Geomorphology, Vegetation Succession, Soil Characteristics and Permafrost in Retrogressive Thaw Slumps near Mayo, Yukon Territory

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(Received 15 April 1988; accepted in revised form 13 September 1988)

INTRODUCTION

The management of thaw-sensitive permafrost terrain is one of the challenges faced by industrial development in the North. Terrain disturbance may alter the ground thermal regime, melt ground ice, and lead to soil subsidence or accelerated erosion (e.g., Mackay, 1970; McRoberts and Morgenstern, 1974). Such conditions may also be created by natural events, for instance forest fires or coastal erosion (e.g., Johnson and Viereck, 1983; Mackay, 1986; Walker, 1983).

Retrogressive thaw slumps are among the most active geomorphological features in permafrost terrain. Also termed ground-ice slumps (Mackay, 1966), thermocirques (Czudek and Demek, 1970), tundra mudflows (Lamonthe and St-Onge, 1961), retrogressive flow slides (Hughes, 1972), bi-modal flows (McRoberts and Morgenstern, 1974), and so forth, they are initiated after ice-rich soil is exposed by disturbance. They consist of a steep, ice-rich headwall and a mudflow of gentler gradient downslope (see Lewkowicz, 1987a, and Mackay, 1978, for details). They are commonly found on the banks of northern rivers and lakes and along the arctic coast, especially where undercutting is active. Some have been initiated by terrain disturbance associated with the use of seismic lines and by road construction (Bliss and Weia, 1971; Lambert, 1972).

The slumps stabilize when ground ice exposed by the retreating headwall has been completely thawed or is covered by debris. Stabilized-sluump floors therefore provide an environment where the recovery and re-establishment of natural conditions after disturbance may be studied. Although there is a general awareness of the need to minimize disturbance to ice-rich terrain, there is relatively little documentation of the recovery and re-establishment of equilibrium ground conditions, or of vegetation successional paths following disturbances such as in these slumps (Chapin and Shaver, 1981; Ebersole and Webber, 1983; Johnson and Viereck, 1983; Lambert, 1972; Vierette and Schandelmeier, 1980; Walker et al., 1987).

In this paper we present results from field studies conducted since 1982 concerning the development of thaw slumps in the Mayo area, central Yukon Territory. We document: (1) the continuing development of two thaw slumps in the study area since 1949; (2) the vegetation succession in the floors of three thaw slumps; and (3) short-term soil development on surfaces of various ages in the slumps. We discuss the time required to re-establish the dominant vegetation on disturbed surfaces in the study area and to initiate pedogenic processes in fresh deposits, and note the nature of permafrost aggradation in a stabilized feature.

SITE CONDITIONS

Mayo (63°35′N, 135°35′W) has a mean annual air temperature of −4.0°C (Atmospheric Environment Service,

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1982) and is in the widespread permafrost zone (Brown, 1978; Fig. 1). The village of Mayo lies in boreal forest of the Stewart River Valley, about 20 km east of (within) the late-Wisconsinan, McConnell glacial limit (Bostock, 1966; Hughes, 1983).

![Permafrost map of the Yukon Territory and western Northwest Territories (after Brown, 1978).](image)

**FIG. 1.** Permafrost map of the Yukon Territory and western Northwest Territories (after Brown, 1978).

The thaw slumps are located in a body of ice-rich glaciolacustrine sediments 3 km southeast of Mayo, where there are several thermokarst lakes (Fig. 2). The ground-ice stratigraphy exposed in one thaw slump headwall is discussed in detail by Burn et al. (1986). Records from over 30 holes drilled to 5 m depth at undisturbed sites in the study area indicate that the ground ice exposed in the headwall is representative of these ice-rich sediments. Apart from the active layer, over 60% by volume of the upper 8 m of the sediments consists of ice (Fig. 3).

There are three thaw slumps in the study area; all were initiated after riverbank erosion led to exposure of ice-rich sediment. Two of the slumps were initiated during the last 40 years and are still active. The third has been stable since at least 1949, throughout the period for which aerial photographs are available.

In the undisturbed forest, the glaciolacustrine silty clay (on average 1% sand, 57% silt, 42% clay) is covered by organic horizons up to 40 cm thick. The active-layer depth in September at forest sites varies from 35 cm to about 100 cm, depending on organic layer thickness, site wetness, and so on. The surface 10 cm of mineral soil is slightly acidic (pH = 6), indicating the mild leaching regime characteristic of central Yukon (cf. Rostad et al., 1977), where mean June-September precipitation is 159 mm (Atmospheric Environment Service, 1982). The surface mineral horizons exhibit a distinct fine subangular blocky or granular structure as a result of ice segregation during the winter and wetting and drying in summer. The most common soil in Stewart Valley is the Orthic Eutric Brunisol (Rostad et al., 1977).

The dominant tree species in the study area is white spruce (Picea glauca), but black spruce (P. mariana) and paper birch (Betula papyrifera) are sparsely distributed throughout the forest. Tree-ring counts from numerous increment borings indicate that trees in the undisturbed forest range from saplings up to 150 years in age. Salix glauca forms clumps in the understory and, with S. arbusculoides, is a common shrub. Shepherdia canadensis, Vaccinium vitis-idaea, Ledum decumbens, Arctostaphylos rubra, Linnaea borealis and Geocaulon lividum are common sub-shrubs. Herbs are dominated by Hedysarum boreale. Several species of orchid

![Oblique aerial photograph of the study area, with the two active thaw slumps (1 and 2) in the foreground and the stabilized slump (3) on the right, 17 June 1982.](image)

**FIG. 2.** Oblique aerial photograph of the study area, with the two active thaw slumps (1 and 2) in the foreground and the stabilized slump (3) on the right, 17 June 1982.

![Headwall of thaw slump 1, Mayo study area, 12 January 1986.](image)

**FIG. 3.** Headwall of thaw slump 1, Mayo study area, 12 January 1986.
and **Moneses unijlora** can be found in closed parts of the forest. The ground cover is dominated by feathermosses, notably **Hylomium splendens**. The white spruce/feathermoss forest type is typical of the warmer soils in valley-bottom locations in the northern boreal forest (Bliss, 1978; Viereck and Schandelmieier, 1980).

According to the native population of Mayo, there have been no fires in the study area during the past 80 years. However, Burn and Smith (1988) suggest that the thermokarst lakes near the thaw slumps formed approximately 130 years ago as a result of forest fire. Charred wood from the forest floor with a radiocarbon age of 150 ± 80 years BP (BGS-846) also suggests that the area was burned early in the last century. In addition, the transitional replacement of feathermosses by *Sphagnum* spp. throughout the boreal forest zone is thought to take 100-200 years after disturbance (Foster, 1984; Van Cleeve and Viereck, 1981). Since feathermosses still dominate the ground cover of the study area, it is likely the most recent fire occurred before 1850.

**FIELD AND LABORATORY METHODS**

The development of thaw slumps in the study area has been traced for the period 1949-76 from aerial photographs taken in 1949, '50, '61, '65, '70 and '76. In addition, plane-table surveys were made in the summers of '82, '83, '84, '85 and '87. More detailed investigations of the results of headwall retreat were made on a daily and weekly basis during the summer of 1982, when twice-daily measurements of ablation were made with white dowel rods placed in holes 30 cm deep drilled into frozen soil or ice. The dowels were frozen in the holes less than three hours after installation (Burn, 1982).

Field studies of vegetation distribution and characteristics of the soil in the slumps were conducted during July 1987. Vegetation unit boundaries in the largest active thaw slump were mapped by plane table, with five vegetation units defined in the slump floor, each being differentiated by its visual homogeneity. Two further units were defined as the communities in the floor of the stabilized slump and in the undisturbed forest respectively. In addition, two final units were identified but are not considered in detail: (1) the uncolonized soil slurry, which had only recently slumped; and (2) an *Equisetum* marshland, fed by headwall meltwater. The marshland unit was assumed to be in equilibrium with present moisture conditions and may continue succession after the slump has stabilized.

Plant specimens were collected during field mapping, and initial species lists were constructed for each unit. Seed plants and trees were identified in the field using Welsh (1974) and Viereck and Little (1972) respectively. Cryptograms were identified using Hale (1979), Lawton (1971) and Thomson (1984) at the University of British Columbia herbarium. Full scientific names of the species are presented in the Appendix. The vegetation characteristics of each unit were determined in four randomly selected sample plots. The sample plot size used in each unit was defined by the Nested-plot technique, and complete species lists and cover-abundance estimates were generated using the Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg, 1974:48, 59).

Vegetation remnants from the original surface in the youngest colonized unit were ignored, and samples were confined to the disturbed surface between remnant islands in order to represent clearly the nature of initial colonization. The sample plot size in this unit was 1 m² (see Table 1). In the older units, where the vegetation islands were less distinct, the species on the islands were included in the sampling. As a result, these vegetation units required larger sample plots (up to 256 m²). Raw cover abundance data from the four sample plots in each unit were averaged qualitatively to produce a single value for each species. Species were placed in partial tables and sorted to emphasize the change in species composition with time.

**TABLE 1. Age of vegetation units and area of sample plots, Mayo thaw slumps**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Sample-plot size (m²)</th>
<th># of trees sampled</th>
<th>Age range from trees (yrs)</th>
<th>Age range from aerial photographs and ground surveys (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Active</td>
<td>0.25</td>
<td>-</td>
<td>-</td>
<td>0-1</td>
</tr>
<tr>
<td>2. Funaria</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1-2</td>
</tr>
<tr>
<td>3. Senecio</td>
<td>128</td>
<td>5</td>
<td>2.5</td>
<td>3-8</td>
</tr>
<tr>
<td>4. Equisetum/</td>
<td>256</td>
<td>4</td>
<td>6.9</td>
<td>4-10</td>
</tr>
<tr>
<td>5. Equisetum/</td>
<td>64</td>
<td>-</td>
<td>-</td>
<td>6-15</td>
</tr>
<tr>
<td>6. Salix/Betula</td>
<td>16</td>
<td>3</td>
<td>12-15</td>
<td>10-21</td>
</tr>
<tr>
<td>7. Picea/Betula</td>
<td>256</td>
<td>3</td>
<td>43</td>
<td>&gt; 37</td>
</tr>
<tr>
<td>8. Picea</td>
<td>256</td>
<td>35</td>
<td>90-150</td>
<td>-</td>
</tr>
</tbody>
</table>

*Years before 1986.*

The ages of vegetation units were determined from aerial photographs, from field observations made since 1982 and by examination of the growth rings of small trees that survived the fall into the slump. (The mean age and diameter of the 15 trees sampled were 37 years and 32 mm respectively.) Specimens were cut, and discs were taken from the bent portion near the base. The number of rings from the bark to the beginning of most recent reaction wood was counted with the aid of a hand lens. This was assumed to approximate the period from disturbance to the 1986 growing season. Dates of disturbance in each unit were established on the basis of at least three trees sampled per unit. The ages of the units were checked with reference to the aerial photograph record of slump development (Table 1).

In order to examine soil development in the slumps, a pit 1 m deep or to the frost table, if the unfrozen layer was less than 1 m, was dug at each sample plot. Soil profiles were examined to determine: (1) depth of litter; (2) depth to frost; (3) depth to lime (CaCO₃); and (4) depth of aggregate development in the soil. The depth of the litter horizon and the depth of aggregate development were determined by eye; the depth to the frost table was measured by probing with a steel rod; and the depth to lime was determined by dropping weak HCl on the soil. Samples were collected from the uppermost 10 cm for laboratory analyses to determine pH (in 0.01M CaCl₂) and calcium carbonate (by gravimetric method for loss of CO₂), organic carbon (by wet oxidation) and total nitrogen contents. Laboratory analyses were conducted according to McKague (1978).

Ground temperatures at depths of up to 5 m have been monitored on a monthly basis since August 1985 at several sites in the study area. The temperatures are read from ther-
mistor cables installed in one-inch PVC pipes filled with diesel oil. The thermistors (YSI 44004) were calibrated to ±0.05°C in a controlled temperature bath before installation. The thermistors are “aged” by the manufacturer, and therefore should not drift from the calibration if installed in this way. The sites were drilled and instrumented in July 1985. The soil materials and moisture contents at each site were determined from continuous-core samples obtained during drilling.

GEOMORPHOLOGY OF MAYO THAW SLUMPS

Thaw slumps are initiated when ice-rich sediment is exposed and begins to melt. Aerial photographs indicate that one (slump 1) of the two active slumps in the study area was initiated shortly before 1949, and the other (slump 2) between 1961 and 1965. Each slump consists of a near-vertical 8 m headwall, an overhanging active layer and a footslope of approximately 2°.

The headwalls of the thaw slumps face northeast and do not receive direct insulation between mid-October and mid-April, when normal air temperatures are continually below 0°C. Headwall retreat occurs only when maximum air temperatures are above 0°C, generally from mid-April to September. Detailed studies of the energetics of slump headwalls have been presented by Pufahl and Morgenstern (1980) and Lewkowicz (1986, 1987a); the latter has developed an effective technique for predicting short-term ablation from meteorological data. The following discussion is limited to a description of the gross characteristics of the development of thaw slumps near Mayo.

Short-term Ablation

Between 30 June and 9 July 1982, mean retreat rates determined with dowel rods at two sites on the slump headwall were 7.4 cm-day⁻¹ and 11.1 cm-day⁻¹. However, on 11 July, 29 cm of retreat was observed at one site during a rainstorm lasting 12 hours. The increase in retreat rate resulted primarily from rapid removal of debris that fell or accumulated on the thawing face. Acceleration of retreat during rainfall has also been noted by Lambert (1972:100).

Long-term Development

The development of the two active thaw slumps, as traced from aerial photographs and ground surveys, is presented in Figures 4 and 5. Mean headwall retreat rates of approximately 14 m-yr⁻¹ and 12 m-yr⁻¹ have been measured, since initiation, for slumps 1 and 2 respectively. At times an annual retreat of up to 16 m has been measured for slump 1 (e.g., 1985). These retreat rates are among the highest recorded in the literature for the development of such features (Table 2) and are partly due to the warm summer temperatures at Mayo (mean July air temperature is 15.2°C) and the long thaw season. Comparable retreat rates have been measured for south-facing headwalls on Banks Island, N.W.T. (Lewkowicz, 1987b). Higher values are reported from sites where both thawing and headwall undercutting are accompanied by rapid removal of slumped debris (cf. Are, 1978; Jahn, 1975:117).

Retreat rate depends not only upon atmospheric conditions, but also upon the rate availability of ice-rich material. Field measurements have indicated that the relationship be-
The following discussion describes the re-establishment of the forest community on disturbed surfaces. The vegetation succession in the thaw-slump floors is documented in Table 3, which provides a visual impression of the change in species composition with time for the various units. During the six years following disturbance, the proximity of the ablating headwall ensures that the soils remain close to saturation. Subsequently, as distance from the headwall increases, two distinct community types develop: (1) a Salix/Equisetum or Equisetum community in areas supplied by headwall meltwater; and (2) in dry areas, a successional sequence re-establishing the original forest community. The latter sequence originates with fast-growing, wind-dispersed herbs and shrubs, followed by tree saplings after 10-15 years. Thirty-five to 50 years after disturbance, a well-stocked Betula papyrifera/Picea glauca stand, with a patchy feathermoss ground cover, is established. Notes on the vegetation characteristics of the units are provided below.

**Unit 1. Active Thaw Front**

Material at the slump face collapses, destroying and burying most of the original vegetation mat. However, small islands of the vegetation mat, up to 2 m in diameter, remain to cover 5-10% of the surface. The species composition of these islands is similar to that of the forest, but many of the annual herbs do not reappear after disturbance. Some islands harbor small spruce saplings, which may be used in older units for reaction-wood dating. No vegetation covers the surface between the islands in the year of disturbance.

**TABLE 2. Measured rates of retreat of thaw-slump headwalls from various locations**

<table>
<thead>
<tr>
<th>Location</th>
<th>Rate (m·yr⁻¹)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Yakutia, U.S.S.R.</td>
<td>7-9.5</td>
<td>Are (1978)</td>
</tr>
<tr>
<td>Ellef Rigger Island, N.W.T.</td>
<td>7-10</td>
<td>Lamonthe and St-Onge (1961)</td>
</tr>
<tr>
<td>E. Banks Island, N.W.T.</td>
<td>7-10</td>
<td>French and Egginton (1973)</td>
</tr>
<tr>
<td>E. Banks Island, N.W.T.</td>
<td>6-8</td>
<td>French (1974)</td>
</tr>
<tr>
<td>S. Banks Island, N.W.T.</td>
<td>14</td>
<td>Lewkowicz (1987b)</td>
</tr>
<tr>
<td>Tuk. Peninsula, N.W.T.</td>
<td>7</td>
<td>Mackay (1986)</td>
</tr>
<tr>
<td>Garry Island, N.W.T.</td>
<td>7-2</td>
<td>Kerfoot and Mackay (1972)</td>
</tr>
<tr>
<td>Mackenzie Delta, N.W.T.</td>
<td>1.5-4.5</td>
<td>Mackay (1966)</td>
</tr>
<tr>
<td>Mayo, Yukon Territory</td>
<td>14-16</td>
<td>This paper</td>
</tr>
<tr>
<td>Colville Delta, Alaska</td>
<td>1-3</td>
<td>Walker (1983)</td>
</tr>
<tr>
<td>Macleod Point, Alaska</td>
<td>10-18</td>
<td>Black (1983)</td>
</tr>
</tbody>
</table>

**Unit 2. Funaria (1-2 years after disturbance, saturated)**

In this unit, the vascular plants Senecio congestus and Epilobium palustre and the moss Funaria hygrometrica colonize the exposed surface, although the first two species do not reach the stage of fluorescence by July. S. congestus is dominant and locally may cover the entire surface.

**Unit 3. Senecio (2-5 years after disturbance, saturated)**

In this unit, more weedy colonizers including Equisetum arvense and willow seedlings appear. Senecio congestus is well established, but faces some competition, as weed species are more diverse and Rubus ideus, Rosa acicularis, Ribes hudsonianum and Hedysarum boreale appear between the surviving islands of forest vegetation. Leptobryum pyriforme is the dominant moss.

**Unit 4. Equisetum/Salix (6-9 years after disturbance, moist)**

Senecio congestus relinquishes dominance to Equisetum arvense and Cinna latifolia, and some forest herbs return. Vegetation from the remnant islands spreads successfully onto the disturbed surface. Willows 1-2 m tall dominate the shrub layer, although spruce and birch seedlings are common. Bryum caespiticum is the dominant moss.

**Unit 5. Equisetum (6-15 years after disturbance, saturated)**

When compared to units 4 and 6, the vegetation in unit 5 illustrates the influence of saturated soil conditions on succession. Water drains from the active slump face into the unit,
maintaining saturated soil conditions. The species diversity is similar to that of adjacent units, but Equisetum arvense dominates, with 50-75% ground cover. The cover provided by the remaining species is patchy.

**Unit 6. Salix/Betula (12-15 years after disturbance, moist)**

The islands that survived disturbance cannot be distinguished in this unit. Forest species are more diverse, and the original weedy colonizers are less diverse. White spruce and paper birch seedlings and saplings are common among the willows. The shrub layer is 2-2.5 m tall.

**Unit 7. Betula/Picea (approximately 43 years after disturbance, moist)**

The species composition in this unit is similar to the undisturbed forest: all important constituents are established, although the diversity is somewhat reduced, and the moss cover is discontinuous. White spruce dominates both the canopy and shrub layers in the unit. However, while paper birch is common in the canopy, birch seedlings are scarce. This is a significant change from the Salix/Betula-dominated unit, where birch seedlings are common, and indicates that spruce should increasingly dominate the canopy, until the forest is primarily composed of this species. The canopy reaches a height of 10 m.

These observations suggest that the original forest community, although immature, may be re-established 35-50 years after disturbance. Hettinger et al. (1973:96) note that the re-establishment of the forest community following fire in the Peel-Porcupine plateau requires a similar period. It is important to recognize that soil moisture conditions may alter vegetation succession locally. The Equisetum communities, which appear at sites fed by slump meltwater, persist briefly
in the area and occupy a significant portion of the floor in the active thaw slump. At such sites, a longer period subsequent to disturbance may be required for re-establishment of the forest community. It should also be noted that a mossy litter layer, characteristic of the undisturbed forest and a critical element in the ground thermal regime, is not continuous in the Betula/Picea-dominated unit at least 43 years after disturbance.

SOIL CHARACTERISTICS

Distinct landform-soil associations have been used in central Yukon to demarcate at least three separate advances of the Cordilleran ice sheet into Beringia during the Pleistocene (e.g., Bostock, 1966; Tarnocai et al., 1985). Soils of the unglaciated area of central Yukon west of the Pleistocene glacial maximum are among the deepest and most intensely weathered in Canada, while those within the limits of McConnell glaciation are relatively undeveloped (Foscoulos et al., 1977).

The various soils have been used successfully as correlative features by Tarnocai et al. (1985) to determine the relative age of glacial landforms in the region. Attempts have also been made to deduce palaeoclimatic information from the intensity of chemical alteration and the physical characteristics of the soils. However, present rates of soil development in the region are unknown, and therefore it is difficult to isolate the relative contributions of time and changing environmental conditions to pedogenesis.

To this end, changes in the physical and chemical composition of soils in the thaw slumps may be used to investigate initial soil development in these deposits, for as the headwall retreats, the footslope mudlobes provide fresh parent material in which pedogenesis is initiated. The results presented form a preliminary examination of pedogenic processes in fresh deposits. With the field evidence available, it is not possible to provide a detailed account of the rate of profile development in the slump sediments.

Field observations and laboratory results of soil analyses are presented in Table 4. Physical indications of profile development appear 6 years after disturbance, in the form of soil aggregates and a sparse litter cover in unit 4. Both of these elements develop with increasing age of surface. In addition, the leaching of lime from the surface of the soil in unit 7 demonstrates the start of chemical weathering after, at most, 40 years.

The assays of pH, organic C, total N and percent CaCO₃ content of samples from the surface 10 cm at all sites fall into two groups. Results from all disturbed sites (units 1-7) form one batch. Some variation within this batch is inherited from the heterogeneous sediment that forms the parent material. The values obtained with the mature forest samples (unit 8) are distinct from the disturbed-site samples. This indicates that soil development at the disturbed sites is still at an early stage. Chemical changes are dependent on the presence of a surface litter horizon in which fulvic and humic acids may be generated. After about 40 years, this horizon is, at most, thin (i.e., less than 5 cm thick), and often absent.

PERMAFROST CONDITIONS

Drilling at several recently disturbed sites in the floors of the active thaw slumps has indicated that the surficial 3 m of slump floors are not perennially frozen during the first 10 years after disturbance (cf. depth to frost, Table 4). However, a comparison of the ground thermal regime at an undisturbed forest site and in the floor of the stabilized slump indicates the re-establishment of permafrost in the slump floor (Fig. 7). The disturbed site was first drilled to 5 m depth in 1982, when all ground below 0.8 m was frozen. Therefore, permafrost was re-established by approximately 38 years after disturbance.

Ground temperature envelopes from both sites for the calendar years 1986 and 1987 are presented in Figure 7. Warmer temperatures were recorded at the disturbed site, where the ground thermal regime is recovering from the disturbance effected by the thaw slump.

However, we should note: (1) that loss of ground ice during thaw-slope development has altered soil thermal properties, and therefore the ground thermal regime at the two sites will differ even if surface temperatures are similar; and (2) that the ground surface temperatures, which drive the ground thermal regime at the sites, are unlikely to be similar before comparable surface conditions are established. In particular, over time a thicker moss layer should cover the disturbed site.

Nevertheless, given present ground temperatures in the slump, the estimate of time since disturbance of about 43 years, and in anticipation of further changes in ground surface conditions, it is unlikely that the ground thermal regime at the disturbed site will reach equilibrium in less than a century after disturbance. In particular, further development of organic horizons, which are discontinuous in the stabilized slump, may be expected to affect ground temperatures.

**TABLE 4. Soil physical and chemical characteristics**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Age (yr)</th>
<th>Depth of</th>
<th>Thickness of</th>
<th>Depth to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>aggregates</td>
<td>litter</td>
<td>frost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(cm)</td>
<td>(cm)</td>
<td>(cm)</td>
</tr>
<tr>
<td>1. Active</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>75</td>
</tr>
<tr>
<td>2. Funaria</td>
<td>1-2</td>
<td>0</td>
<td>0</td>
<td>&gt;110</td>
</tr>
<tr>
<td>3. Senecio</td>
<td>2-5</td>
<td>0</td>
<td>0</td>
<td>&gt;110</td>
</tr>
<tr>
<td>4. Equisetum/Salix</td>
<td>6-9</td>
<td>0.5</td>
<td>0.2</td>
<td>&gt;110</td>
</tr>
<tr>
<td>5. Equisetum</td>
<td>6-15</td>
<td>0.6</td>
<td>0.2</td>
<td>&gt;110</td>
</tr>
<tr>
<td>6. Salix/Betula</td>
<td>12-15</td>
<td>3.8</td>
<td>0.3*</td>
<td>135</td>
</tr>
<tr>
<td>7. Picea/Betula</td>
<td>43</td>
<td>7.2</td>
<td>3.9*</td>
<td>95</td>
</tr>
<tr>
<td>8. Picea</td>
<td>mature</td>
<td>11.6</td>
<td>7.1</td>
<td>49</td>
</tr>
</tbody>
</table>

*Discontinuous in places non-existent.

Note: Results are mean values of four samples from each unit.

SUMMARY AND CONCLUSIONS

The observations presented here describe the regeneration of forest vegetation after its obliteration during thaw-slope
undisturbed site

Stabilized thaw slump floor

FIG. 7. Temperature envelopes (10 October 1985 to 10 October 1987), soil material and gravimetric water contents at a mature forest site and in the stabilized slump.

development at sites near Mayo, Yukon Territory. The re-establishment of plant communities is associated with the initiation of soil development in fresh soil substrata. Ground temperature measurements indicate permafrost aggradation in a regenerating slump floor. From the various observations presented, we conclude:

(1) Succession toward a closed-canopy spruce forest is well under way about 40 years after disturbance. The community differs from the mature forest in that the bryophyte cover is poorly developed and birch trees constitute a large portion of the canopy. The absence of birch saplings from the shrub layer implies that *Picea glauca* will inevitably become established as the principal tree species. It is possible that the absence of birch saplings is due to chance, and that such saplings may appear in a few years' time. However, we consider this unlikely, since birch is virtually absent from the mature forest.

(2) Soil development on fresh surfaces is initiated in the first decade following disturbance, but chemical changes may only be detectable after a longer period, once an organic horizon has developed. After 40-50 years, the soils still appear quite immature.

(3) Near-surface permafrost is eradicated during and in the years immediately following thaw slumping. However, it is re-established in the 40 years after disturbance, but is still not in equilibrium with surface conditions and may be expected to continue aggrading.

ACKNOWLEDGEMENTS

Field studies were started under the supervision of M.W. Smith, Carleton University. The work has been supported by the Department of Indian Affairs and Northern Development (NSTP); the Earth Physics Branch, Energy, Mines and Resources, Canada; the Atmospheric Environment Service, Environment Canada; the Arctic Institute of North America; the Canadian Commonwealth Scholarship Committee; and the University of British Columbia Killam Fellowship Committee. D. Moon, Agriculture Canada, kindly provided laboratory facilities for soil analyses, and L. Chan gave appreciated guidance and instruction. Cryptogams were identified with the help of Julie Oliveira, University of British Columbia Herbarium. Discussions and assistance in the field from C.A.S. Smith, Agriculture Canada, and Jane Porter are gratefully acknowledged. The field program would not have been possible without the continuing hospitality of Jim and Shann Carmichael, for which we are most grateful.

Valuable comments on the manuscript have been received from A.G. Lewkowicz, J.R. Mackay, M.E.A. North, W.B. Schofield, H.O. Slaymaker, C.A.S. Smith and two referees. The figures were drawn by P.J. Jance.

REFERENCES


THAW SLUMPS NEAR MAYO, YUKON / 39


THAW SLUMPS NEAR MAYO, YUKON / 39

CLADONIA UNICIALES (L.) WIGG
Polytrichum juniperinum Hedw.
Tomentypnum nitens (Hedw.) Loeske
Cladonia major (Hag.) Sandst.
Cladonia cyanipes (Sommerf.) Nyl.
Sphagnum girgensoossii Russ.
Diceranum acutifolium (Lindb. and Arn.) C.Jens.
Dirichium heteromallum (Hedw.) Britt.

APPENDIX

Full scientific names of plants in Mayo study area

i. Cryptogams

Funicula hygrometrica Hedw.
Lepidobryum pyriforme (Hedw.) Wils.
Marchantia polymorpha L.
Bryum caespiticum Hedw.
Peltigera aphthosa (L.) Willd.
Aulacomnium palustre (Hedw.) Swaegr.
Hylcomonium splendens (Hedw.) B.S.G.

Cladonia uncialis (L.) Wigg
Polytrichum juniperinum Hedw.
Tomentypnum nitens (Hedw.) Loeske
Cladonia major (Hag.) Sandst.
Cladonia cyanipes (Sommerf.) Nyl.
Sphagnum girgensoossii Russ.
Diceranum acutifolium (Lindb. and Arn.) C.Jens.
Dirichium heteromallum (Hedw.) Britt.

Stereocaulon grande (H. Magn.) H.Magn.

ii. Herbs

Senecio congestus (RBr.) DC.
vul. palustris (L.) Fern.
Chenopodium capitatum (L.) Achers.
Dichondra richardsonii (Sweet) Schulz
Senecio lugens Rich.
Epilobium palustre L.
Polygonum alaskanum (Small)

Wight
Stellaria longifolia Muhl.
Equisetum arvense L.
Cinna latifolia (Trev.) Griseb.
Epilobium angustifolium L.
Hedysarum boreale Nutt.
Arnica alpina (L.) Olin.
Equisetum scirpoides Michx.

Hordeum jubatum L.
Habenaria hyperborea (L.) R.Br.
Gentianella propinqua Rich.
Parnassia palustris L.

Astragalus agrestis Dougl.
Erigeron acris L.
Corallorhiza trifida Chatelin
Aster commutatus
Ranunculus orthorrhynchus Hook.
ssp. alachensis (Benson) Hult.

Achillea millefolium L.
Rubus arcticus L.
Carex concinna R.Br.
Habenaria obtusata (Pursh.) Rich.

Listera borealis Morong
Moneses uniflora (L.) Gray.
Goodyera repens (L.) R.Br.
Carex aurea Nutt.

iii. Sub-shrubs

Rheum glandulosum Grauer
Rubus idaeus L. var. canadensis
Ribesudsonianum Rich.
Shepherdia canadensis (L.) Nutt.
Vaccinium vitis-idaea L.

Aster acicularis Lindl.
Ledum decumbens (Ait.) Lodd.
Linnaea borealis L.

Arctostaphylos rubra (Fern.) Rhed. and Wils.
Pyrola asarifolia Michx.
Viburnum edule (Michx.) Raf.
Potentilla fruticosa L.

Geocaulon livicum (Rich.) Fern.

Emetrum nigrum L.

Pyrola secunda L.

iv. Trees and shrubs
Salix lasiandra Benth.

Salix interior Bovee
Salix alaxensis (Anderss.) Cov.

Salix novae-angliae Anderss.
Salix arbusculoides Anderss.

Salix glauca L.

Populus balsamifera L.

Betula papyrifera Marsh.

Picea glauca (Moench) Voss