PERMAFROST-AFFECTED SOILS IN THE PANGNIRTUNG PASS AREA, BAFFIN ISLAND, CANADA

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Abstract

Soils were studied along Pangnirtung Pass on Cumberland Peninsula in the southeastern part of Baffin Island, N.W.T. The soils studied are dominantly Cryosols. They have developed on till, eolian, fluvial and colluvial materials, and have active layer depths between 60 and 150 cm. Turbic Cryosols have developed primarily on till. These soils (Orthic Dystric Turbic Cryosols and Regosolic Turbic Cryosols) are acidic and have a loamy sand texture. Static Cryosols (Orthic Dystric Static Cryosols, Regosolic Static Cryosols, Brunisolic Dystric Static Cryosols and Gleysolic Static Cryosols), which are found on different parent materials, are also acidic, and in most cases they have a sandy or coarse sandy texture. The deepest solum development is found in Brunisolic Dystric Static Cryosols developed on well-drained eolian materials. Gleysolic Static Cryosols have developed on poorly drained locations. In addition, small areas of Organic Cryosols occur in the northern part of Pangnirtung Pass.

Introduction

Permafrost-affected soils were studied in the Auyuittuq National Park Reserve on Baffin Island. The soils, which are dominantly Cryosols, are found primarily along the lower slopes and the valley floor of Pangnirtung Pass on Cumberland Peninsula. Bockheim (1979) provided information both on the major soils of south-western Cumberland Peninsula and on the use of soils as an indicator for determining the relative age of glacial and marine sediments. Soil studies by Blouin et al. (1975), Birkeland (1978), Evans and Cameron (1979) and Locke (1985) focussed on dating the parent material. Tarnocai and Veldhuis (1998) mapped the soils of Pangnirtung Pass and characterized the soils along the full extent of the pass. In this paper the characteristics, distribution and genesis of Cryosols (permafrost-affected soils) occurring in the study area are discussed on the basis of four selected soil profiles.

Study area

Auyuittuq National Park Reserve is located on Cumberland Peninsula in the southeastern part of Baffin Island (Figure 1). The bedrock in this area is of Precambrian age, with the dominant rocks being granites, granitic gneisses and granitic para-gneisses. The area is a remnant of an old peneplain that underwent two successive uplifts accompanied by numerous dislocations and fractures during the Tertiary (Taylor, 1981). The ensuing glacial, fluvial, eolian and mass-wasting processes further reshaped the surfaces of the park (Thompson, 1954). The study area encompasses

Figure 1. Location of the study area at Pangnirtung Pass, Baffin Island, N.W.T., Canada.
Pangnirtung Pass, from Overlord in the south to North Pangnirtung Fiord in the north (Figure 1). This pass is a narrow, boxed-in corridor that begins at sea level and rises to about 350 m at Summit Lake. The vertical cliffs rise abruptly to approximately 1000 m, although in some cases they can reach 1500 m. The only transitions between the vertical cliffs and the valley floor are the narrow talus slopes and debris cones. The great majority of glacial deposits within the Auyuittuq National Park Reserve are of Wisconsinan age. Deglaciation occurred about 8000 years ago (Andrews, 1989).

The study area lies within the Oceanic High Arctic Ecoclimatic Region (Ecoregions Working Group, 1989). The average monthly temperatures at the Pangnirtung meteorological station (Yorke, 1972 cited in Canadian Parks Service, 1989) vary between 7.8°C (July) and -27.0°C (February), with extreme minimum and maximum temperatures of 26.7°C and -43.3°C. The mean annual air temperature is -9.8°C. The total annual precipitation is 395 mm, of which 174 mm is rain and 221 mm is snow. One of the most important aspects of the climate is its variability from one area to another. The sizes and orientations of the valleys and the closeness to ice bodies or open water can greatly influence the local climate. The topography, which can result in the funneling of air in certain fixed directions, can cause extreme wind speeds and increased wind chill (Maxwell, 1980).

Methods

During June and July of 1995 and 1996, soils were described and sampled at the Owl River, Rundle and Overlord study sites (for locations, see Table 1). Soil samples were analyzed in the Agriculture and Agri-Food Canada (Ottawa, Canada) laboratory and at the Institute of Landscape Ecology (Muenster, Germany). After air-drying, soil samples were sieved (<2 mm) and particle size analysis was done using the pipette method (Carter, 1993). Soil pH was measured in 0.01M calcium chloride with a glass electrode. Elemental analyzers (LECO, CARLO ERBA NA 1500) were used for organic carbon and total nitrogen. In order to determine the different forms of iron and aluminum, the dithionite-citrate, acid ammonium oxalate and sodium pyrophosphate methods were used (Carter, 1993). The soil horizon designations and soil classification are according to the Canadian System of Soil Classification (Soil Classification Working Group, 1998). The U.S. Soil Taxonomy is also given (USDA Soil Survey Staff, 1998).

Results

Two types of moraines were identified in the study area, those produced by late Wisconsin glaciation and those produced by neoglacialation. In addition to till, other major parent materials are glaciofluvial and eolian material, and colluvium. Permafrost is continuous and the active layer is generally 60 to 150 cm thick. Patterned ground occurs throughout the study area.
area, primarily in the form of nonsorted circles and ice-wedge polygons, with rare occurrences of earth hummocks (Washburn, 1980). Such patterned ground is much more common in the northern part of the study area than in the south. The vegetation cover is continuous except on active eolian and fluvial surfaces and varies from dwarf shrub-sedge-moss-lichen tundra vegetation on the southern inshore regions to stony sedge-moss-lichen tundra on the highlands and northern fiords (Porsild, 1957).

In the northern part of Pangnirtung Pass, where the valley bottom is very wide (about 3.5 km), Owl River was one of the main study sites. Although Orthic Dystric Static Cryosols are the dominant soils at this study site, Orthic Dystric Turbic Cryosols (Figure 2; Tables 1 and 2), Regosolic Turbic Cryosols (Tables 1 and 2), and Regosolic Static Cryosols also occur. In most cases, the permafrost table is about 80 cm deep. Brunisols have developed in those areas where permafrost occurs at depths greater than 1 m. The pH of the Cryosols studied in the northern part increases from pH 4.5 in the topsoil to about 5.0 in the C horizon, and the texture varies between sandy loam and sand (Table 3). In all cases, the organic carbon content of the B and C horizons is very low compared to that of the carbon-enriched A horizons. Most of the extractable iron and aluminum values for the two soils sampled at this site fall within the mid-range of the values for the four soils.

![Figure 2. Soil profile at the Owl River 1 study site.](image-url)

### Table 2. Pedon descriptions

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Thickness (cm)</th>
<th>Colour</th>
<th>Coarse fragm. (%)</th>
<th>Structure(^1)</th>
<th>Consistency(^2)</th>
<th>Horizon boundary(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahy</td>
<td>1–30</td>
<td>10 YR 3/3</td>
<td>10</td>
<td>we, fi, gr</td>
<td>ns, l, np</td>
<td>gr, wa</td>
</tr>
<tr>
<td>Bmy</td>
<td>2–38</td>
<td>10 YR 3/4</td>
<td>10</td>
<td>we, fi, gr</td>
<td>ns, l, np</td>
<td>gr, wa</td>
</tr>
<tr>
<td>Bcy</td>
<td>12–25</td>
<td>10 YR 4/4</td>
<td>10</td>
<td>sg, sl</td>
<td>ns, l, np</td>
<td>gr, wa</td>
</tr>
<tr>
<td>Cy</td>
<td>25–60</td>
<td>10 YR 5/2</td>
<td>10</td>
<td>sg, sl</td>
<td>ns, l, np</td>
<td>gr, wa</td>
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</tbody>
</table>

**Owl River 2**

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Thickness (cm)</th>
<th>Colour</th>
<th>Coarse fragm. (%)</th>
<th>Structure(^1)</th>
<th>Consistency(^2)</th>
<th>Horizon boundary(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahy</td>
<td>2–25</td>
<td>10 YR 2/2</td>
<td>-</td>
<td>we, fi-m, gr</td>
<td>ns, l, np</td>
<td>cl, ir</td>
</tr>
<tr>
<td>Cy</td>
<td>10–40</td>
<td>2.5 Y 4/2</td>
<td>-</td>
<td>sg</td>
<td>ns, l, np</td>
<td>gr, ir</td>
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**Rundle**

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Thickness (cm)</th>
<th>Colour</th>
<th>Coarse fragm. (%)</th>
<th>Structure(^1)</th>
<th>Consistency(^2)</th>
<th>Horizon boundary(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ah</td>
<td>5–11</td>
<td>7.5 YR 4/4</td>
<td>-</td>
<td>we, fi-m, gr</td>
<td>ns, vf, s, np</td>
<td>cl, wa</td>
</tr>
<tr>
<td>Bm</td>
<td>12–17</td>
<td>7.5 YR 3/3</td>
<td>-</td>
<td>we, fi-m, gr</td>
<td>ns, vf, s, np</td>
<td>cl, ir</td>
</tr>
<tr>
<td>Bhf</td>
<td>7–15</td>
<td>7.5 YR 3/4</td>
<td>-</td>
<td>we, fi-m, gr</td>
<td>ns, vf, s, np</td>
<td>cl, ir</td>
</tr>
<tr>
<td>Cg</td>
<td>19–25</td>
<td>2.5 Y 3/2</td>
<td>-</td>
<td>sg, sl</td>
<td>ns, vf, s, np</td>
<td>ab, sm</td>
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</tbody>
</table>

**Overlord**

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Thickness (cm)</th>
<th>Colour</th>
<th>Coarse fragm. (%)</th>
<th>Structure(^1)</th>
<th>Consistency(^2)</th>
<th>Horizon boundary(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ah</td>
<td>1–3</td>
<td>10 YR 3/2</td>
<td>-</td>
<td>we, fi-m, gr</td>
<td>ns, l, np</td>
<td>gr, wa</td>
</tr>
<tr>
<td>C</td>
<td>20–26</td>
<td>10 YR 3/1</td>
<td>10</td>
<td>we, fi-m, gr</td>
<td>ns, l, np</td>
<td>gr, wa</td>
</tr>
</tbody>
</table>

\(^1\) we–weak, fi–fine, gr–granular, sg–single grain, sl–structureless, fi–m–fine to medium  
\(^2\) ns–nonsticky, l–loose, np–nonplastic, vf–very friable, s–soft  
\(^3\) gr–gradual, wa–wavy, cl–clear, ir–irregular, ab–abrupt, sm–smooth
studied, with the highest and lowest values occurring in soils in the southern part of the pass. In addition to mineral Cryosols, poorly drained Terric Organic Cryosols were found in a peatland area at June Valley.

The soils of the southern part of Pangnirtung Pass, where the valley bottom is narrowest (about 1.0 km), are represented by a Gleysolic Static Cryosol at the Rundle study site (Tables 1 and 2) and a Regosolic Static Cryosol at the Overlord study site (Tables 1 and 2). In these soil profiles permafrost occurs nearer to the surface than in the profiles investigated at Owl River. The pH of the Gleysolic Static Cryosol that developed on eolian sand at the Rundle study site is almost the same in all horizons (Table 3). The soil organic matter content is relatively high, even in the C horizon. Extractable iron and aluminum are also high, especially in the Bhf horizon. The Regosolic Static Cryosol at the Overlord study site developed on loam-textured colluvial material. There is almost no change in pH with depth, and the soil organic matter content of the C horizon is also relatively high. The extractable iron and aluminum values, however, are the lowest of all profiles.

**Discussion**

The soils of Pangnirtung Pass are strongly affected by permafrost with the result that Cryosols are the dominant soils. Brunisols and Regosols occur in only a few parts of the study area. Mineral Cryosols cover most of the pass, with minor occurrences of Organic Cryosols. In most cases the permafrost table occurs within 1 m of the surface. Bockheim (1979) did not find ice-cemented permafrost within the 1 m control section on well-drained sites on the Cumberland Peninsula. Because of the gravelly and coarse sandy parent material of the glaciofluvial and till deposits, the drainage is well to imperfect in most cases, but sometimes even rapid. In the profiles presented, the amount of sand in the C horizons is generally more than 80%. Since only small areas, such as the June Valley study site, are poorly drained, there are limited possibilities for organic soils to develop. The wide distribution of coarse parent materials is a major factor in the greater extent of Static Cryosols compared to Turbic Cryosols. Bockheim (1979) and Evans and Cameron (1979) emphasized the low clay content of the soils on Baffin Island, indicating that little chemical weathering has occurred. Similarly, the clay contents of the soil profiles in this study range from only 0.6% to 3.4%.

The southern part of Pangnirtung Pass is geomorphologically still a very active area (e.g., active glaciation, landslides and erosion) with young soils (Birkeland, 1978; Bockheim, 1979). The Regosolic Static Cryosol at the Overlord study site is an example of a relatively young (Late Holocene) soil with a low concentration of pedogenic oxides. Evans and Cameron (1979) have also found such low amounts of Fe and Al oxides on Baffin Island, in the area near Broughton Island. Because of the colluvial material, the properties of the soil horizons of the Regosolic Static Cryosol do not vary greatly. Unlike previous soil studies, a Gleysolic Static Cryosol...
with typical iron and aluminum enrichment was found at the Rundle study site. In addition, because of poor drainage conditions and a vegetation cover of low shrubs, lichens and grasses, the organic matter content of the A horizon is high.

The parent material at the Owl River study site is a till that is, in some cases, covered by eolian or fluvial material. The distribution of the soils at this site reflects the marked variation of drainage conditions (well to imperfect) and properties of the parent materials. Soils on moist areas of this site, especially those lacking veneers or those with only fluvial veneers, are associated with cryoturbation and with considerable organic matter accumulation in the topsoil. Some of these soils have no B horizon development (Regosolic Turbic Cryosol) while in others a B horizon has developed, primarily in the fluvial veneer (Orthic Dystric Turbic Cryosol). On other portions of this site, where various thicknesses of eolian or fluvial veneer occur, the soils, especially those with well-drained conditions, are noncryoturbated (Static Cryosol). The pH of these well-drained soils is similar to that of soils on imperfectly-drained sites, but they have a much lower organic carbon content in the topsoil. Although permafrost is present on these well-drained sites, the genesis of the soils is associated with brunification processes. Thus, all well-drained soils at the Owl River study site have brownish B horizons. This B horizon development is stronger and thicker in the Brunisolic Dystric Static Cryosols than in the Orthic Dystric Static Cryosols.

Conclusions

- The soils of Pangnirtung Pass are dominated by Cryosols whose pedogenesis is strongly affected by permafrost.

- All soils in the study area are acid (pH 4.5 -5.0), have sand to sandy loam textures, and contain low amounts of clay and extractable iron and aluminum.

- Soils of the southern part of the pass are generally young (Regosolic Static Cryosols), primarily because of active geomorphological processes such as glaciation, landslides and erosion.

- Soils of the northern part of the pass are more strongly developed than those of the southern part. As a result, Orthic Dystric Turbic Cryosols, are common. These soils are usually associated with patterned ground.

- Minor amounts of shallow Organic Cryosols occur in the northern part of the pass. These soils are usually associated with ice-wedge polygons.

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References


