 0.40 | 0.41 |
| **Lithology, versus granite and gneissic rocks (average)** | | | | | | | | | | | | | | | | | | | | |
| Pebbles | Mafic-ultramafic rocks | 0.63 | 1.50 | 0.35 | 3.09 | High | High | 3.02 | 11.37 | 0.33 | 5.58 | 1.44 | 1.13 | 1.84 | 1.00 |
| Fury and Hecla Group sedimentary rocks (average) | 0.05 | 1.20 | 0.06 | 0.59 | Low | Low | 0.58 | 0.33 | 0.36 | 0.35 | 0.14 | 0.72 | 1.23 | 1.04 |
The Archean mafic–ultramafic rocks till group is enriched in several elements (Ca, Mg, Sr, Fe, Cr, V, Ti, Ni, Pb, Cu, Zn, U, La, P) relative to other samples in the study area (Table 2). Background concentration of pyrite in this group is high (0.57% of the 0.25–0.5 mm heavy mineral concentrate). The sand content of this group is similar to the other groups (72.6%), but clay content is the highest (6.8%) of the four noncarbonate groups listed in Table 1. This pattern probably indicates that the terminal grade size of mafic–ultramafic minerals is smaller relative to quartz and feldspar, which are typically more abundant in the rock types that comprise the other four till groups. An alternate explanation would be that chemical weathering was more prevalent in the area of the mafic–ultramafic rocks and therefore generated more clay-size minerals for incorporation into the local till. The average colour of the mafic–ultramafic till is light yellow-olive brown.

In the Archean to PP metasedimentary rocks till group, the geochemical values for most elements are in-between the mafic–ultramafic rocks till group and felsic gneiss and granite till group (Table 2). This could be explained by the presence of mafic–ultramafic rocks within an area that has been chiefly mapped as metasedimentary rocks, or by the geochemistry of the metasedimentary rocks themselves. The SiO2 content of this group is slightly higher (65%) than for the felsic gneiss and granite (64%) group and significantly higher than the mafic–ultramafic rocks group (58%; Table 2). The average colour of the till in the Archean to PP group is light grey-brown.

The felsic gneiss and granite till group has the highest sand content (78%) and a general brown colour. Apatite and P concentrations are generally spatially similar and apatite seems to be equally distributed among all Archean and PP rocks till samples. As shown in Table 2, for all listed comparable elements (Ca, Mg, Sr, Fe, Cr, V, Ti, Ni, Pb, Cu, Zn, U, La, P), the average elemental ratios between the mafic–ultramafic till group and the felsic gneiss and granite till group are quite high in the till <63 µm fraction (average ratio = 2.0). The average elemental ratio between the mafic–ultramafic pebbles (mostly gabbro from dykes) and granite and gneissic rock crushed pebbles is also quite high (average ratio = 2.6).

The Fury and Hecla Group sedimentary rocks till group is generally light reddish-brown. The SiO2 content is the highest (80%; Table 2) of all groups and linked with the preponderance of quartz arenite in the bedrock. Semiqualitative XRF analysis of the pebbles confirmed the prevalence of Si in the Fury and Hecla Group pebble fraction. For the Fury and Hecla Group, the ratio of selected elements (Ca, Mg, Sr, Fe, Cr, V, Ti, Ni, Pb, Cu, Zn, U, La, P) versus the felsic gneiss and granite average 0.68 in the till <63 µm fractions and 0.56 for the crushed pebbles (Table 2). Although the absolute concentrations are not to be compared directly between the till <63 µm fraction analyzed by the partial method of aqua-regia digestion followed by ICP-MS or ICP-ES and the crushed pebbles (bulk fraction) analyzed by the whole rock XRF method, the values of relative ratios are consistent with the pebble lithological counts found in this region (see Tremblay and Godbout, 2018; Tremblay et al., 2020).

The felsic gneiss and granite / Paleozoic carbonate rocks till group is a mix of both rock types (see Figure 2 in Tremblay and Godbout, 2018, and Tremblay et al., 2020). The SiO2 content of this group is slightly higher (65%) than for the mafic–ultramafic rocks till group (64%) group and significantly higher than the mafic–ultramafic rocks group (58%; Table 2). The average colour of the till in the Archean to PP group is light grey-brown.

**Economic considerations**

The results and interpretation of till sedimentology, geochemistry and heavy mineral data can be used for mineral exploration, potential development of natural resources and infrastructure, and environmental geochemical studies. Regionally elevated values in certain elements are indicative of a potential for mineral exploration. The Archean–PP supracrustal rocks (mafic–ultramafic and metasedimentary rocks) have elevated background levels in base-metal elements such as Ni, Cu and Zn. The highest background Au and gold grains values are found in metasedimentary rocks, but no high grain counts are reported.

About 45 km up-ice from where the erratic clast of massive hematitic (specularite) banded iron formation was found in surficial sediments (Figure 2f; Tremblay and Godbout, 2018), a BIF-bearing supracrustal belt was discovered by Lebeau et al. (2020), with a minimum apparent thickness of 300 m and possible extension over 15 km, interpreted from an aeromagnetic anomaly. The exposed BIF sequence displays both hematite (specularite) and magnetite contained in massive, sulphide-bearing and silicate facies. A glacial dispersal train from this BIF-bearing supracrustal belt highlighted by <2 µm till data, may be indicative of locally anomalous values in mafic elements (Figure 2f, h).

The highest U values detected (up to 20 ppm; Figure 2e) are spatially linked to granitic rocks and, secondarily, mafic rocks and felsic gneiss and are generally correlated with known U mineralization in bedrock (NunavutGeoscience.ca, 2015).
Other than two sites with Cr-diopside grains (de Kemp and Scott, 1998), no KIMs were found in the NFHMC samples (Figure 2l). The sampling grid is, however, widely spaced (about 15 km between sites) and the possibility of undetected narrow till dispersal trains of KIMs may exist between sample sites. The Cr-diopside grains might have been transported from a potentially considerable distance to the northeast due to the presence of an ice stream in the region (Bernier Bay ice stream).

Corundum in till samples 18TIAT-172 and 18TIAT-173 are white and translucent (Figure 3) and relatively abundant, with an average count of 125 grains (17%) in the 0.25–0.5 mm NFHMC fraction (Figure 2m). The occurrence of numerous corundum grains in two adjacent till samples (15 km apart) indicates that the potential source area might be fairly large. The angular shape of the grains, and the association with monazite and barite grains in NFHMC, suggests an origin of crystalline metamorphic or igneous rocks. The source of the corundum might be the granite (syenite) in the southern part of the exposures of this rock type near the Fury and Hecla Group contact, which is up-ice (north) of the two corundum-bearing till samples. Additionally, in the region surrounding these till samples, potential exists for a preferential accumulation of corundum grains in both fluvial and glaciﬂuvial sedimentary settings due to their high density (4.0 g/cm³). The economic potential of the corundum as gemstones depends on whether their colour and saturation could be enhanced by thermal treatment (Nassau, 1981; Emmett and Douthit, 1993; Shor and Weldon, 2009), as well as the size of the crystals in the host-rock. New till samples were taken in 2019 to assess the glacial transport and provenance of the corundum and additional analysis will be performed to further detail the source of the corundum grains.

Conclusions

Geochemical, sedimentological and heavy mineral data from till and the geochemical data from pebbles were compiled, mapped and classified. These data were used to classify the till samples into five groups that reflect the characteristic influence of different rock types. Ratios between the main lithology types (mafic–ultramafic or metasedimentary rocks groups) and the felsic gneiss and granite group were used to compare results between different analytical techniques. The CIELAB colour classification system is an efficient tool to distinguish between different till groups. The region displays significant mineral exploration potential for uranium, iron and diamonds (two sites with kimberlite indicator minerals). A minor and still uncertain potential is also highlighted for abundant white and clear grains of corundum. Relatively high background values of base metals (Ni, Cu, Zn) were found in the Archean mafic–ultramafic rocks till group, and gold grains (and Au) in the Archean to Paleoproterozoic metasedimentary rocks till group.

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