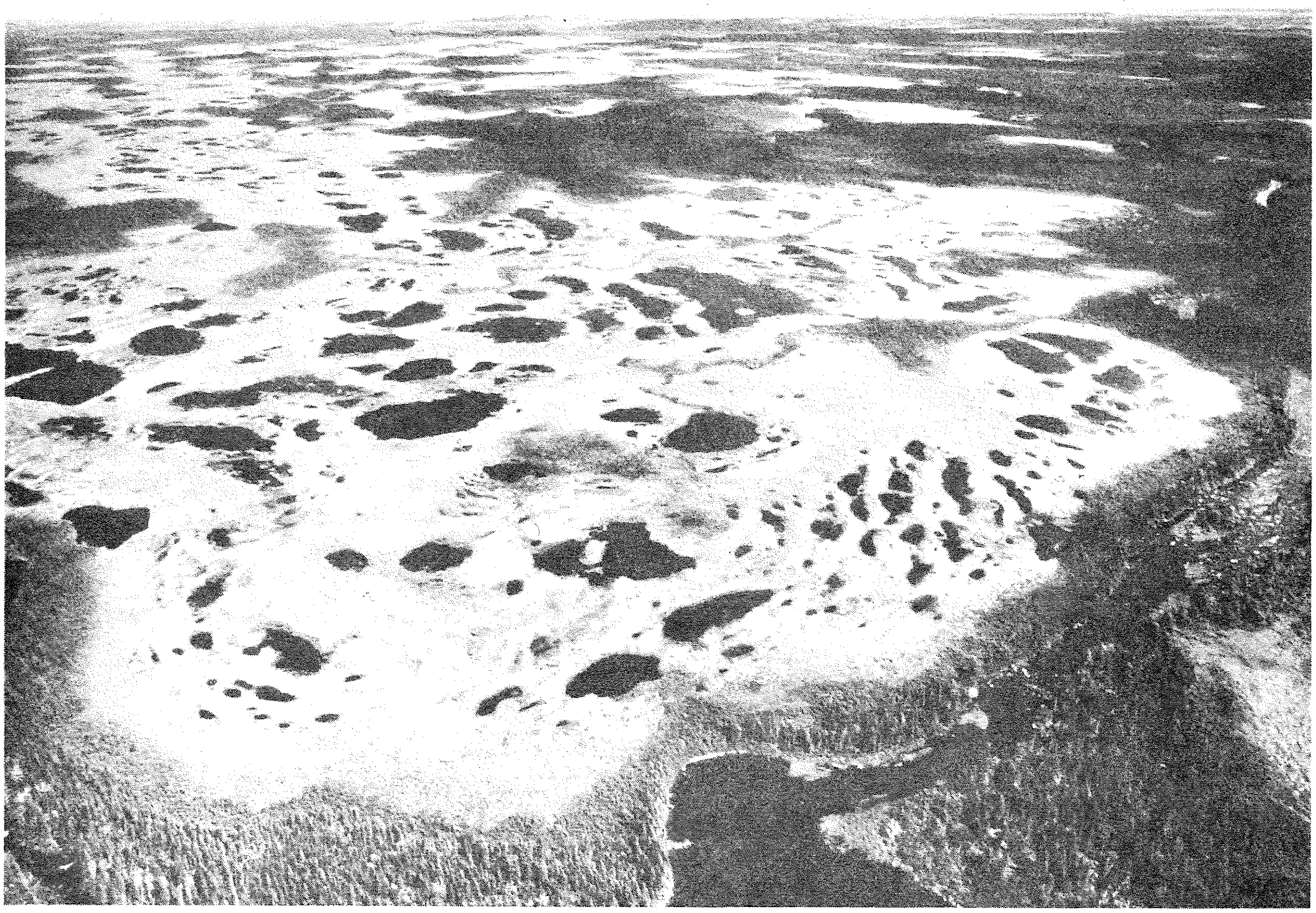
Proceedings of a workshop on an organic soil mapping and interpretation in Newfoundland



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PROCEEDINGS OF A WORKSHOP ON ORGANIC SOIL MAPPING AND INTERPRETATION

May 26-29, 1980, St. John's, Newfoundland

Compiled and Edited by C. Tarnocai

Land Resource Research Institute
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Organic Soil Mapping and Interpretation Workshop

St. John's, Nfld., 26-29 May 1980

The workshop opened at 8:30 a.m. in the Conference Room, Research Station, St. John's West. H. W. R. Chancey, Director of the Station, welcomed those attending and gave a brief resume of the Station's research operations, with emphasis on its peat research at the Colinet Peat Sub-station. He expressed his appreciation for the workshop being held in Newfoundland and assured those attending that they would be interested in the extent and complexity of Newfoundland's organic soils. He concluded his remarks by assuring that the Station would be pleased to provide any assistance necessary to ensure the workshop's sucess.

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OPENING REMARKS

J.H. Day

To provide background for this workshop I would like to recount several bits of history that activated a thought process.

- taxonomic classification of organic soils is in place, fully tested and adopted by CSSC and ESCC
- capability classification of organic soils developed in Ontario, tested there and in Manitoba, but has not been tested on national basis, nor adopted by CSSC.
- classification of organic landforms has been developed and extensively tested in great Plains and NWT, tested in PEI, Ontario and Quebec and found wanting in some respects. It has not been adequately tested in West Coast Maritime conditions.
- difficulties in application of landform classification to Quebec and Ontario conditions, coupled with relocation of Tarnocai to Ottawa and assignment to new duties; he was charged with testing and necessary modification to accommodate new observations in Quebec, Ontario and following the work of Veer in PEI.
- Tarnocai assisted reconnaissance mappers in Ottawa area to absorb skills and philosophy required to intergrate organic soils into map legends.
- my observation that in general organic soils are inadequately mapped and described in current and recent projects in Eastern Canada and in most of western Canada.
- interpretive ratings of these soils remains underdeveloped with respect to soil survey reports.
- recent pressure for accumulated development of peat resource for production of energy, about which we know almost nothing, and for agriculture production.

In conclusion, last winter's culmination of events prompted a decision to convene a workshop at which the focus should be placed on improving the skills of soil surveyors that are required for mapping and interpreting peatlands and organic soils. This location was chosen simply because this is where the action is and when there is an appreciable concentration of surveyors and expertise in the agricultural uses of peatlands.

I asked Charles Tarnocai to organize this workshop because:

- he has demonstrated experience in Manitoba and NWT where most of Canada's peatlands are located.
- he plays an active role in wetland classification committees of DOE, leader of ECSS peat landform subcommittee, leader of soil taxonomy subcommittee, recently became CDA representative to NRC subcommittee on Peatlands.
- in short he is a convinced peatnik that I can assign work to. I believe you will find him enthusiastic about peatlands and mapping of same.

I solicite your close attention and fullest participation in this workshop.

Our collective experience here should provide guidance and impetus for other similar workshop that I plan to organize in other provinces in the future. It is up to us to produce soil maps of the highest quality and utility in keeping with the objectives suggested by requesting agencies.

Let us begin now.

DEVELOPMENT, AGE AND CLASSIFICATION OF CANADIAN PEATLANDS

Charles Tarnocai

INTRODUCTION

Peatlands comprise approximately 12% of the land area of Canada (Clayton et al. 1977). The term "peatland" is defined as a poorly drained terrain (wetland) having greater than 40 cm of peat on the surface.

The greatest concentration of peatland occurs in a broad belt extending from central Labrador, passing through the Hudson Bay Lowland, and reaching northwest across the southern part of the N.W.T. and the northern part of the Prairie provinces. These vast, flat, poorly drained areas with a cool and moist climate provide the environmental setting for the development of peatlands.

Under the moist maritime climate existing along both the Pacific and Atlantic coasts, peatlands are also very common. In these high rainfall areas peatlands are found not only in the valley bottoms but also on moderate and steep slopes.

In other parts of Canada peatlands are less common and they are non-existent in the southern part of the Prairie provinces.

In this paper a brief discussion of the development, age and classification of Canadian peatlands will be given.

PEATLAND DEVELOPMENT

Peatlands are dynamic systems formed by the interaction of biological and physical environmental factors. The stratigraphy of peat materials deposited through long periods of time is evidence of the environmental conditions operating throughout that period of time. The depositional sequence indicates the dynamic conditions in the peatland as a result of environmental changes, e.g. climatic and hydrological variation or the development of permafrost.

Examination of peat deposits suggests that two basic types of peatland development take place: the filling-in process (Tarnocai 1978, Zoltai and Tarnocai 1975, Dansereau et al. 1952) and the gradual build-up process (Tarnocai 1978, Zoltai and Tarnocai 1975).

The filling-in process (Figure 1A) begins in a shallow lake or pond. The basal peat may contain marl or gastropods in the aquatic peat and this is followed by fen peat. Fen peat begins to form along the lakeshore and eventually forms a floating mat which slowly extends into the center. The water space between this floating fen mat and the aquatic peat layer on the lake bottom is then slowly replaced by peat material. The peatland at this stage is still influenced by mineral-rich waters (minerotrophic). These peat deposits are sometimes capped by sphagnum peat when the peatland is no longer influenced by mineral-rich waters. At this stage it has become elevated above the regional water table and hence is ombrotrophic.

The gradual build-up process (Figure 1B) begins in moist areas where the water table is close to the surface or where an increase in moisture regime results in the invasion of mosses, particularly Sphagnum species. This process does not produce marl or aquatic peat. There may be a thin organic-rich mineral layer at the base of the peat deposit but it is followed by layers of either forest or sphagnum peat or both. Very often this process produces a blanket-like peat deposit on the terrain, covering not only the level areas but also the gentle slopes and very often the uplands as well. Such peat deposits, in most cases, are not very deep and their depth varies greatly according to the topography. This process operates under ombrotrophic conditions even though it is initiated on extremely calcareous till materials, e.g. in central Manitoba.

AGE OF PEAT DEPOSITS

Radiocarbon dates of basal peat materials indicate that peat deposition did not begin until several thousand years after the continental ice melted on the mainland. The oldest date in the Mackenzie River area is 8190 ± 60 BP (Table 1) and in Manitoba 7220 ± 110 BP (Table 1). When all of the radiocarbon dates from Manitoba and the Districts of Mackenzie and Keewatin in the Northwest Territories are compared, it appears that the majority of peat deposits began to develop between 4000 to 6000 BP (2000 to 4000 BC). On the arctic islands, however, the basal peat dates are much older - 8500 to 9000 BP (6500 to 7000 BC) - indicating that peat development began much earlier than on the continent.

There is evidence that there was a relatively warm and dry period, lasting several thousand years, after the retreat of glacial ice from the North American continent (Nichols 1969, Ritchie and Hare 1971, Terasmae 1972). It is possible that during this period it was generally too warm and dry for optimum peat development. In the high arctic areas the climate was assumed to have been cooler and moister (although warmer than at present) after the retreat of glacial ice and, consequently, conditions were favorable for peat development. As the climate became colder, peat development ceased in the high arctic and the boreal and subarctic regions became established as the areas of optimum peat development.

PEATLAND CLASSIFICATION

The peatland classification used in Canada has a hierarchical structure with each level stressing a different aspect of the peatland (Tarnocai 1980). The broadest subdivision is made on the class level. The peatland classes are based on features that either constitute or contribute to the physiognomy of the peatland. Classes also repre-

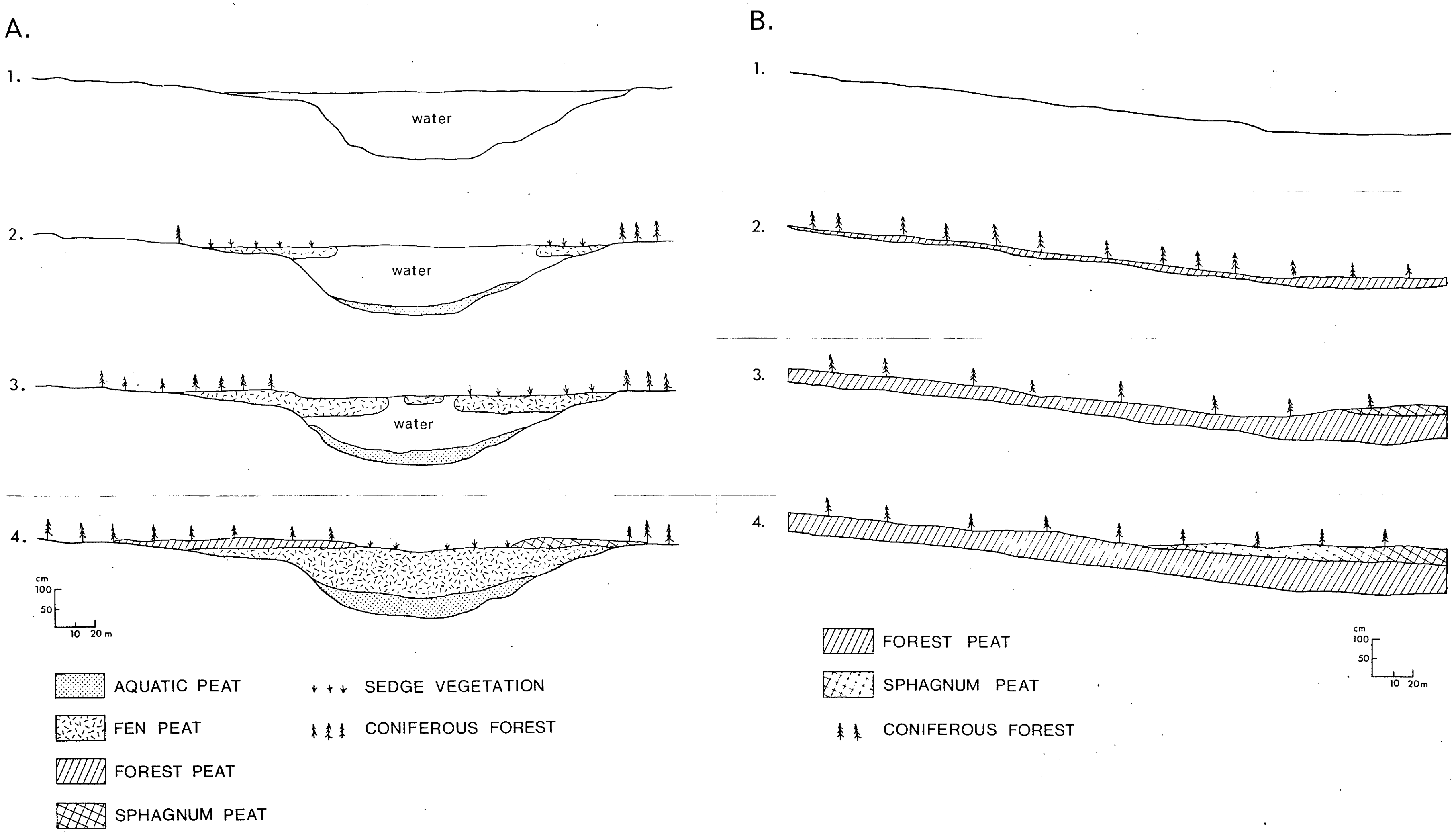

Figure 1. Schematic diagrams showing the probable stages of the filling-in process (A) and the gradual build-up process (B).

Table 1. Radiocarbon dates of basal peat.

Location	Age of Basal Peat (years)	Source
Porcupine Mountain, Manitoba	6770 ± 70 BP	Nichols 1969
Clearwater Bog, Manitoba	1280 ± 75 BP	Nichols 1969
Grand Rapids, Manitoba	7220 ± 110 BP	Richie and Hadden 1975
52°53'N & 99°08'W, Manitoba	4670 ± 130 BP	Klassen 1967
Lynn Lake, Manitoba	6530 ± 130 BP	Nichols 1967
67°16'N & 135°14'W, NWT	8190 ± 60 BP	Zoltai and Tarnocai 1975
67°41'N & 132°05'W, NWT	7200 ± 60 BP	Zoltai and Tarnocai 1975
66°13'N & 130°52'W, NWT	5600 ± 70 BP	Zoltai and Tarnocai 1975
69°07'N & 132°56'W, NWT	6020 ± 100 BP	Zoltai and Tarnocai 1975
65°50'N & 129°05'W, NWT	6120 ± 120 BP	Mackay and Mathews 1973
65°15'N & 126°42'W, NWT	3960 ± 50 BP	Korpijaakko et al. 1972
69°30'N & 135°47'W, NWT	4140 ± 140 BP	Lowdon et al. 1971
Ennadai Lake, NWT	5780 ± 110 BP	Nichols 1967
Bathurst Island, NWT	9210 ± 170 BP	Blake 1964
75°50.5'N & 98°02.5'W, NWT	8420 ± 80 BP	Lowdon and Blake 1975
Sherard Valley, Melville Island NWT	9040 ± 160 BP	Barnet 1973

sent two basic peatland environments: ombrotrophic (bogs) and minerotrophic (fens, swamps and marshes). The second level in the classification is based on the surface and subsurface morphology of the landform (e.g. domed, plateau, flat, basin, etc.) or on the surface pattern (e.g. polygonal, ribbed, etc.). Some peatland forms may be related to hydrological or hydrotopographical features (spring, stream, shore, etc.).

The peatland classes - bog, fen, swamp and marsh* - along with the associated peatland forms are given below.

Bog

A bog is a peat-covered or peat-filled wetland, generally with a high water table. The water table is at or near the surface. The bog surface is often raised, or level with the surrounding wetlands, and is virtually unaffected by the nutrient-rich ground waters from the surrounding mineral soils. Hence, the ground water of the bog is generally acid and low in nutrients. The dominant peat materials are sphagnum and forest peat underlain, at times, by fen peat. The associated soils are Fibrisols, Mesisols and Organic Cryosols. The bogs may be treed or treeless and they are usually covered with Sphagnum and feather mosses, and with Ericaceous shrubs.

1. Surface raised above the surrounding terrain
    2. Surface convex
        3. Core frozen; abruptly domed; usually in fens
            4. Over 1 m high, diameter up to 100 m ---------- Palsa Bog
            4. Less than 1 m high, diameter up to 3 m ------- Peat Mound Bog
        3. Core not frozen
            5. Convex surface small (1-3 m dia.); occurring in fens ---------------------------- Mound Bog
            5. Convex surface often extensive; not occurring in fens ---------------------------- Domed Bog
    2. Surface flat to irregular
        6. Core perennially frozen
            7. Surface with network of polygonal fissures
                8. Surface even ------------------------------Polygonal Peat Plateau Bog
                8. Surface with high centres in a polygonal network ------------------------Lowland Polygon Bog
            7. Surface without polygonal fissures
                9. Surface about 1 m above the surrounding fen ------------------------------------ Peat Plateau Bog
        6. Core not frozen
                10. Bogs generally tear-drop shaped --------- Northern Plateau Bog
                10. Bogs not tear-drop shaped; abundance of surface water --------------------------- Atlantic Plateau Bog

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* Only some of the marshes are considered to be peatlands, most of them are mineral wetlands. Since very little information is available concerning those marshes which are associated with greater than 40 cm of peat, all marsh types are included in this classification.

1. Surface not raised above surrounding terrain
    11. Surface relatively level
        12. With abrupt marginal peat walls ----------------- Collapse Bog
        12. Without marginal peat walls
            13. Adjacent to water bodies
                14. Floating ------------------------------ Floating Bog
                14. Not floating ------------------------- Shore Bog
            13. Not adjacent to water bodies
                15. Surface flat; topographically confined
                    16. Basin deposit; depth greatest in center -------------------------- Basin Bog
                    16. Flat deposit; depth generally uniform ------------------------- Flat Bog
                15. Surface flat to undulating, often appreciably sloping
                    17. Surface pattern of ridges and pools distinct ------------------------ String Bog
                    17. Surface pattern of pools usually absent; extensive --------------- Blanket Bog
    11. Surface not level
        18. Core not frozen
            19. Surface concave --------------------------- Bowl Bog
            19. Surface appreciably sloping ---------------- Slope Bog
        18. Core perennially frozen
            20. Surface appreciably sloping ---------------- Veneer Bog

<u>Fen</u>

A fen is a peat-covered or peat-filled wetland with a high water table which is usually at or above the surface. The waters are mainly nutrient-rich, minerotrophic waters from mineral soils. The dominant peat materials are shallow to deep, well to moderately decomposed fen peat. The associated soils are Mesisols, Humisols and Organic Cryosols. The vegetation consists dominantly of sedges, grasses, reeds and brown mosses with some shrub cover and, at times, a scanty tree layer.

1. Surface not raised above surrounding terrain except in low hummocks and ridges.
    2. Surface pattern of ridges and depressions
        3. Sub-parallel pattern of ridges and furrows
            4. Broad pattern; often very extensive
                5. Northern regions; lowland drainage; peat deep ---------------------------- Northern Ribbed Fen
                5. Atlantic regions; mainly upland drainage; peat shallow---------------- Atlantic Ribbed Fen

4. Narrow ladderlike pattern; along bog flanks ---------------------------- Ladder Fen

3. Reticulate pattern of ridges -------------------- Net Fen

2. Without pronounced surface pattern

5. Featureless, adjacent to water bodies

6. Floating ----------------------------------- Floating Fen

6. Not floating; located in main channel or along banks of continuously flowing or semi-permanent streams -------------------------- Stream Fen

6. Not floating; located along shores of semi-permanent or permanent lakes --------------- Shore Fen

5. With surface water or filled depressions; not adjacent to water bodies

7. Depressed thaw hollows --------------------- Collapse Fen

1. Surface raised or appreciably sloping

8. Mounds with frozen core in patterned fens ------------ Palsa Fen

8. Without frozen core

9. Surface irregular due to upwelling water -------- Spring Fen

9. Surface regular but sloping --------------------- Slope Fen

1. Surface flat or depressional

10. Core perennially frozen

11. Surface with network of polygonal fissures ------ Lowland Polygon Fen

10. Core not frozen

12. Surface level without pronounced surface pattern- Horizontal Fen

12. Occupying open-ended, eroded channels, abandoned glacial meltwater spillways or intermittent drainage courses ------------------------------- Channel Fen

Swamp

A swamp is a peat-filled area or a mineral wetland with standing or gently flowing waters occurring in pools and channels. The water table is usually at or near the surface. There is strong water movement from the margin or other mineral sources, hence the waters are nutrient-rich. If peat is present it is mainly well decomposed forest peat underlain at times by fen peat. The associated soils are Mesisols, Humisols and Gleysols. The vegetation is characterized by a dense tree cover of coniferous or deciduous species, tall shrubs, herbs, and some mosses. The classification key to swamp wetland forms is as follows:

1. Adjacent to water body

2. Located along banks of continuously flowing or semi-permanent streams ----------------------------- Stream Swamp

2. Located along shores of semi-permanent or permanent lakes --- Shore Swamp

1. Not adjacent to permanent water body
    3. In topographically defined basins
        4. On perimeter of peatlands ---------------------- Peat Margin Swamp
        4. Basin deposit; depth greatest in center ------ Basin Swamp
    3. Not in topographically defined basins
        5. Flat deposit; depth generally uniform -------- Flat Swamp
        5. Poorly drained area; associated with floodplains --------- Floodplain Swamp
        5. Discharge area; surface irregular ------------ Spring Swamp

Marsh

A marsh is a mineral or a peat-filled wetland which is periodically inundated by standing or slowly moving waters. Surface water levels may fluctuate seasonally, with declining levels exposing drawdown zones of matted vegetation or mud flats. The waters are nutrient rich. The substratum usually consists dominantly of mineral material, although some marshes are associated with peat deposits. The associated soils are dominantly Gleysols with some Humisols and Mesisols. Marshes characteristically show a zonal or mosaic surface pattern of vegetation comprised of unconsolidated grass and sedge sods, frequently interspersed with channels or pools of open water. Marshes may be bordered by peripheral bands of trees and shrubs, but the predominant vegetation consists of a variety of emergent nonwoody plants such as rushes, reeds, reed grasses, and sedges. Where open water areas occur, a variety of submerged and floating aquatic plants flourish. The classification key to marsh wetland forms is as follows:

1. Influenced by marine tidal water
    2. In river estuaries or connecting bays where tidal flats, channels and pools are periodically inundated by water of varying salinity
        3. Located above mean high water levels; inundated only at highest tides and/or storm surges -------- Estuarine High Marsh
        3. Located below mean high water levels; frequently inundated -- Estuarine Low Marsh
    2. On marine terraces, flats, embayments or lagoons behind barrier beaches, remote from estuaries, where there is periodic inundation by tidal brackish or salt water, including salt spray
        4. Located above mean high tide levels; inundated only at flood tides ------------------------------ Coastal High Marsh
        4. Located below mean high water tide levels -------- Coastal Low Marsh

1. Occupying valleys, gullies, channels, streams, floodplains and deltas
    5. Adjacent to, or flooded by, flowing water
        6. Located on active fluvial floodplains adjacent to channels -------------------------------- Floodplain Marsh
        6. Occupying shorelines, bars, streambeds or islands in continuously flowing water courses -------------- Stream Marsh
        6. Occupying open-ended, eroded channels, abandoned glacial meltwater spillways or intermittent drainage courses ---------------------- Channel Marsh
    5. Occupying deltas with open drainage or water circulation due to unrestricted connections to active river channels and/or lakes
        7. Seasonally inundated ------------------------------- Active Delta Marsh
        7. Inundated only during infrequent high river flows or wind tides --------------------------------- Inactive Delta Marsh

1. Occupying topographically defined catch basins, fed by local runoff or ground water
    8. Flat or concave basins in topographic low areas at the terminus of internal drainage systems, forming a close catchment for gound water discharge or surface inflow --- Terminal Basin Marsh
    8. Shallow, gently sloping depressions that occur as natural swales or occupy intervening areas between ridges or undulations on low-relief landforms ----------- Shallow Basin Marsh
    8. Sharply defined catch basins usually located in high or intermediate topographic positions on moderate- to high-relief hummocky moraine, glacio-lacustrine or glacio-fluvial landforms ----------------------------- Kettle Marsh

1. Not in topographically defined catch basins
    9. Occupying groundwater discharge sites, usually on or at the base of slopes --------------------------------- Seepage Track Marsh
    9. Occupying the shores of semi-permanent or permanent lakes --- Shore Marsh

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The Potential of Peatlands for Forestry and Fuel in Newfoundland

by

E. Doyle Wells

&

Frederick C. Pollett

Introduction

The peatlands of Newfoundland comprise about 20% of the landscape or approximately 2 million hectares; in terms of world peatland reserves, Newfoundland ranks eighth (Wells & Vardy, in press). The utilization of these peatlands is mainly as a natural habitat for flora and fauna with localized areas being used for agricultural and forestry research, community pastures and small-scale peat moss operations. During the past few years, however, a great deal of interest has been expressed by government, industry, and private concerns regarding the afforestation potential and, especially, the fuel peat potential of these peatlands.

Peatland afforestation is only in the preliminary stages of development in Newfoundland. During the past 13 years approximately 50 hectares of peatlands have been planted on an experimental basis by the Canadian Forestry Service and Bowater Newfoundland Limited (for detailed descriptions of each plantation see Päivänen and Wells, 1976). The experiments included species trials, planting method trials and, on several sites, ditch-spacing trials. Intensive research, however, has not been conducted on any of the plantations; survival and growth rates only have been documented for several sites (Richardson, 1979; Richardson and Chaffey, 1977; Richardson et al., 1976). Thus, the ecological basis for the future establishment of plantations is still lacking.

Peatlands have never played a significant role in supplying energy needs in Newfoundland. During the 1940's and 1950's small quantities of fuel peat were manually harvested from the blanket bogs in southeastern Newfoundland for home-heating purposes. Since that time oil and natural gas have replaced peat, wood and coal as the major sources of energy. At present the increasing cost of oil and the uncertainty of future oil supplies have led North Americans to seek alternate sources of energy. Although much emphasis has been directed toward the utilization of wood and coal, the energy potential of peat as an alternate source of fuel is receiving considerable attention.

The peatlands in Newfoundland may play an important role both in increasing forest production and supplying future energy requirements. This paper presents an overview of the peatland types that occur throughout the Island, and assesses the potential of each peatland type for afforestation or fuel peat.

Peatland Types and Distribution

A total of nine morphological peatland types have been described for Newfoundland (Pollett, 1972a; Pollett and Wells, 1980; Wells, 1976; in press). In this section all nine types are briefly discussed and illustrated with oblique aerial photographs and stratigraphic profiles (Figures 1, 2, 3). The description of organic soils (Of, organic/fibrisol; Om, organic/mesisol; Oh, organic/humisol) is based on the Canadian System of Soil Classification (CDA, 1978). The description of humification is based on the von Post scale (H1 to H10), (von Post, 1926). Surface vegetation types are described in detail by Pollett and Wells (1980), Wells (1976) and Wells (in press). A distribution map showing the major concentration of each peatland type is shown in Figure 4.

A. Bogs

1. Atlantic Plateau Bog (Figure 1A)

Atlantic plateau bogs occur in western, northwestern and northern Newfoundland. They have developed on relatively flat to gently undulating terrain, quite often on outwash deposits and marine terraces or between ridges of till-covered bedrock. The surface of the bog is also relatively flat with sloping margins of 20-30 percent. Depths vary from 2-4 metres. Large round pools are a common surface feature of the plateau bogs in northern Newfoundland. The pools become smaller and less frequent as one progresses southward. Many of the plateau bogs in western Newfoundland are characterized by small pools that are arranged in a ladder-like pattern along drainage paths or along the steep-sloping bog margins.

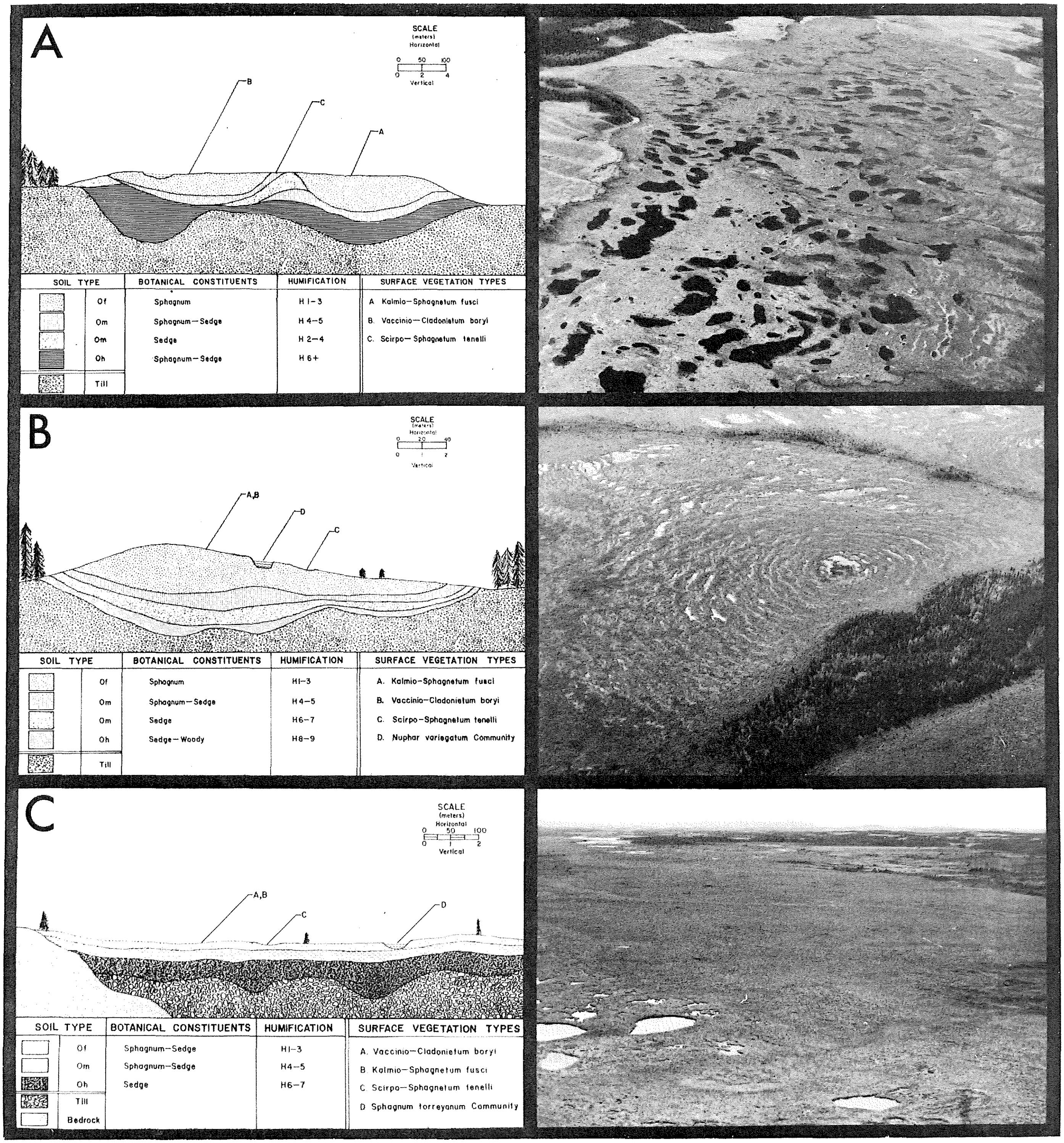


Figure 1. Stratigraphic profiles and oblique aerial photographs of Atlantic plateau bog (A), eccentric domed bog (B), and blanket bog (C).

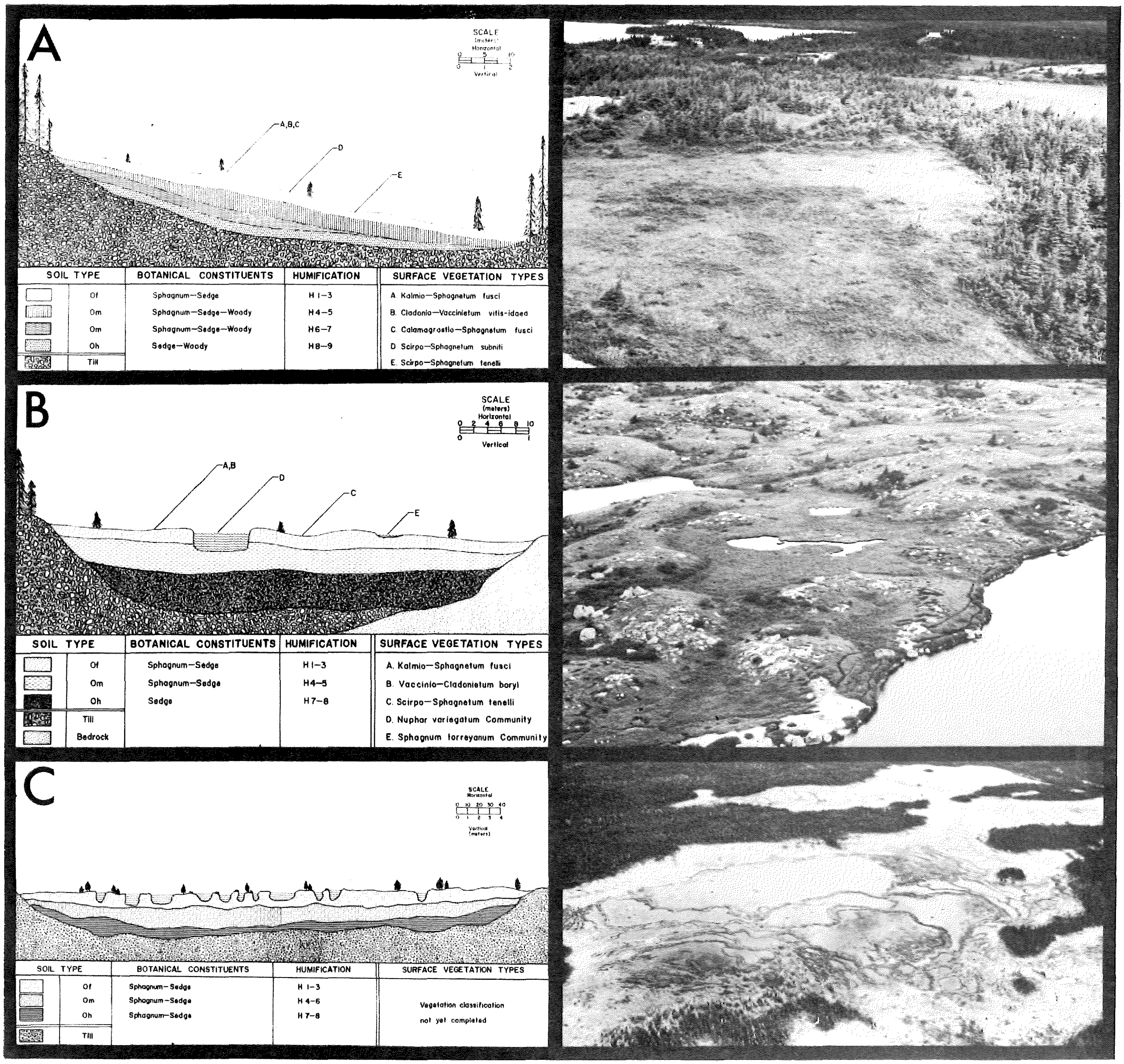


Figure 2. Stratigraphic profiles and oblique aerial photographs of slope bog (A), basin bog (B), and string bog (C).

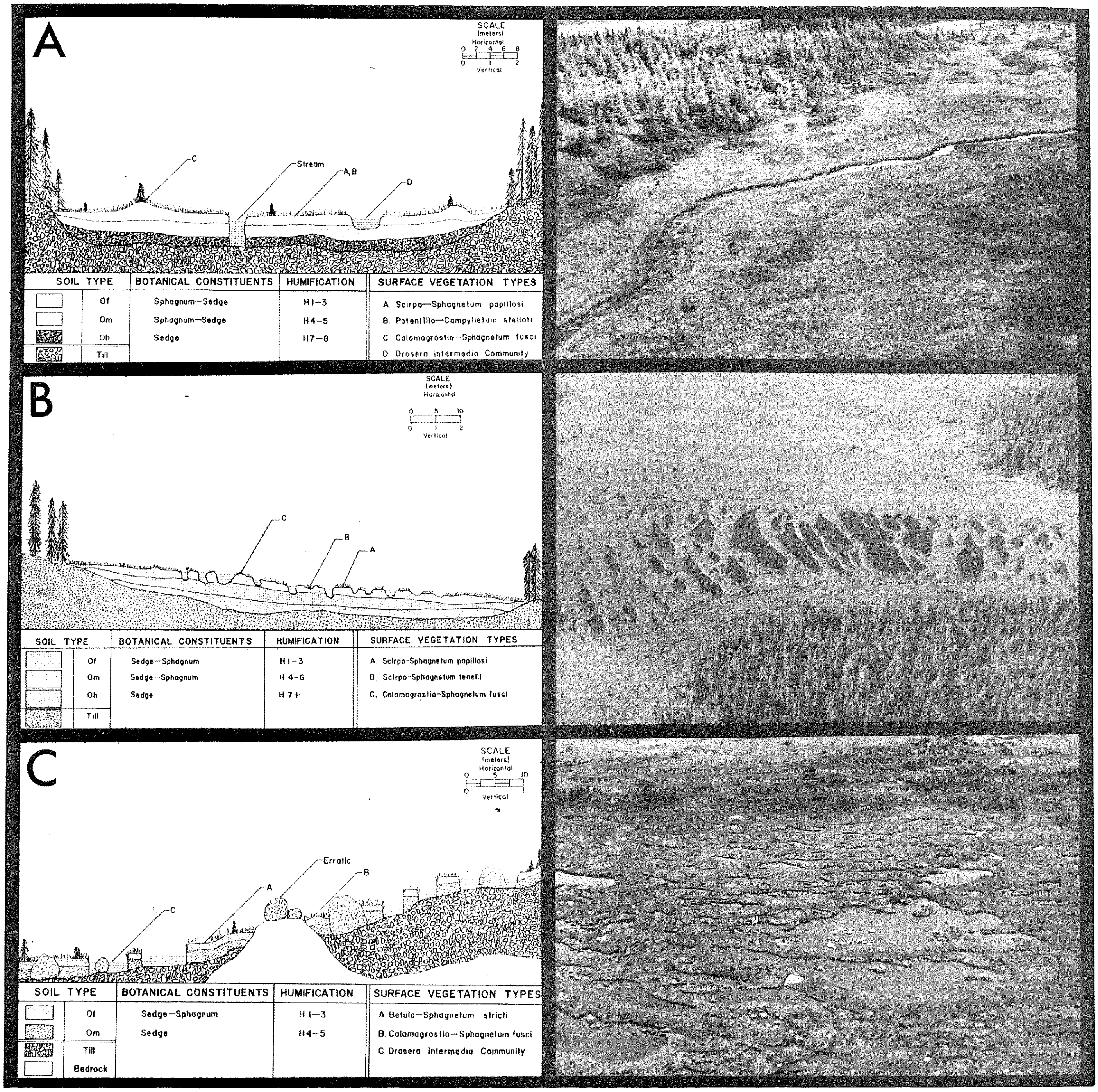


Figure 3. Stratigraphic profiles and oblique aerial photographs of slope fen (A), ladder fen (B) and ribbed fen (C).

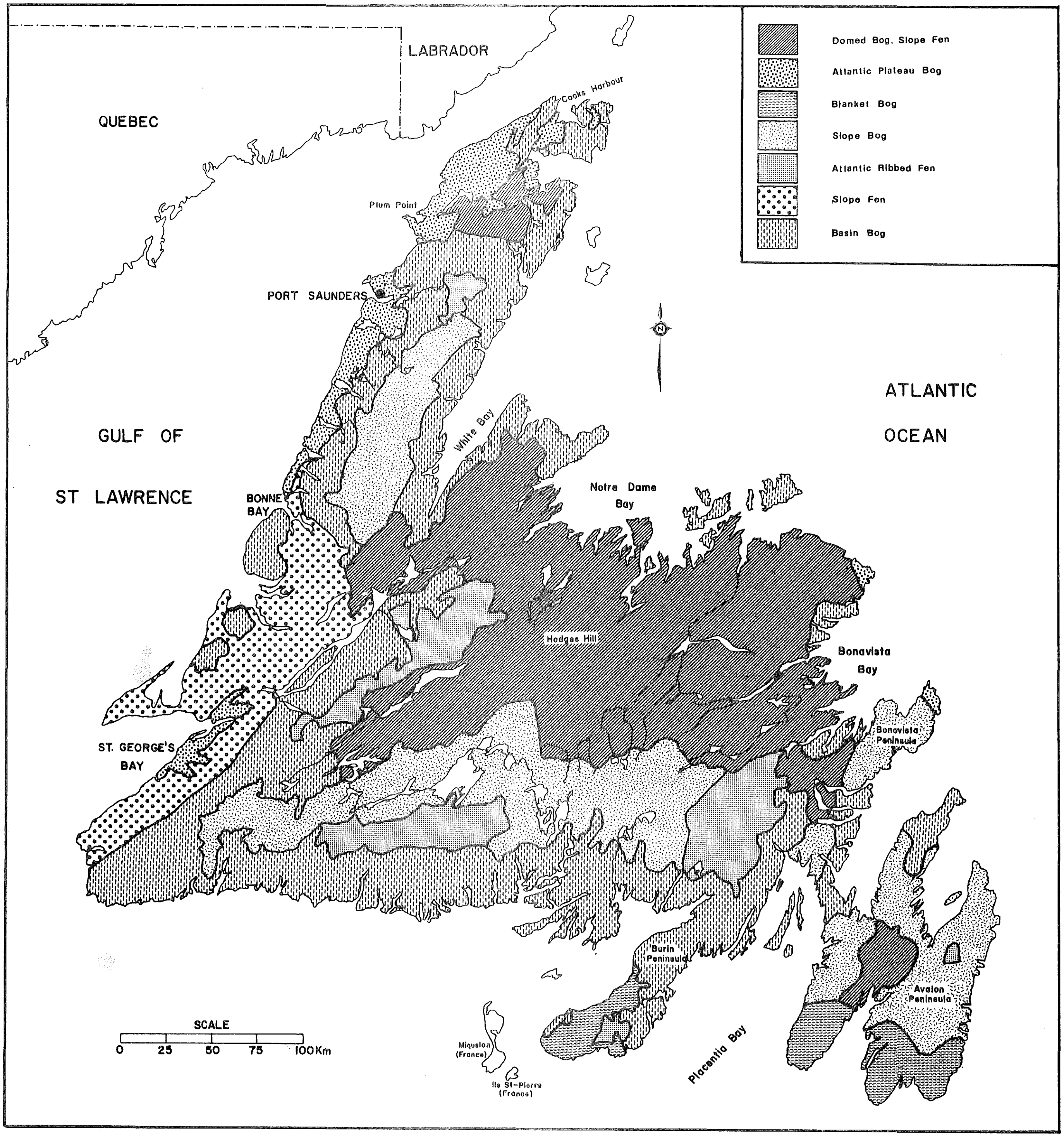


Figure 4. Peatland distribution map showing areal extent of major peatland types in Newfoundland.

The plateau bogs in western Newfoundland have a moderate to high potential for both afforestation and fuel peat. The underlying peat consists of moderately decomposed (H4-H5) Sphagnum-Sphagnum/sedge remains over a more humified (H6+) Sphagnum/sedge peat. Several limiting factors for afforestation, however, are exposure and the nutrient-poor conditions of the bog.

2. Domed Bogs (Figure 1B)

Domed bogs occur within the forested regions of the Avalon Peninsula, central Newfoundland, the northern part of the Northern Peninsula and, to a lesser extent, western Newfoundland. They are treeless and usually have pools or wet depressions that are arranged in concentric or eccentric patterns. The concentric domed bog is raised in the center with elongated, curvilinear-shaped pools that are positioned at right angles to slope and radiate outwards in all directions from the center. Eccentric domed bogs are raised at one end and the pools form semi-circular patterns.

Both bog types are deep (4-10 m) and are composed mainly of a Sphagnum-Sphagnum/sedge peat. They have a high potential for peat moss but a low potential for afforestation because of exposure and extremely poor nutrient conditions. Fuel peat is present in most of the bogs but is only accessible if the upper Sphagnum layers are removed.

3. Blanket Bogs (Figure 1C)

Blanket bogs occur only within southeastern Newfoundland. They vary in thickness from 1-3 m and often extend over the landscape (both valley and hill) for 8-10 kilometres. They are usually treeless and have relatively few ponds. The extensive development of this peatland type is related mainly to climatic conditions. Both the highest mean annual rainfall (135 cm) and fog frequency (1,145 mean annual hours of visibility 0.8 km or less) (AES, 1941-70) for Newfoundland occur in this bog region.

This peatland type probably has the greatest potential as a source of fuel peat in Newfoundland. The upper layer of Sphagnum-sedge peat is poorly decomposed (H1-H3); however, below this the peat varies in decomposition from H4-H8 (-H10).

4. Slope Bogs (Figure 2A)

Slope bogs occur throughout Newfoundland. Usually they are small, shallow (1-2 m) and topographically confined to poorly-drained slopes. In areas of high precipitation, however, such as in western and southeastern Newfoundland, slope bogs may become extensive. Trees and pools are usually absent.

Sphagnum mosses dominate the surface vegetation. Beneath this, the peat is moderately to well decomposed and consists mainly of Sphagnum-sedge remains. The larger slope bogs have a high potential for fuel peat.

5. Basin Bogs (Figure 2B)

Basin bogs occur throughout the exposed heaths of southern and eastern Newfoundland and in localized areas throughout the Long Range Mountains. They are especially common in areas of poorly-draining deep tills and hummocky moraine. They offer very little potential for afforestation or fuel peat because of their relatively small size ($\leq$ 10 ha); furthermore, they are nutrient-poor, and very exposed.

6. String Bogs (Figure 2C)

String bogs occur mainly in Labrador, but occur sporadically in the south-central region of Newfoundland. They are treeless, 2-3 m thick, and are distinguished by an alternating sequence of bog strings and linear-shaped pools at right angles to the main direction of slope. The surface vegetation consists mainly of Sphagnum mosses and shrubs on the strings; the underlying peat is loose and stringy and composed of Sphagnum and sedge remains. This peatland type has limited potential for afforestation or fuel peat because of the abundance of pools.

B. Fens

1. Slope Fens (Figure 3A)

Slope fens develop in areas that are poorly drained but receive nutrient-enriched seepage waters from the surrounding mineral soils. They are common within the forested regions of western and northern Newfoundland, particularly in areas of limestone bedrock. To a lesser extent, they occur within central Newfoundland but are rarely found in the eastern portion of the Island because of the base-poor mineral substrate. The fens are sloping (5-30%), shallow (1-2 m) and are often bordered at the base by a drainage channel. In some sites streams traverse the deposit. Small pools are usually present but seldom form patterns.

This peatland type is suitable for afforestation purposes and fuel peat. It is the most nutrient-rich peatland type (Pollett, 1972b) with a peat that is composed of predominantly sedges and grasses with some Sphagnum remains. However, its small size is often a deterrent factor in large-scale ditching and drainage operations.

2. Ladder Fens (Figure 3B)

Ladder fens develop along the margins of raised bogs primarily in central Newfoundland. They are shallow (1-2 m), and minerotrophic, receiving drainage waters from both the bog and the nearby upland mineral soils. Linear-shaped pools are arranged in a ladder-like pattern at right angles to slope. The peat is composed of sedge and Sphagnum/ sedge remains. This fen is unsuitable for afforestation and fuel peat because of the abundance of surface water.

3. Ribbed Fens (Figure 3C)

Ribbed fens are common on the exposed upland regions of the Island. They are shallow (0.1 m - 2 m), sloping (5-30%) and characterized by an abundance of pools. The pools vary in shape from long and linear on steep slopes to irregular discontinuous networks on flatter sites. In some areas of west-central Newfoundland ribbed fens appear to blanket the landscape. This peatland type is unsuitable for afforestation mainly because of the abundance of pools and severe exposure; the sedge peat has limited potential as a source of fuel because of the shallow depth and abundance of surface water.

Potential of Peatlands for Forestry

Several major problems associated with peatland afforestation trials in Newfoundland have been site selection, the application of proper drainage techniques and the use of proper drainage equipment.

Ecologically, the most suitable peatland site for afforestation is the slope fen. It is usually the most sheltered and nutrient-rich peatland type (Pollett, 1972b) thereby eliminating the need for fertilization. Furthermore, since it is naturally sloped, it drains well if properly ditched. But most slope fens are too small ($<$ 10 ha) to warrant large scale investments. Unless several sites can be found adjacent to one another, the larger and more nutrient-poor plateau or domed bogs become the alternate choice. However, the added cost of fertilization and winter exposure are major concerns to the investor. Loss of needles from snow blasting is a common feature of young trees on the open bogs.

All of the peatland afforestation sites in Newfoundland have been improperly ditched. Only small furrow ditches (50-60 cm deep) have been established on the sites whereas proper drainage ditches, trap ditches and main ditches have been omitted. The furrow ditches have been orientated mainly at right angles to the contours (i.e. in the direction of slope) in order to drain into a stream or into the forest. Ditching methods as outlined by Paivanen and Wells (1976) indicate that drainage ditches, or contour ditches, should be placed at a small angle to the contour lines to ensure a gradient toward the main ditches. Furrows which are only necessary for site preparation, should be placed perpendicular to the contour ditches.

Improper drainage techniques and the absence of main or trap ditches, however, should not be attributed solely to oversight on the part of the operator or researcher. The lack of proper drainage equipment has been a major limiting factor in the success of afforestation projects in Newfoundland. All of the sites were ditched with the Parkgate Tyne plough pulled by one or two tractors with specially designed tracks for traversing peatlands. The plough is adequate for furrowing but its capabilities and maneuverability are limited to the more open central areas of the peatland sites. Thus, successful afforestation projects in Newfoundland are dependant on proper ditching equipment capable of establishing complete drainage-ditch networks.

The potential of peatlands for forestry cannot easily be determined from the limited amount of data presently available. Drainage projects are necessary to establish the optimal ditch spacing, ditch depth, and the optimum water table level and soil moisture content for different tree species. The selection of the tree species for future planting can only be determined if species trials are established now. Moreover, fertilization trials should be established to determine optimal soil nutrient conditions especially on the ombrotrophic bogs. Regional variations in climate, topography and geology are also major considerations in site selection and establishment of future plantations. Afforestation experiments should therefore be conducted throughout Newfoundland in order to determine the optimal planting conditions within different environmental gradients.

Potential of Peatlands For Fuel

The extensive deposits of peatlands in Newfoundland have prompted industry, government and private concerns to explore the possibility of utilizing peats for energy. A study carried out by the Newfoundland Light and Power Company in 1975 indicated that the fuel properties of the plateau bog peat near Stephenville Crossing, western

Newfoundland, compare favourably with Irish and Finnish peats (Table 1). The Newfoundland Department of Mines and Energy, is currently assessing the potential for fuel peat developments in four major energy sectors: 1) residential; 2) commercial/institutional; 3) industrial; and, 4) electrical generation. Projections of oil to peat conversions, fuel peat consumptions (based on a 50% moisture content) and oil displacement by the year 1989 are presented in Table 2. A pilot fuel peat harvesting project to supply local, domestic energy requirements is also being initiated on a blanket bog near St. Shotts, southeastern Newfoundland. In addition, a fuel peat demonstration initiated in 1979 near Bishops Falls, central Newfoundland will provide peat to fuel the furnaces at the Price (Newfoundland) Pulp and Paper mill at Grand Falls.

The peatlands of Newfoundland offer definite potential as an alternate energy source. The results of a peatland inventory for the island of Newfoundland (Figure 5) indicate that more than 1.7 billion m^3 of fuel peat occur in central and western Newfoundland. In central Newfoundland most of the fuel peat deposits are less than one metre in depth or are overlain by large quantities of fibric peat (domed bogs). In western Newfoundland, however, the fuel peat is thicker, more extensive and relatively close to the surface; it is found mainly within the large plateau bogs.

Concentrated deposits of 118.2 million m^3 of fuel peat have been identified for the areas of Stephenville crossing and Codroy (Sites 1 and 2, Figure 6). These figures represent bogs with an area of at least 50 ha, and a minimum depth of one metre of fuel peat, (H5+) within an area of 50 km radius. Preliminary analysis of the 1980 peatland

Table 1. Comparison of fuel peat properties in western Newfoundland (Stephenville Crossing) with those of Ireland and Finland. Figures for western Newfoundland and Ireland are from Gosine (1980); figures for Finland are from Asplund (1979). Additional sources of data are indicated below.

Area	CV Kj/kg	Ash % wt	Volatile matter % wt.	Moisture % wt. before draining
Stephenville Crossing (1)	22 026	2.15	68.68	91.5
Ireland	22 538	2.7 (2)	67.60 (3)	94.0 (4)
Finland (5)	18 500- 21 500	4-7	61-71	-

(1) Tibbetts (1976)
(2) Collins and Thornhill (1975)
(3) Cronin and Lang (1954)
(4) Flood (1972)

Table 2. Projected oil to peat conversions, fuel peat consumption, and oil displacement for residential, commercial/institutional, and industrial sectors of Newfoundland by 1989. (From Wells and Vardy, in press).

	Number of conversions oil to peat	Peat consumption tonnes/yr.	Oil displacement barrels/yr.	Percentage of current (1979) oil consumption
Residential	5,000	45 000	85,000	3.3
Commercial/ institutional	500	80 000	150,000	8.7
Industrial	8	160 000	305,000	5.7
Totals	5,508	285 000	540,000	

Figure 5. Peatland inventory schedule and total peatland reserves of northeastern and western Newfoundland (Figures courtesy of Northland Associates Ltd., St. John's, Nfld.) (from Wells and Vardy, in press).

Region	Northeastern Newfoundland	Western Newfoundland	Totals
Study Year	1978	1979	
No. of deposits	19,577	6,407	25,984
Area(ha) % of region	135 493 12.0	87 885 9.3	223 378
Fibric (H1-H3) % of total	2 166 642 180 68.64	962 719 160 54.72	3 129 361 340 63.66
Mesic (H4-H7) % of total	978 105 960 30.99	795 637 380 45.22	1 773 743 340 36.08
Humic (H8-H10) % of total	11 715 000 0.37	1 023 040 0.06	12 738 040 0.26
Total (m^3)	3 156 463 140	1 759 379 580	4 915 842 720

Fens > 5 ha; bogs > 30 ha; minimum depth of 1.5 m.

TOTAL FUEL PEAT = 1 786 481 380 m^3 (in situ peat)
(Mesic + Humic)
= 339 million tonnes* (at 50% moisture content)
= 642 million barrels oil equivalent** (approx.)

Total energy consumption in Newfoundland in 1979
= 18.25 million barrels oil equivalent.

*Conversion factors for peat (m^3) (in situ) to tonnes of peat at 50% moisture content = 0.19 (based on Montreal Engineering study of peat bogs in northeast New Brunswick, Contract CANMET/EMR 8-9039).

**Conversion factor for tonnes of peat at 50% moisture content to barrels of oil equivalent = 1.9 (based on figures from "Energy from peat in Finland", published by VTT, Technical Research Centre of Finland).

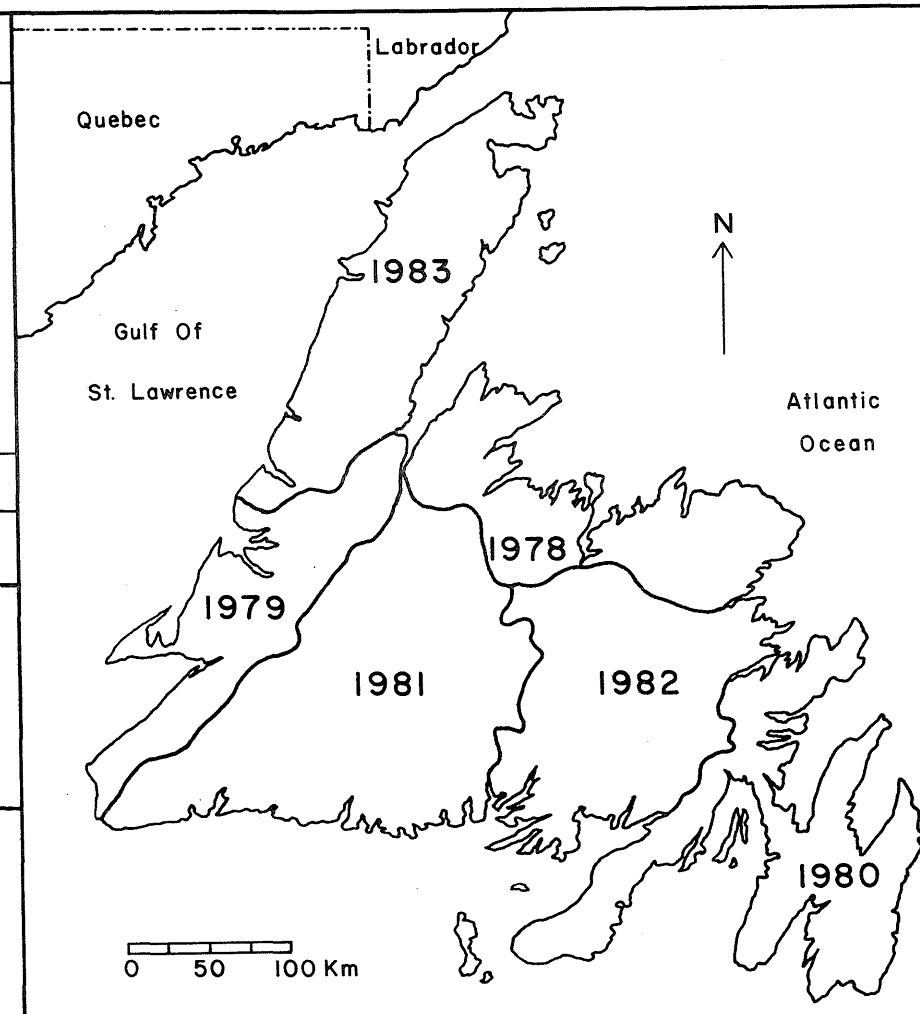


Figure 6. Major peat fuel concentrations and energy potential (from Wells and Vardy, in press).

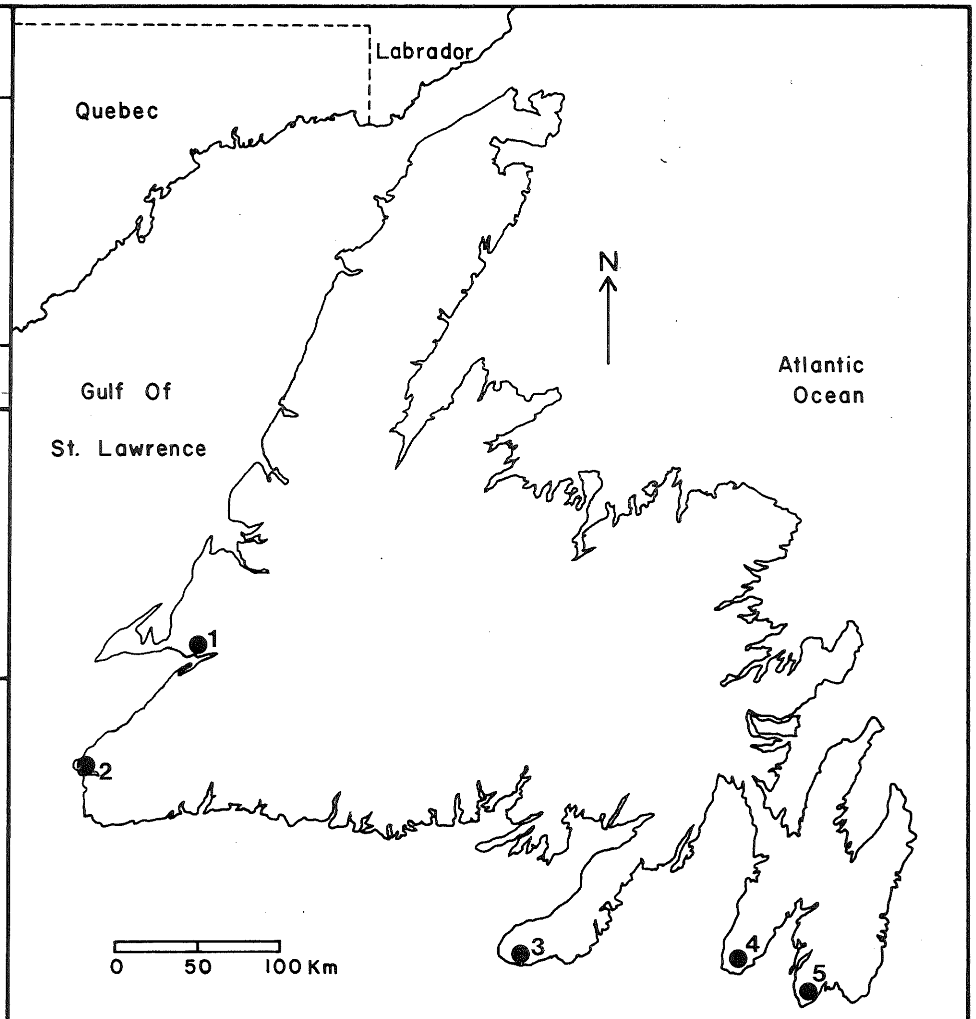
Location	Peat fuel reserves (m^3)	Barrels oil equivalent*	Millions KWH annually	Plant life
1. Stephenville	72 770 100	26 200 000	406	25
2. Codroy	45 418 500	16 350 000	252	25
3. Lamaline**	75 000 000	27 000 000	420	25
4. Branch**	75 000 000	27 000 000	420	25
5. St. Shotts**	75 000 000	27 000 000	420	25
Total	343 188 600	123 550 000	1 918	

Total peat reserves in all five locations = 123 550 000 (barrels oil equivalent)

Total energy consumption in Newfoundland, 1979 = 18 250 000 (barrels oil equivalent)

Conversion factors for peat (m^3) in situ to barrels oil equivalent = 0.36 (based on figures from Montreal Engineering study of peat bogs in northeast New Brunswick; and, "Energy From Peat in Finland" published by VTT, Technical Research Center of Finland) (See Figure 4).

**Preliminary estimates; peatland survey not completed. (Figure courtesy of Northland Associates Ltd., St. John's, Nfld.)



inventory data for the Avalon and Burin Peninsulas also indicate concentrated deposits of about 75 million m^3 of fuel peat for each of the blanket bog areas near the communities of Lamaline, Branch and St. Shotts (Sites 3, 4, 5; Figure 6). Thus, the five concentrated fuel peat deposits could conceivably supply 1, 918 million kilowatt hours of electricity annually for the next 25 years. This equals one-third of the current electrical energy consumption on the Island of Newfoundland.

Summary

Nine morphological peatland types are described for Newfoundland. They are Atlantic plateau bog, blanket bog, domed bog, slope bog, basin bog, string bog, slope fen, ladder fen, and ribbed fen. Three of these peatland types - plateau bog, blanket bog and to a lesser extent, slope bog - contain fuel peat that is relatively close to the surface. Since they are often quite extensive, they offer the greatest potential for fuel peat development. Several smaller peatland types such as basin bogs and slope fens also contain peat suitable for fuel. However, their depth (1-2 m) and relatively small size (< 10 ha) prevent utilization based on current harvesting methods.

The potential of peatlands for afforestation has not been fully demonstrated in Newfoundland. Preliminary results from six experimental sites indicate that the more nutrient-rich slope fens are the most desirable, ecologically; however, their small size is a deterrant factor in any large scale ditching and drainage operations. Economically, the larger plateau bogs, slope bogs and domed bogs are the most suitable for large scale drainage projects. However, exposure is a serious problem on these larger sites especially during the winter; also these bogs are nutient-poor and the costs of fertilization must be considered.

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INTRODUCTION TO PEAT LANDFORMS OF PRINCE EDWARD ISLAND

C. Veer

First of all I must thank the organizers of this workshop for giving me this opportunity to contribute my small part in the characterization and sampling of organic soils in this part of the world.

It somehow seems out of place that a person living and working in Canada's smallest province and which has a mere 6500 ha of organic terrain, is given this opportunity.

As most of you know soil surveyors have been in the process of remapping the soils of Prince Edward Island since 1970. In the development of the first field legend the organic soils ended up under the heading miscellaneous soils and the CSSC subgroups were to be field symbolized on bogs of significant size. No doubt it was an improvement on the peat and muck classification that had been used by most soil surveyors in the maritime provinces up until then.

However, when the time arrived to make practical statements on the organic soil areas it was clear that significant information was lacking and that the final product was not much of an improvement since the peat and muck days. Obviously we had a problem.

In asking ourselves what the problems were, some answers were obvious and nearly all might be boiled down to the fact that most soil surveyors are unfamiliar with the organic terrain environment, i.e. unfamiliar with its hydrology, materials, and botany.

The general concept is that in terms of mineral soils organic terrain is always poorly drained and all parent materials are more or less decomposed. Peat and muck therefore does not seem to be such a bad concept. Of course other professions, or disciplines if you like, were and are interested in organic terrain and they also make their classification schemes. However, not much cooperation is evident between disciplines. This, let us hope, will change. By 1977 we had reached the point of knowing the whereabouts of many Terric Humisols and Fibric Mesisols without knowing what do with this information. It was obvious that many subgroups occurred in rather different environments.

It was also obvious that in order to be able to observe systematically we needed a scheme, a theory if you like, to provide us with categories of thought.

The scheme that evolved on Prince Edward Island to satisfy this need and that gave us categories of thought is based on concepts evolved elsewhere and modified to fulfill what we thought were our needs.

What, you might wonder, were our needs?

Well, first of all, we took the position that our main assumption should be that in the foreseeable future most organic terrain remains in its present land use, that is not intentionally exploited by man. We also concluded that it is not of much practical use for the present at least, to know in great detail the spatial distribution of soils to the subgroup or series level on most if not on all organic terrain in the province.

What we did consider important is the relative ion concentration in the organic terrain environment, the floristic composition and position in the landscape.

Given these three variables it was felt that the most urgent questions asked at the present could be sufficiently well answered and that if at some time in the future it was necessary to locate organic terrain with certain attributes, likely candidates could readily be located for further study. One important parameter is not clearly expressed in the scheme as yet, namely, the behaviour of the watertable, although generalization might be made. If it were possible to incorporate this in a classification, it might help us in explaining plant succession, biomass production, humification, etc.

Since we on Prince Edward Island are concerned with only a small land mass and, for all practical purposes one climatic region, it was decided to construct a rather simple landform classification based on genetic material and surface expression. It could be argued that the hierarchy of the classification would have been better served if it had started with ecological systems such as in the U.S. Wetland classification, i.e. Marine, Estuarine, Riverine, Lacustrine, Palustrine. However, we felt that our needs were adequately taken care of by relating genetic material and surface expression and their position in the landscape as it is in turn expressed in the landform. In the Prince Edward Island classification we named organic terrain with acid and nutrient poor materials and characterized by a moss and ericaceous plant community a bog landform.

Those with slightly acid and relatively rich materials characterized by a non-ericaceous plant community were termed a swamp landform, and organic terrain with intermediate acid and nutrient materials was termed a fen landform.

When we consider that there is an infinite gradation in many landforms it looks like a neat package on paper.

We further divided the genetic landform materials on the basis of surface expression as expressed as a signature on aerial photographs.

The bog, fen, and swamp landforms were split on the basis of what we thought to be differences that would express natural capabilities and exploitation limitations and I am thinking of natural capabilities such as the supportive ability for wildlife (such as ducks or beaver); the somewhat nondestructive extraction of resources such as white cedar wood for posts and shingles, saw logs, pulpwood, fuelwood, etc.; and the destructive extraction of resources such as the mining of horticultural peat and also fuel peat. Depending on which viewpoint one takes, we could also consider the use of organic terrain for agriculture and horticulture, which of course ultimately is also destructive.

All this of course is nothing new. What we think is different in the Prince Edward Island classification is the way in which our landform scheme connects to the organic soil Great Groups (Fibrisol, Mesisol, Humisol).

Many field observations showed us that certain subgroups appeared more frequently on one landform than on another landform. Thus on a Plateau Bog landform as recognized by its signature on an aerial photograph we have a high probability of finding a Typic Fibrisol or, for another example, on a Brookswamp landform a Terric Humic Mesisol.

We realize fully that these are probabilities and that nature has worked under very diverse conditions in the last 10,000 years or so.

In order to get around this problem and to give us the ability to describe any soil found on a landform, the concept of Association and Map Units was introduced into the scheme. This now gives us the ability to indicate any soil without losing its connection with the landform.

Every organic landform was given a corresponding association name. For example the Armadale association is found on the plateau bog landform. But the plateau bog landform by definition has normally inclusions of other subdominant landforms such as flat bog landform or channel fen landform. The only symbolization that is required is Armadale (ARD). The ARD expresses therefore a broadly defined environment without going into any detail. But still it creates a thought process that includes peat materials, hydrology, floristics, wildlife, forestry, trafficability, or whatever. Of course often more detail is required and the various subdominant landforms will be delineated. It happens that the most common map unit on the plateau bog landform is a Typic Fibrisol (map unit ARD1). Frequently it is a Mesic Fibrisol (map unit ARD2).

The Mesic Fibrisol map unit is considered to be the most common map unit on the flat bog peat landform (map unit POW1). Thus, map unit ARD2 and POW1 may contain soils of the same series if all the series criteria are met.

I hope that I have given you the thoughts and principles on which organic soils classification for Prince Edward Island rests.

DEVELOPMENT OF ORGANIC SOILS AND DESCRIPTION OF PEAT MATERIALS

Charles Tarnocai

The term "organic soils" refers to all of the soils which are included in the Organic Order as well as to the Organic Cryosols (Canada Soil Survey Committee 1978). These soils comprise approximately 12% of the land area of Canada. On approximately 927 113 km^2, according to the Soil Map of Canada (Clayton et al. 1977), they are the dominant soils and, on an additional 152 751 km^2, they occur in association with other soils.

Organic Soil Development

Peat deposits are the result of either the filling-in or the gradual build-up processes or of a combination of these two processes. In some cases, the peat deposition processes produce an organic soil with very little or no further chemical or physical changes having to take place. There is, however, generally further decomposition. In either of these instances subsequent major chemical, physical and morphological changes occur when permafrost develops (Tarnocai 1972). A majority of the organic deposits in northern Canada have reached an advanced state of development in a permafrost-free environment with permafrost forming at a much later date.

The genesis of organic soils began at the time when the basal peat was deposited and continues to the present. During this time physical and chemical changes have taken place in the soil but the changes are not as great, even in the lower or older layers, as in some mineral soils. Organic soils in a sense represent a high energy balance system where a great deal of energy is stored and very little is released (by degradation). The energy which is released is mainly from the surface layers with an increasingly smaller amount released from the lower layers.

The peat parent material is continuously being added to the surface by vegetation litter. Thus, the parent material of organic soil reflects the succession of vegetation, characterized by layers differing not only as to their degree of decomposition but also as to the nature of the parent materials.

Organic soil, in most cases, is composed of more than one peat layer. These peat layers are the reflection of the type of vegetation contributing to the organic layer rather than of the later soil-forming processes, as in the case of the development of soil horizons in mineral soils.

Peat Materials

Four main types of peat materials are usually associated with organic soils: sphagnum, fen, forest and sedimentary peats. Their separation is based on both the botanical origin and the physical and chemical properties of the peat material. Since this is biological material originating from a particular vegetation, each type of peat material is related to a certain type of vegetation and peat landform. Because of the slow deposition rate of the peat material and the variation in conditions such as climate, ground water, and drainage that could take place during this period, the composition of this vegetation changes. Pure types as well as intergrades and transitional types can develop.

This is reflected by the peat material, which may occur as a relatively pure substance or which may be transitional in its physical and chemical properties.

A description of these peat materials is given below; their physical and chemical properties are included in Tables 1, 2 and 3.

1. Sphagnum Peat

Sphagnum peat material develops on poorly to very poorly drained sites which are isolated from mineral-influenced ground water. The dominant peat-former is Sphagnum moss, although small amounts of leaves and woody material from Ericaceous shrubs and woody material from spruce and tamarack may also be present.

Sphagnum peat is usually undecomposed (fibric), light yellowish-brown to very pale in color and loose and spongy in consistence with the entire Sphagnum plant being readily identifiable. The rubbed fiber content of sphagnum peat is approximately 60 percent. The material has the lowest pH, ash content, bulk density and CEC of all peat materials.

2. Fen Peat

Fen peat material develops on very poorly drained sites which are influenced by minerotrophic ground waters. This peat material is derived primarily from sedges (Carex spp.), brown moss (Drepanocladus spp.) and woody species of willow, birch and tamarack.

The separation of sub-types of fen peat is based on the dominance of the plant material comprising the peat.

2.1 Brown Moss Fen Peat

Brown moss fen peat is composed of dark coloured mosses of the Genera Drepanocladus, Calliergon and Aulacomnium with the moss plants generally being readily identifiable with the naked eye. This peat is usually moderately decomposed to undecomposed, loose to slightly matted, extremely to very strongly acid, and has a bulk density of approximately 0.11 g/cm^3.

2.2 Sedge Fen Peat

Sedge fen peat is composed dominantly of Carex spp. with some Eriophorum spp. This peat is generally moderately decomposed and matted. The sedge leaves and Eriophorum plant remains are readily identifiable by the naked eye. The peat contains large amounts of very fine roots of the above plant species. It is extremely to strongly acid and has a bulk density of approximately 0.11 g/cm^3.

2.3 Woody Fen Peat

Woody fen peat is composed dominantly of woody species such as tamarack and willow. The matrix of this peat, however, contains various amounts of materials derived from Carex spp. This peat is usually moderately decomposed and, in general, wood fragments are easily identifiable. It is extremely to strongly acid and has an average bulk density of approximately 0.11 g/cm^3 but, with high wood content, the bulk density may go as high as 0.18 g/cm^3.

2.4 Sedge-Brown Moss Fen Peat

Sedge-brown moss fen peat is composed of both Carex spp. and brown moss species. This peat is generally moderately decomposed and has a loose or slightly matted appearance. It is very strongly acid and has a bulk density of approximately 0.11 g/cm^3.

3. Forest Peat

Forest peat material develops on poorly to very poorly drained sites. It is generally associated with swamps and bogs and the material is derived primarily from forest vegetation.

The separation of sub-types of forest peat is based on the dominance of the plant material comprising the peat.

3.1 Feather Moss Forest Peat

Feather moss forest peat is composed of feather mosses (Hypnum spp., Hylocomium spp., and Pleurozium spp.) and some woody materials derived dominantly from coniferous tree species.

This peat is moderately decomposed, light brown in color, and loose or slightly matted. The feather mosses are easily identifiable with the naked eye. The rubbed fiber content is generally 10-60% and the peat is extremely to strongly acid. The bulk density is approximately 0.12 g/cm^3 and is very similar to that of those peats dominated by brown mosses.

3.2 Woody Forest Peat

Woody forest peat is composed dominantly of woody materials derived mainly from tree species. The woody materials are derived from both coniferous and deciduous tree species. In general the wood fragments are easily identifiable in this peat. Well decomposed woody forest peat, however, must be very carefully examined, usually with a 10X hand lens, in order to identify the wood fragments.

Woody forest peat is extremely to slightly acid. The average bulk density is approximately 0.15 g/cm^3, the highest of all peat materials, and it may go as high as 0.21 g/cm^3 in material with high wood content.

3.3 Feather Moss-Woody Forest Peat

Feather moss-woody forest peat is composed of both feather mosses and woody plant remains. This peat is generally moderately decomposed and has a slightly matted appearance. It is extremely to strongly acid and has a bulk density of approximately 0.11 g/cm^3.

4. Sedimentary Peat

Sedimentary peat develops in shallow lakes and ponds. This peat is primarily derived from aquatic plant debris (algae and aquatic mosses) which has been modified by aquatic animals. The material is plastic and slightly sticky and is dark brown to gray in color. It shrinks upon drying to form clods that are very difficult to rewet.

This peat is generally well comminuted and has few or no plant fragments recognizable by the naked eye. It is extremely acid and has a large ash content. The carbon content is generally 17-52%. The average bulk density is 0.13 g/cm^3, but may go as high as 0.17 g/cm^3 and the pyrophosphate test usually produces a pale-colored extract.

Table 1. Ranges and Means for Selected Physical and Chemical Analysis of Peat Materials from the Mackenzie River Valley, N.W.T. (Mills 1974)

Peat Material	No. of Samples		Fiber Content, % Unrubbed	Fiber Content, % Rubbed	C/N Ratio	C.E.C. m.e./100 gm	Pyrophos. %	Ash %
Sphagnum Peat	19	Range	64-98	4-62	38-127	81-162	5-93	0.9-12.1
		Mean	79.16	32.11	72.1	107.3	23.37	4.24
		S.D.	10.84	20.58			23.33	
Forest Peat	4	Range	46-64	6-12	25-32	102-106	19-68	4.6-7.8
		Mean	54.00	8.50	28.5	104	33.75	6.2
		S.D.	7.83	2.52			23.09	
Sedge-Brown Moss Fen Peat	17	Range	28-92	2-60	16-51	85-131	5-100	3.5-20.0
		Mean	59.06	16.24	33.9	111.3	33.23	10.7
		S.D.	17.79	17.04			22.22	
Woody Fen Peat	2	Range	48-60	4-18			40-80	
		Mean	54.00	11.00	27	131	60.00	9.4
		S.D.	8.49	9.90			28.28	

Table 2. Range and Means for Selected Physical and Chemical Analysis of Peat Materials from the Roseau River Watershed, Southeastern Manitoba (Mills 1974)

Peat Material	No. of Samples		Fiber Content, % Unrubbed	Fiber Content, % Rubbed	C/N Ratio	C.E.C. m.e./100 gm	Pyrophos. %	Ash %	Bulk Density g/cc
Sphagnum Peat	15	Range	58-100	18-92	50.3-99.9	91.9-157.9	0.2-13.4	3.0-20.0	0.05-0.10
		Mean	84.27	51.33	68.12	119.06	7.23	7.29	0.074
		S.D.	16.12	24.05	18.35	18.09	3.13	5.31	
Woody Forest Peat	22	Range	34-88	0-44	20.4-49.2	76.2-255.5	5.9-91.0	7.0-31.9	0.07-0.52
		Mean	59.33	12.57	34.96	186.50	39.49	18.27	.167
		S.D.	13.55	16.05	11.65	40.70	25.82	6.52	
Feather Moss Forest Peat	12	Range	24-78	4-32	15.6-49.9	161.7-255.6	12.5-59.1	10.1-33.0	0.11-0.16
		Mean	53.00	11.00	32.93	202.47	33.73	17.32	0.149
		S.D.	14.83	8.55	10.23	32.85	13.07	6.42	
Sedge-Brown Moss Fen Peat	36	Range	24-84	2-24	18.7-48.8	86.4-239.4	5.2-60.4	5.5-39.7	0.08-0.20
		Mean	47.89	8.00	26.39	150.87	22.72	14.47	.131
		S.D.	10.36	5.92	10.62	32.94	14.84	8.35	
Woody Fen Peat	10	Range	30-78	2-20	23.8-34.9	107.9-217.5	5.4-23.2	4.9-59.9	0.09-0.15
		Mean	54.60	8.40	30.17	155.29	11.90	15.06	0.119
		S.D.	13.79	5.06	3.84	37.37	6.22	16.75	

Table 3. Physical and chemical characteristics of peat materials (Tarnocai 1980).

Peat Material	No. of Samples	Range(r) Mean(u)	Fiber Content Rubbed %	Fiber Content Unrubbed %	Ash %	pH H_2O	pH $CaCl_2$	C %	B.D. g/cm^3	Exchangeable cations meg/100g Ca	Exchangeable cations meg/100g Mg	CEC meg/100
Sphagnum Peat	9	r	42–84	66–98	1-10	3.4–3.9	2.9–3.4	43.8–47.8	0.08–0.10	7.7–16.9	2.6–13.7	19.4–31.5
		u	59	79	4	3.7	3.1	46.3	0.09	11.5	9.2	22.8
Brown Moss Fen Peat	3	r	22–70	64–85	3–18	4.1–5.1	3.2–4.8	42.8–50.4	0.09–0.12	18.9–185.2	13.7–28.4	33.1–213.7
		u	41	74	8	4.5	3.9	46.2	0.11	76.9	18.6	95.8
Sedge Fen Peat	29	r	4–36	26–78	2–23	3.4–6.0	3.0–5.8	42.2–55.7	0.06–0.15	6.5–165.0	2.2–54.8	19.0–168.4
		u	14	54	8	4.6	4.2	48.7	0.11	47.7	21.2	67.4
Woody Fen Peat	10	r	8–30	40–76	8–52	2.5–5.7	2.2–5.5	27.6–52.8	0.08–0.18	23.3–146.2	21.2–70.5	56.2–181.8
		u	17	56	19	5.0	4.7	45.7	0.11	59.5	40.8	101.9
Sedge-Brown Moss Fen Peat	4	r	5–16	30–72	4–11	4.8–5.1	4.2–4.8	45.4–52.4	0.10–0.11	66.5–96.9	4.3–17.2	70.8–112.2
		u	12	53	8	4.9	4.5	47.9	0.10	80.6	10.7	91.5
Feather Moss Forest Peat	10	r	6–24	38–74	5–56	3.6–6.0	2.8–5.8	25.0–49.3	0.09–0.12	69.0–144.0	11.1–23.8	80.1–168.6
		u	14	59	19	4.9	4.4	43.3	0.10	117.52	13.9	159.5
Woody Forest Peat	32	r	1–40	36–78	2–53	3.2–6.6	2.8–6.3	27.0–54.2	0.09–0.21	11.9–168.8	1.2–35.5	16.5–205.3
		u	13	57	16	4.9	4.8	46.5	0.15	95.6	21.6	121.4
Feather Moss-Woody Forest Peat	4	r	10–59	40–59	5–10	4.2–5.6	3.9–5.2	44.9–52.4	0.11	27.0–30.0	16.9–49.1	36.7–79.1
		u	24	57	8	4.9	4.6	47.5	0.11	28.3	33.8	57.3
Sedimentary Peat	9	r	2–36	34–94	15–64	2.4–4.5	2.4–4.2	17.4–52.2	0.06–0.17	24.2–99.0	3.2–21.8	55.5–103.1
		u	12	65	39	4.1	3.5	33.7	0.13	58.2	13.2	78.9

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SAMPLING METHODS

Charles Tarnocai

Due to the water-saturated conditions which exist in organic soils, most of the sampling is carried out by use of peat augers, operated by one man, to sample the peat deposit to a depth of 5 m or more. All of these augers are of the core type which remove a complete or half cylinder of peat from the ground. Depending on the sampler used, varying degrees of disturbance are experienced by the sample.

Excavation of the peat by shovel is only feasible when the deposit is drained and, even then, only provides access for sampling of the near-surface portion of the peat deposit. Blocks are sometimes cut from a frozen peat deposit by chain saw when a large volume of sample is required or when a large profile is needed for examination. Brief descriptions of the most common sampling methods used by Soil Survey follow.

MINI-MIZED MACAULAY PEAT SAMPLER

This sampler is a smaller version of the 2-inch Macaulay peat sampler designed by the Macaulay Institute for Soil Research, Scotland. The sampler cuts a 50-cm long, one-half cylinder of material that is relatively undisturbed and for which a reasonably accurate volume can be determined. The boundaries between successive samples, however, are somewhat disturbed by the cone. In order to compensate for this disturbance it is preferable to collect alternate samples from an adjacent hole. The intervening peat material need not be removed from above the desired sampling depth. A more detailed description of the Mini-Mized Macaulay sampler and an explanation of its operation are given by Day et al. (1979).

HILLER SAMPLER

This sampler has been used for peat studies for well over half a century. Rotating the sampler at the desired sampling depth scrapes the surrounding peat into the sample chamber. Thus, the sample is disturbed and is not suitable for volume determinations. A more detailed description of the Hiller Sampler and an explanation of its operation are found in MacFarlane (1969).

PORTABLE SAMPLER

This sampler is used mainly for coring frozen peat and stone-free, frozen, fine textured material. The sampler consists of a steel coring bit, five 1-m long extension rods and the T handle. With this tool it is possible not only to determine the depth of the frozen peat deposit and the thickness of various peat layers but also to obtain samples for physical and chemical analysis and for ice content and bulk density determinations. A more detailed description of the portable sampler and an explanation of its operation are found in Zoltai (1978).

ELECTRIC CHAIN SAW

The chain saw is used only in perennially or seasonally frozen peat. With the chain saw a vertical profile can be exposed for the examination of frozen peat materials and for obtaining samples for physical and chemical analysis, ice content determination, and for thin sections. The excavation is carried out by using the chain saw to make vertical cuts in an approximately 30 x 30 cm grid pattern. These blocks, which are still attached at the base, are cut away by using an electric hammer.

No modification of the chain saw is required for this work and the chain saw is operated in the normal way. The use of the electric chain saw is recommended instead of the gasoline type since the fumes generated in the soil pit by the gasoline engine result in serious headaches and discomfort.

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ORGANIC SOIL FIELD TESTS

J.H. Day

When describing and mapping organic soils, surveyors use simple field tests to assist in making their judgments or to validate them at a later time. For many, that time occurs during the evenings in a motel when judgments on fiber content and other values can be confirmed.

The methods and equipment used were briefly described and shown to the participants. The attached material was published in "The System of Soil Classification for Canada" (1974).

MORPHOLOGICAL FEATURES AND NOMENCLATURE

To characterize organic soils adequately, their morphology should be described as thoroughly and quantitatively as possible. Morphological features that seem most important in descriptions follow.

Layer Thickness

Cryic organic soils usually have very irregular surfaces with mounds of variable vertical and horizontal dimensions. If the mounds are organic and are so closely spaced that the pedons are less than 5 m, the soil should be classified as though the mounds had been leveled. If the mounds are mineral or are so widely spaced that they do not occur in each pedon of 5 m, the soils should be classified as they now exist.

Definition of Size of Fibers

Fibers are the organic materials retained on a 100-mesh sieve (0.15 mm diameter), except for wood fragments that cannot be crushed in the hand and are larger than 3/4 inch (2 cm) in the smallest dimension. Reed and rush fragments retained on the sieve should be picked out and weighed separately.

Fiber Content, Pyrophosphate Test, and pH in $CaCl_2$

The amount of fiber and its durability (as measured by destruction on rubbings) are the most important characterizing and differentiating features among different kinds of organic soils. The fiber content for the undisturbed and rubbed states should be estimated in a moist to wet condition; if the soil is dry, it should be moistened.

For the undisturbed or unrubbed estimate, a fragment of the layer is broken in the vertical direction and an area of at least 4 sq. inches (25 cm) is scanned with the aid of a 10 X hand lens. With practice, fiber content can be estimated to the nearest 5 to 10%. Horizontal planes should be avoided when making the estimate because they may be cleavage faces that have a concentration of a certain size of fibers.

To determine the content of fiber after rubbing, a fragment of the layer is rubbed between the thumb and forefinger about ten times or a fragment is macerated with a knife blade in the palm about ten times using very firm pressure. The material is then molded into a ball, broken in half, and the broken face is observed with a lens to estimate the fiber content. Skill in estimating the correct fiber content, as with hand texturing, is enhanced by comparing the estimate with a laboratory-determined value.

The determination of fiber content and pyrophosphate solubility is easily performed in the laboratory or wherever tapwater is available, by using a 5- or 6-ml plastic hypodermic syringe modified to make a measuring device.

The syringe is modified by cutting away half of the cylinder wall, in a longitudinal direction, between the 0- and 6-ml marks. The plunger end, the needle end, and the piston are not altered in any way. Only syringes that have calibration marks embedded in the plastic are suitable for extended use (Fig. 1).

The procedures for preparing the sample and for determination of unrubbed and rubbed fiber, pyrophosphate solubility, and pH follow.

1. Preparation of sample
   Place about 25 cm of sample on a strip of paper towel, forming the sample into a cigar shape. Roll up in the paper towel and squeeze lightly to express surplus water, that is, dry the sample until it does not glisten but is still very moist. Unroll and, using scissors, cut the sample into 0.5 cm lengths. Mix the cut pieces to ensure representative subsamples.

2. Determination of unrubbed fiber content

2.1 Pack the modified syringe adjusted to 5 cm^3 capacity level-full with sample, pressing hard enough to express air but not water. Transfer all the soil material, using the rounded end of a spatula 6 mm wide, to a 3-inch-diameter (7.5 cm), 100-mesh sieve.

2.2 Wash the sample with cold water from a faucet adjusted to deliver about 400 ml in 5 seconds until the water passing through the sieve appears clean when observed against a white surface. Collect the sample at one side of the sieve. Dry the sample by pressing a finger against it over a wad of towel held against the bottom surface of the sieve.

2.3 Transfer the sample cleanly into the modified syringe and pack it level-full into the smallest volume by simultaneously pushing the syringe piston and leveling the surface with a spatula. Be sure that the moisture content is the same as that in the initial sample (Step 1). Water can be withdrawn from the sample by lightly pressing a piece of paper towel on the sample surface.
   Read the volume and express as a percentage of the initial volume.
   This percentage represents the unrubbed fiber content.
   Transfer the sample to the 3-inch (7.5 cm) sieve.

3. Determination of rubbed fiber content

3.1 Rub the above sample lightly between thumb and finger(s) under a stream of water until the water passing through the sieve is clean. Clean fibers will roll between thumb and fingers rather than glide or smear.

3.2 Dry the sample residue on the sieve as described above in Step 2.2. Transfer the sample residue to the modified syringe and measure its volume as described in Step 2.3. This percentage represents the rubbed fiber content. Discard the residue.

4. Determination of pyrophosphate solubility

Place a heaping 1/8 teaspoon (1 g) of granular sodium pyrophosphate in a small plastic screw-topped container (Fig. 1). Add 4 ml of water and stir briefly. Pack the modified syringe, adjusted to 5 cm^3 capacity, with material from the sample prepared in Step 1 above. Place the sample into the plastic container, stir, cover, and let stand overnight. Mix again thoroughly. Insert one end of a strip of chromatographic paper, about 5 cm long, vertically into the suspension with tweezers. Let stand until paper strip has wetted to the top with screw top in place to avoid evaporation from the paper strip. Remove test strip with tweezers, cut off and discard the soiled end. Blot the remaining strip on absorbent paper. Compare color with Munsell chart, using good illumination and viewing through holes in the chart (Fig. 2).

5. Determination of pH in $CaCl_2$

The pH in 0.01 M $CaCl_2$ may be measured on the sample prepared in Step 1 above. To make allowance for the dilution of the $CaCl_2$ solution by the water contained in the peat, the $CaCl_2$ solution used is prepared at 0.015 M.

Place 4 ml of 0.015 M $CaCl_2$ in a small plastic screw-topped container. Transfer 1/2 teaspoonful of packed moist sample into the plastic container, mix, after about 15 minutes read pH on narrow-range test papers or by a combination glass electrode.

Color

Color is determined in the moist or wet condition on a broken face, on a mass that has been firmly pressed between the thumb and forefinger, and on the rubbed mass. These kinds of color determinations help to distinguish the different kinds of diagnostic layers. Fibric layers containing mostly sphagnum fibers exhibit a substantial change in color after being pressed, compared with the color of a broken vertical face. Generally, the mesic layers have a rubbed color darker than the unrubbed color. Also, humic layers with over 50% mineral matter are unique in that the difference in color between the wet rubbed condition and the dry rubbed condition is greater than for other kinds of layers. The rubbed mass usually increases in value by one or more units upon drying.

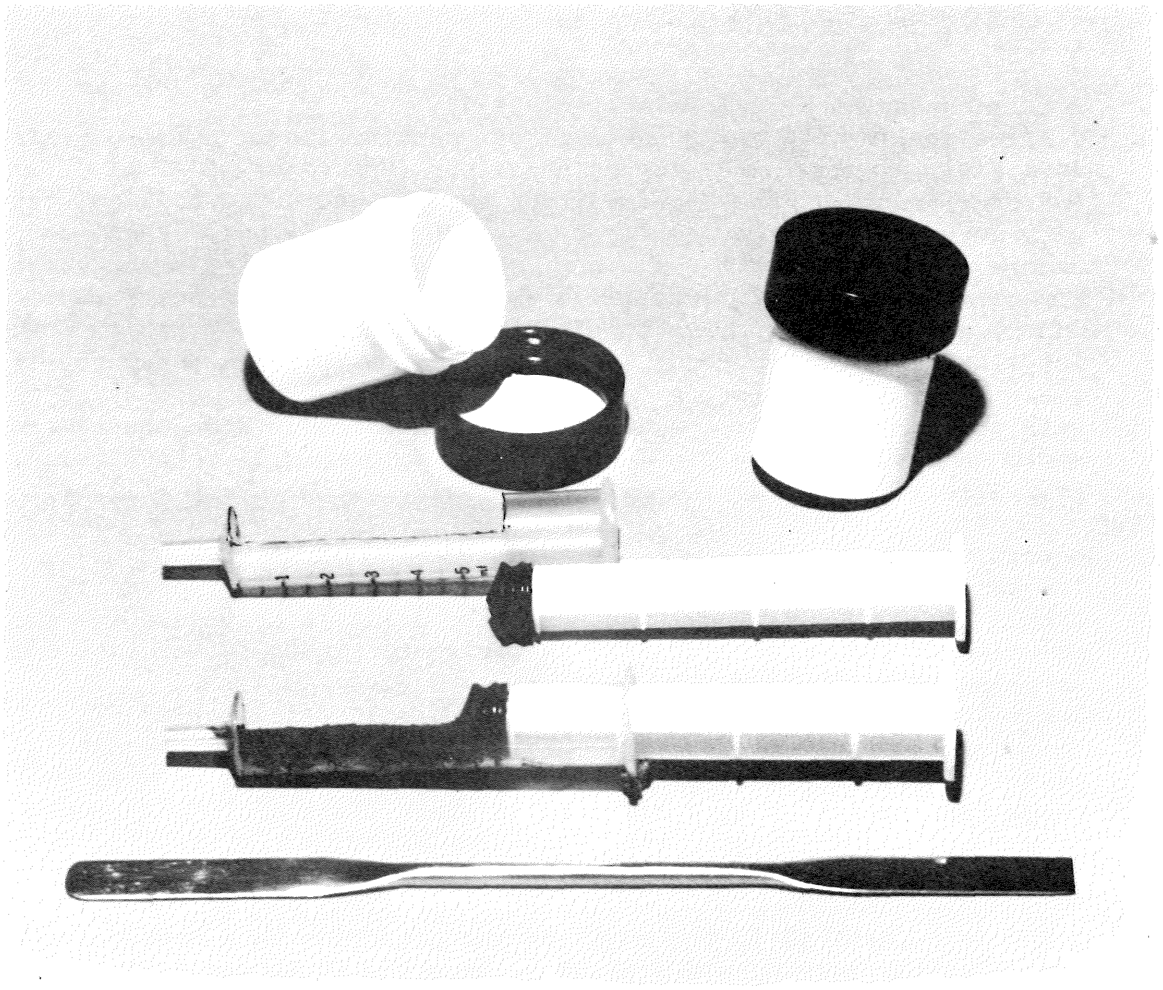

Fig. 1 Empty modified syringe, level-full syringe, plastic screw-top jars, and spatula used in determining some properties of Organic soils.

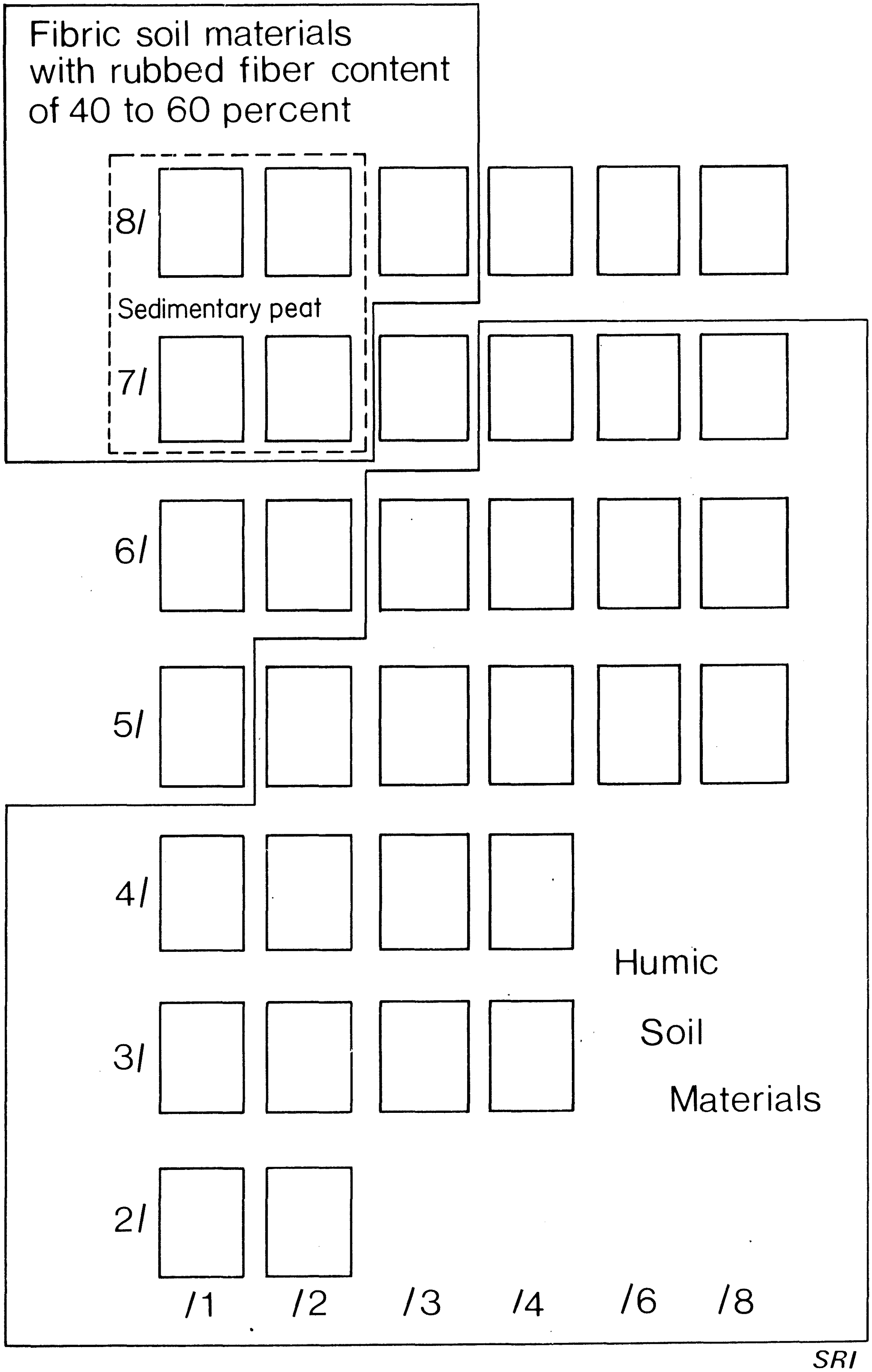

Fig. 2 Sketch of 10YR Munsell color chart showing the sodium pyrophosphate extract color separations for fibric, mesic and humic materials.

THE VON POST TEST

P. Heringa

Decomposition of organic material is encouraged by warm temperatures, increased oxygen, and the abundance of nutrients and moisture. Early western European classification of the humification of bogs has been described by Von Post (1). A fistful of the wet, undrained peat is squeezed to gauge the amount of decomposition. The color of the solution as well as the amount and structure of the remaining organic material are expressed in a "humification" scale of 1 to 10.

1. Undecomposed - plant structure unaltered; yields only clear water colored light yellow brown.

2. Almost undecomposed - plant structure distinct; yields only clear water colored light yellow brown.

3. Very weakly decomposed - plant structure distinct; yields distinctly turbid brown water, no peat substance passes between the fingers, residue not mushy.

4. Weakly decomposed - plant structure distinct; yields strongly turbid water, no peat substance escapes between the fingers, residue rather mushy.

5. Moderately decomposed - plant structure clear but becoming indistinct; yields much turbid brown water, some peat escapes between the fingers, residue very mushy.

6. Strongly decomposed - plant structure somewhat indistinct, but clearer in the squeezed residue that in the undisturbed peat; about a third of the peat escapes between the fingers, residue strongly mushy.

7. Strongly decomposed - plant structure very indistinct but recognizable, about half the peat escapes between the fingers.

8. Very strongly decomposed - plant structure very indistinct; about two-thirds of the peat escapes between the fingers, residue almost entirely resistant remnants such as root fibers and wood.

9. Almost completely decomposed - plant structure almost unrecognizable; nearly all peat escapes between the fingers.

10. Completely decomposed - plant structure unrecognizable, all peat escapes between the fingers.

This method gives an expression of decomposition which is of major importance to users of peat. It does not indicate the resistance to mechanical handling or the rubbed finber content used in the Canadian Classification as described by Lynn [2], and on page 50 of this report.

A correlation of the Von Post (Humification Scale) and the rubbed fiber content is illustrated in Figure 1.

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(1) Post, L. Von. Einige Subschwedische Quellmoore, Upsala 1916

(2) Lynn, W. Unpublished Procedure, SCS, Lincoln, Nebraska

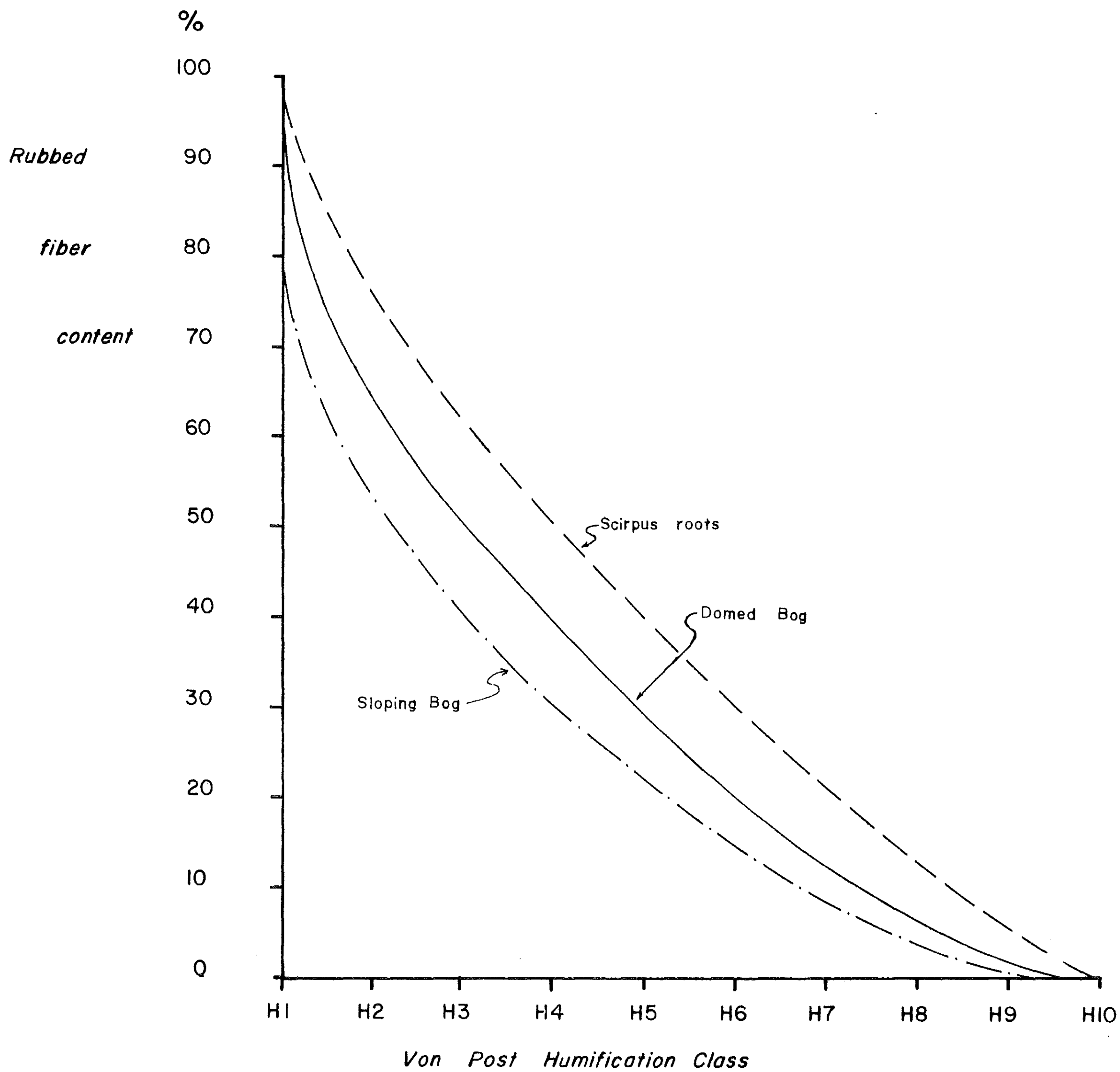

Figure 1. Correlation of the Von Post humification scale and the rubbed fiber content.

THE TECHNIQUE OF MAPPING ORGANIC SOILS

Charles Tarnocai

INTRODUCTION

Soil mapping identifies, describes, and delineates the distribution of soils in a map form in relation to other prominent features, such as landform, parent material and vegetation.

The approach taken to mapping organic soils is not very different from the approach taken in the standard survey of mineral soils. That is, the approach used, as fully as the mapping scale permits, portrays a maximum amount of information respecting the morphological, chemical and physical properties of soils and other parts of the landscape. The method of mapping organic soils described in this paper differs in one aspect from the method used in mapping mineral soils in that it relies much more heavily on landform. In a way the peat landform, represented by similar pedons and polypedons, provides the framework for mapping units, soil series, and associations.

ORGANIC SOIL MAP UNIT

Organic soil map units are representations on a soil map of parts of peatlands having similar peat landforms and soil properties. These soil properties vary within a narrow limit, the exact range depending on the intensity of the survey. The peat landform, however, provides an overall framework for establishing organic soil map units.

Because the peat landform classification is hierarchical in its structure, it permits the recognition of local landform units for most scales of mapping. At the class level general peat landforms (bogs, fens, swamps and marshes) provide a useful basis for mapping at small scales, usually less than 1:250 000, while at the form level local peat landforms (e.g. basin swamp) are the most useful basis for medium and large scale mapping (1:250 000 to 1:25 000).

Landforms provide a natural basis for establishing mapping units in peatlands because they reflect uniform ecological conditions. This uniformity in ecological conditions is reflected in the vegetation communities they support and in the compositional nature of the peat deposit itself. This uniformity also permits a much higher degree of confidence in the mapping of relatively inaccessible peatlands, requires less dependence upon ground truthing, lends itself to air photo and other remotely sensed imagery interpretations and, finally, reduces the cost and time required to conduct such a survey.

The close relationship between peat landforms, organic soils and peat materials has been demonstrated in a study carried out in the Ottawa area (Tarnocai 1980). It was found that swamps are generally dominated by Mesisols with minor amounts of Humisols also being present

(Figure 1). The associated peat materials are dominantly forest peat and minor amounts of forest peat underlain by fen peat. The Huntley soil associations are related to the swamp type of landforms (Table 1). These soils have developed dominantly from nutrient-rich, moderately to well decomposed, forest peat. The Huntley 1 association is characterized by deep (greater than 160 cm) peat materials while the Huntley 2 and Huntley 3 associations are both characterized by shallow peat materials. Huntley 2, however, is dominated by Terric Mesisol and Huntley 3 is dominated by Terric Humisol.

The reverse situation applies in fens (Figure 2B). In this case Humisols dominate with minor amounts of Mesisols also being present. The peat material occurring in this peatland is moderately to well decomposed sedge fen peat (Figure 2B). The Queenswood soil associations are related to this fen peat landform (Table 1). In this case Queenswood 1 is associated with deep sedge fen peat and Queenswood 2 is associated with shallow sedge fen peat.

Mesisols with a surface layer of sphagnum peat (sphagnic phase) are associated with the bog type of peatland. These soils have developed on sphagnum peat underlain by fen or forest peat (Figure 2A and B). The Mer Bleue 1 soil association is related to these peat landforms and is dominated by Typic Mesisol, sphagnic phase (Table 1).

The incorporation of the landform and the associated soil and vegetation descriptions into mapping unit descriptions greatly enhances the possibilities and usefulness of interpretations for biologically oriented fields such as agriculture, forestry and wildlife habitat characterization. The identification of a landform type together with a knowledge of its properties is very useful for engineering interpretations, trafficability studies, and prediction of physical conditions to a considerable depth. The close relationship between landform and peat material enhances such interpretations.

An example of this approach to mapping organic soils is the study carried out in the Roseau River Basin, Manitoba (Mills et al. 1977), in which the landform, soil and vegetation elements are all identified by map symbols.

PHOTO INTERPRETATION

Photo interpretive ability depends upon the accuracy with which the observer can recognize, while using the stereoscope, objects with which he is familiar on the ground. It is of the utmost importance that photo interpreters develop the ability to correlate features on the ground with those in the photographs. Familiarity with local conditions will do more than anything else to improve the quality of photo interpretation.

Photo interpretation of organic terrain usually begins with the analysis of the photo patterns. The most common and most important pattern elements of the natural landscape for interpretation are landforms,

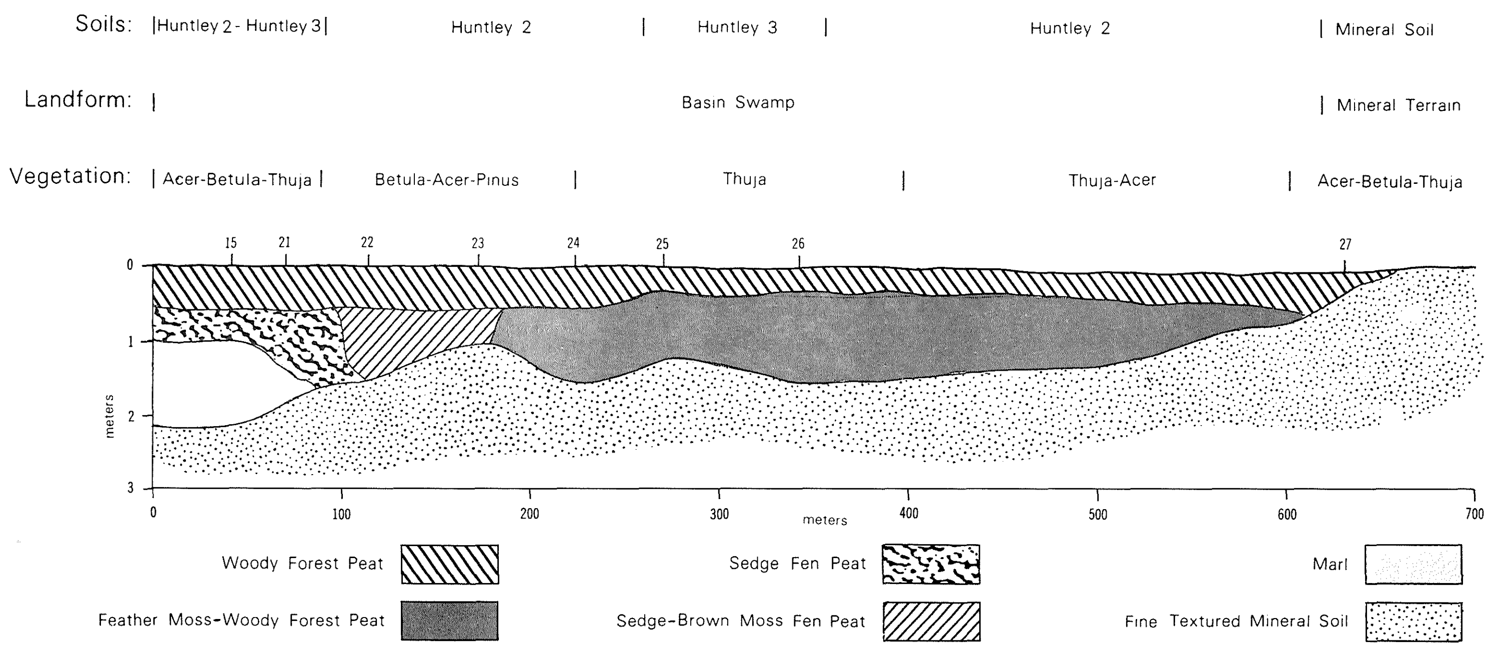

Figure 1. Cross-section of a peatland located south-east of the Ottawa International Airport. The bore holes are identified by their numbers (15, 21, etc.) and their locations are indicated on the cross-section.

Table 1. Grouping of organic soils according to landforms and peat materials.

Soil Association	Landform	Organic Parent Material	Drainage	Taxonomy	Vegetation
Huntley 1	Basin Swamp Stream Swamp	Greater than 160 cm of moderately to well decomposed woody forest peat underlain by woody or sedge fen peat.	poor to very poor	Typic Humisol Mesic Humisol	Mixed maple, birch and aspen (hardwood) or dense cedar forest with an understory of ferns, grasses, mosses and tall shrubs. Stream swamps are usually associated with alder and willows.
Huntley 2	Basin Swamp Peat Margin Swamp	40 to 160 cm of moderately to well decomposed woody forest peat or woody forest peat underlain by sedge or moss fen peat.	poor to very poor	Terric Mesisol Terric Humic Mesisol	Mixed maple, birch and aspen (hardwood) or hardwood - cedar or dense cedar forest with an understory of ferns, mosses, grasses and tall shrubs.
Huntley 3	Basin Swamp	40 to 160 cm of moderately to well decomposed woody forest peat or woody forest peat underlain by sedge or moss fen peat.	poor to very poor	Terric Humisol Terric Mesic Humisol	Mixed maple, birch and aspen (hardwood) or hardwood - cedar or dense cedar forest with an understory of ferns, mosses, grasses and tall shrubs.
Mer Bleue 1	Flat Bog Domed Bog Basin Bog	30 to 160 cm of undecomposed sphagnum peat underlain by moderately decomposed fen or forest peat. Mineral contact occurs at a depth greater than 160 cm.	poor	Typic Mesisol, sphagnic phase Fibric Mesisol, sphagnic phase	Black spruce and tamarack forest with an understory of Sphagnum and feather mosses and Ericaceous shrubs or Ericaceous shrubs and Sphagnum mosses with patches of black spruce and tamarack.
Queenswood 1	Horizontal Fen	Greater than 160 cm of moderately to well decomposed fen peat.	poor to very poor	Humic Mesisol Mesic Humisol	Sedges and mosses.
Queenswood 2	Horizontal Fen	40 to 160 cm of moderately to well decomposed fen peat.	poor to very poor	Terric Humisol Terric Mesic Humisol	Sedges, mosses and some shrubs with clumps of tamarack.
Mineral Soil	Mineral Wetland	Less than 40 cm of moderately to well decomposed peat underlain by fine to medium textured mineral material.	poor to very poor	Rego Gleysol, peaty phase Rego Humic Gleysol, peaty phase	Mixed aspen, maple and birch or willows.

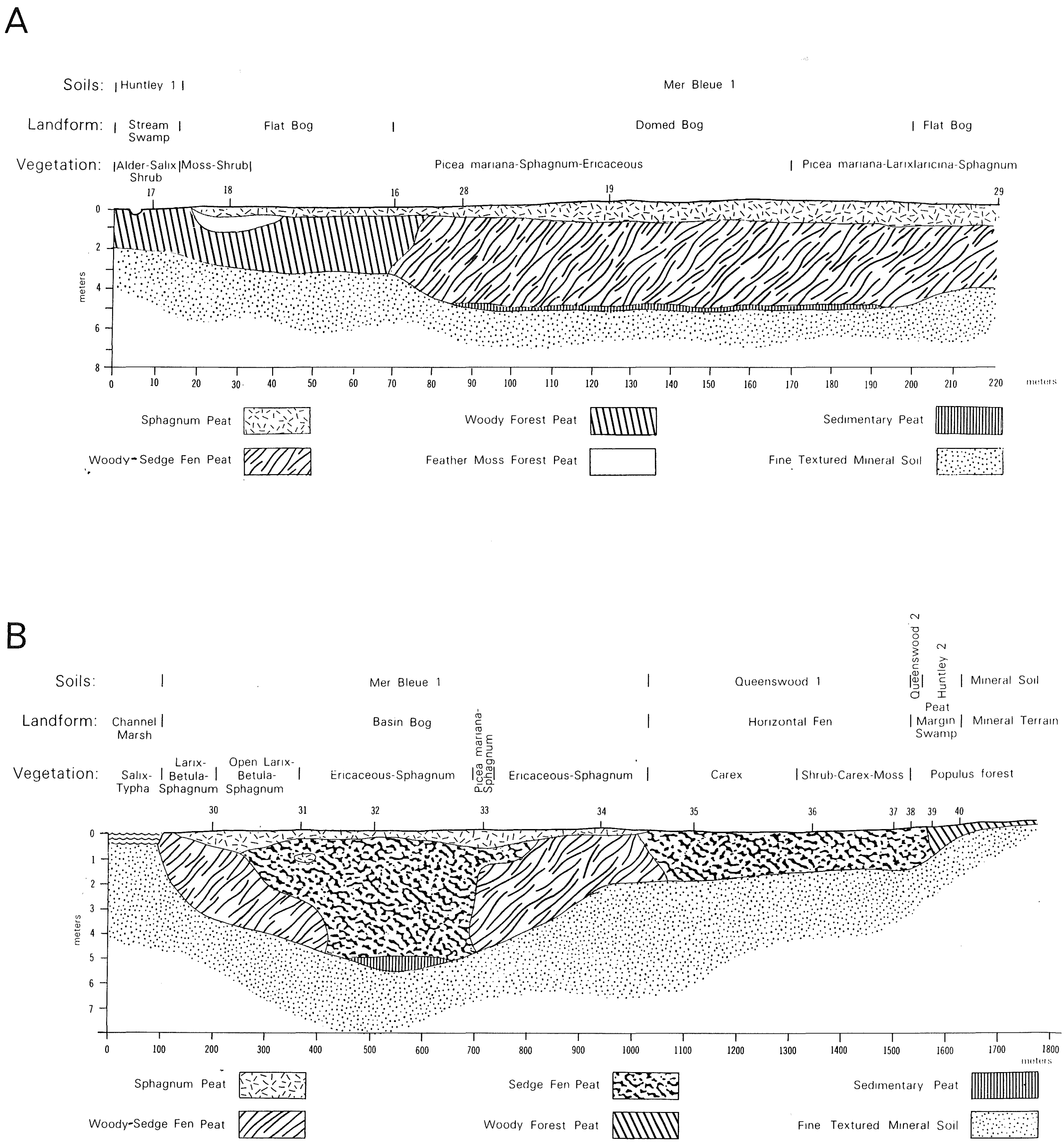

Figure 2. Cross-sections of the Mer Bleue peatland near Ottawa. The bore holes are identified by their numbers (17, 18, etc.) and their locations are indicated on the cross-section.

vegetation and drainage. The energy which is responsible for creating the image on the film material is mainly reflected from the vegetation canopy. Stereoscopic examination of these images makes possible the identification of peat landforms, vegetation and drainage. Soils and associated peat materials can be interpreted using the peat landform in correlation with the ground truth data.

Since the peat landform plays an important role in the interpretation of organic soils, a great deal of work has been carried out in identifying peat landforms on aerial photographs (Tarnocai 1970, 1972, 1974 and Mollard 1972). The stereopairs given in these publications provide excellent examples of different peat landforms found in Canada.

FIELD DATA COLLECTION FOR MAPPING

Field data collection for organic soils associated with peatlands is not much different than data collection for mineral soils. The inaccessibility (lack of roads, etc.) and the continuous wetness associated with organic soils do, however, definitely make the task of data collection harder than on well drained mineral soils. To overcome these difficulties tracked vehicles (J-5 Bombardiers) are commonly used in Manitoba for organic soil mapping. Helicopters are commonly used in soil surveys but, since most of the bogs and swamps are associated with forest cover, finding a landing site is often difficult. Landing sites are located on fens or on seismic lines resulting from oil exploration (northern Alberta and the Mackenzie Valley). Data is collected along the roads in peatlands where this is possible. The last, and probably equally as important, method for collecting field data is by use of foot traverses.

By use of a peat auger field checks of organic soils can be made on a random basis or in a more systematic manner along a transect in the peatland. Because of poor accessibility the random system is most commonly used. The random or exploratory auger holes provide very general information concerning the peat deposit. This should be followed, where possible, by more systematic sampling along a transect. Auger holes should be located along the transect and should be situated on each peat landform and also where changes in peat landform, peat material or vegetation take place. In all cases these auger holes extend to the mineral soil. The transect should be surveyed and leveled and the position of auger holes and the boundaries of peat landforms and vegetation should be recorded during the survey. Using this information, it is possible to produce an accurate cross-section of the peatland (Figures 1 and 2) which indicates not only the surface features (landforms and vegetation boundaries) but also the subsurface features (soils, position and extent of different peat and mineral layers, etc.). This information aids in setting up organic soil series and associations.

Soil materials recovered during this augering procedure are used for soil descriptions and samples are collected for physical and chemical analyses.

Using this system of data collection, the following information should be collected on peatlands and organic soils.

1. Characterization and sampling of the organic soil series or association and establishment of its relationship with the peat landform.

2. Delineation and areal extent of the soil series or association on the photographs, maps and transects.

3. Vegetation characteristics associated with each soil series or association and peat landform.

4. Drainage characteristics of the peatland.

5. Topography of the peatland.

6. Chemistry of the surface waters.

7. Depth of the organic material to the underlying mineral strata and the peat stratigraphy of the peat landform.

8. Nature of the underlying mineral material.

SOIL LEGEND CONSTRUCTION

The soil legend identifies and describes in general terms all of the map units shown on the soil map. During the course of a soil survey the development of the legend usually occurs in stages. A preliminary soil legend is commonly generated before or during the photo interpretation. This preliminary legend then goes through a succession of improvemental stages during the field examination of soils. This legend is then finalized after the soils and peat landforms have been examined, identified and described.

The soil legend should include the nature of the parent material (type of peat, rate of decomposition, and depth of peat), peat landform, drainage class, topography, soil taxonomy, map unit name and symbol, underlying mineral substrate and the associated vegetation. The map legend should also include cross-sections to show the relationships between the peat landform, mapping unit, soil, vegetation and peat materials (Mills et al. 1977).

Examples of organic soil legends or the organic soil portion of map legends used by the Soil Survey are shown in Tables 2-4. These examples indicate that handling organic soils in soil map legends is not different than handling mineral soils. All of these legend examples represent an open legend type. The soils were mapped on the series (Table 2), association (Table 3), or complex of series levels (Table 4).

On many of our soil maps the organic soils are surveyed at a much lower intensity level than are the mineral soils. The legend and the map unit symbol, however, give the impression that they are handled on the same level as the rest of the soils (mineral). Only after a careful examination of the report does it become clear that the soil and map unit descriptions

Table 2. Soil legend of the Roseau River Watershed map area, Manitoba (Mills et al. 1977)

MAP SYMBOL	SOIL NAME	PROFILE TYPE	ORGANIC PARENT MATERIAL: KIND	ORGANIC PARENT MATERIAL: DEPTH (cm)	UNDERLYING SUBSTRATE	DOMINANT LANDFORM	DOMINANT VEGETATION*
	Buffalo Bay	Typic Humisol	Mesic to humic forest	>130	undifferentiated	Mesic swamp	eC-Fm-bS-tL
	Baynham	Typic Mesisol	Mesic forest	>130	undifferentiated	Flat bog	bS-Er-Fm
Ca	**Cayer**	Terric Mesisol	Mesic fen	40-130	clayey	Horizontal fen	Cx-Dp
Cr	**Crane**	Terric Mesisol	Mesic fen	40-130	loamy till	Horizontal fen	Cx-Dp
	Cantyre	Terric Mesisol, sphagnic phase	Sphag/for-fen & fen	40-130	loamy	Hydric swamp	tL-Cx-Mo-Bi
Gd	**Grindstone**	Terric Mesisol	Mesic forest	40-130	loamy till	Flat & sloping bog	bS-Er-Fm
Gd(sp)	**Grindstone, shallow phase**	Terric Mesisol	Mesic forest	40-90	loamy till	Flat & sloping bog	bS-Er-Fm
Ha	**Haute**	Terric Humisol	Mesic to humic forest	40-130	loamy	Mesic swamp	eC-Fm-bS-tL
	Halcrow	Terric Mesisol, sphagnic phase	Sphag/for-fen & fen	40-130	loamy till	Hydric swamp	tL-Cx-Mo-Bi
	Howell	Terric Mesisol, sphagnic phase	Sphag/for-fen & fen	40-130	clayey	Hydric swamp	tL-Cx-Mo-Bi
	Julius	Sphagno-Fibrisol	Sphagnum	>160	undifferentiated	Domed bog	bS-Sp-Er
Kc	**Kircro**	Terric Mesisol	Mesic fen	40-130	sandy	Horizontal fen	Cx-Dp
Kc(b)	**Kircro, burnout phase**	Terric Mesisol	Mesic fen	40-130	sandy	Horizontal fen	Cx-Dp
	Katimik	Typic Mesisol, sphagnic phase	Sphag/for-fen & fen	>130	undifferentiated	Hydric swamp	tL-Cx-Mo-Bi
	Katimik drained phase	Typic Mesisol, sphagnic phase	Sphag/for-fen & fen	>130	undifferentiated	Hydric swamp	tL-Cx-Mo-Bi
Lb	**Lamb Lake**	Terric Mesisol, sphagnic phase	Sphag/mesic forest	40-130	loamy till	Flat & sloping bog	bS-Er-Mo
Mc	**Macawber**	Typic Mesisol	Mesic fen	>130	loamy till	Horizontal fen	Cx-Dp
Mh	**Murray Hill**	Terric Mesisol	Mesic fen	40-130	loamy	Horizontal fen	Cx-Dp
Mh(b)	**Murray Hill, burnout phase**	Terric Mesisol	Mesic fen	40-130	loamy	Horizontal fen	Cx-Dp
Ms	**Marsh Complex**	Rego Gleysol	Humic Aquatic	0-40	undifferentiated	Catchment marsh	Cx-Ty-Ph
Mu	**Mud Lake**	Terric Humisol	Mesic to humic forest	40-130	loamy till	Mesic swamp	eC-Fm-bS-tL
Ok	**Okno**	Terric Mesisol	Mesic forest	40-130	clayey	Flat & sloping bog	bS-Er-Fm
Or	**Orok**	Terric Mesisol, sphagnic phase	Sphag/mesic forest	40-130	clayey	Flat bog	bs-Er-Mo
	Overflowing	Hydric Mesisol	Mesic fen	>130	undifferentiated	Hydric fen	Cx-Dp-Bw
Re	**Reed River**	Terric Humisol	Mesic to humic forest	40-130	sandy	Mesic swamp	eC-Mo-bS-tL
Rr	**Rat River**	Terric Mesisol	Mesic forest	40-130	sandy	Sloping bog	bS-Er-Fm
Sd	**Stead**	Typic Mesisol	Mesic fen	>130	undifferentiated	Horizontal fen	Cx-Dp

Organic Soils

Soil Association	Parent Material	Landform	Soil Landscape Unit	Depth and Description of Materials	Drainage	Vegetation
Queenswood (Q)	Moderately to well decomposed fen peat, occasionally underlain by woody fen peat	Horizontal fen	Q1	40-90 cm. sedge fen peat overlying fine to coarse textured mineral substratum	Very poor	Sedges, mosses and shrubs with clumps of tamarack
			Q2	90-160 cm. sedge fen peat over fine to coarse textured mineral substratum	Very poor	
			Q3	>160 cm. sedge fen peat, or sedge fen peat underlain by woody fen peat	Very poor	Sedges, mosses and shrubs
Huntley (H)	Moderately to well decomposed forest peat occasionally underlain by fen peat	Horizontal catchment swamp, or alluvial swamp	H1	>160 cm. woody forest peat	Poor to very poor	Cedar forest or mixed aspen, birch, maple and cedar forest with an understory of mosses, grasses, ferns, and tall shrubs. Alluvial swamp usually associated with alder and willows.
		Horizontal catchment swamp	H3	40-90 cm. woody forest peat over fine to coarse textured mineral substratum	Poor to very poor	Cedar forest or mixed aspen, birch, maple, and cedar forest or aspen forest with an understory of mosses, grasses, ferns and tall shrubs.
			H6	90-160 cm. woody forest peat over fine to coarse textured mineral substratum	Poor to very poor	

Table 3. Soil legend of the Osgoode-Rideau map area, Ontario (Schut et al. 1979)

Table 4. Soil legend of the Cormorant Lake map area, Manitoba (Tarnocai 1975)
(Soils identified by asterisks (*) represent dominant organic soils)

Parent Material	Landform	Climatic Zone	Natural Drainage	Map Symbol	Soil Name and Dominant Texture	Profile Type	Dominant Vegetation	Topography	Stoniness
Extremely calcareous medium textured till	Moraine plain and drumlins and/or flutings within a moraine plain	3 and 4A	Well	At	Atikameg Series (loam)	Degraded Eutric Brunisol	Black spruce, jack pine, aspen	Very gently undulating	Very stony to excessively stony
			Imperfect	Ci	Chitek Series (loam)	Gleyed Degraded Eutric Brunisol	Black spruce, aspen, willow	Very gently undulating	Moderately stony to exceedingly stony
			Poor	Dr	Dering Series peaty phase (loam)	Rego Gleysol - peaty phase	Black spruce, Ledum sp., Feather and Sphagnum mosses	Depressional to level	Moderately stony to very stony
40 to 130 cm of mesic forest peat or thin (0 to 60 cm) fibric sphagnum peat overlying mesic forest peat	Flat bog and blanket bog	3 and 4A	Poor to very poor	Akx	Atik Complex (underlain by medium to fine textured calcareous lacustrine sediments)	Terric Fibric Mesisol* Terric Mesic Fibrisol Terric Mesisol Terric Fibrisol	Black spruce with an understory of feather and Sphagnum mosses and ericaceous shrubs	Level to depressional	Stone-free
				Ikx	Iskwasum Complex (underlain by extremely calcareous till)				
60 to 160 cm of fibric sphagnum peat, which may be underlain by significant amounts of forest or sedge peat	Flat bog and blanket bog	3 and 4A	Poor to very poor	Chx	Chocolate Complex (underlain by medium to fine textured calcareous lacustrine sediments)	Terric Mesic Fibrisol* Terric Fibric Mesisol Terric Fibrisol	Stunted black spruce and tamarack with an understory of Sphagnum mosses and ericaceous shrubs	Depressional to level	Stone-free
				Fax	Farewell Complex (underlain by extremely calcareous till)				
				Otx	Optic Lake Complex (underlain by non-calcareous till)				
Deep to very deep perennially frozen forest peat or thin (<60 cm) sphagnum peat overlying forest peat	Plateau bog and domed bog	3 and 4A	Well to imperfect	Nlx	Nekik Lake Complex	Mesic Organo Cryosol	Black spruce with an understory of Cladonia, Labrador-tea and feather mosses	Level or irregular domes and ridges	Stone-free
Deep to very deep perennially frozen sphagnum peat or sphagnum peat overlying forest and/or fen peat	Plateau bog and domed bog	3 and 4A	Well to imperfect	Cmx	Cormorant Lake Complex	Fibric Organo Cryosol	Black spruce with an understory of Cladonia, Labrador-tea and feather mosses	Level or irregular domes and ridges	Stone-free

have been provided without a single organic profile description or any analytical data. The intensity of ground checks is also much lower in organic soil areas when these are compared to mineral soil areas.

It is to be preferred that organic and mineral soils be mapped on the same intensity level. If this is not possible, then the fact should be clearly indicated in the report and on the map. On the map a more generalized map unit description should be used. This was the case in the Cormorant Lake map area in Manitoba. Ground checks from a helicopter and road traverses provided enough information for mapping mineral soils on the series level but not enough for organic soils. Thus, the organic soils were mapped on the more generalized series complex level (Table 4).

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INTERPRETATION OF ORGANIC SOIL PROPERTIES FOR AGRICULTURE

John L. Nowland

A. Preamble

Among soil surveyors there is the radical left who will do what they can to interpret their information for users. Sometimes they run the risk of overselling their product. Then there is the right wing, who expect the user to climb down into the soil pit and dig for the information, not only in the soil, but in its lexicon. The right wing is occasionally slow to achieve impact. Neither of the two wings has had much to offer on organic soils, primarily because of inadequacies in basic mapping.

Throughout the evolution of soil interpretations, from the earlier good-fair-poor ratings for individual crops, through the Canada Land Inventory era, to modern land evaluation, organic soils have not been treated like mineral soils. One wonders why the organic areas on maps did not carry pictures of dragons, pterodactyls and savages, such as the mediaeval cartographers used to embellish their terra incognita. In many accompanying texts, the organic soils are described with some diffidence, at the end between beaches and cemeteries. Analytical data are nearly as rare as dragon's teeth.

The reasons are not entirely clear. The limited agricultural use of organics in Canada and lack of skills in farming them perhaps crippled the motivation to map them properly. But that did not seem to happen in the mapping of other huge areas of non-agricultural soils in forested regions. The late development of the organic taxonomy may have been partly responsible, and its arrival did create some ripples, if not frenzied activity. Unfamiliarity with the basic attributes of organic soils, their significance and landform relationships, as well as the inadequacy of the usual tools for the job, probably sapped the fieldwork effort. Mosquitoes, of course, were a minor consideration.

There have been improvements in the mapping in recent years. Where this has happened, the existing frameworks for systematically assessing the suitability of organic soils for agriculture seem adequate enough, but there remains a great deal of scope for local refinement.

I will review as briefly as possible the main factors used in evaluating organic soils, and then how these factors can be incorporated in a systematic framework.

B. Factors used in evaluating organic soils for agriculture

I have grouped the factors in the following sequence: climate, landforms, hydrology, soil physical attributes, soil fertility, botanical composition, surface vegetation and certain economic and social considerations. This is by no means in order of importance but proceeds from the broad climatic and landform considerations to the particularities of the soil and its management.

1. CLIMATE

Climatic condition determine the choice of crops that can be grown, their yield potential and the timing of field operations. Within a macroclimate affecting all soils in an area, the microclimate on, and in, the peatland has to be considered, since it is cooler than on surrounding mineral soils. This results from such factors as the insulating properties of peats, their high water content and, in many cases, low landscape position receiving cold air drainage.

The climatic factor has commonly been expressed by the soil temperature criteria used for the Map of Soil Climates of Canada (Table 1) (1). Thus the Mild and Cool temperature régimes are good for crops; but Cold and Very Cold régimes, such as occur in Newfoundland for example, pose severe constraints. The severity of the constraint in the Cold regime is very uncertain, yet critical, and should be a top priority in data collection.

Table 1. Soil temperature regime criteria and cropping constraints.

Regime	Soil temp. at 50 cm (^{o}C) mean annual	mean summer.	Constraints
Mild	8-15	15-22	none
Cool	5-8	15-18	minor
Cold	2-5	8-15	severe
Very Cold	-7-2	5-8	very severe.

The Soil Moisture Regime classification of the Soil Climates Map places most organic soils in the Aqueous, Aquic and Peraquic classes. Table 2 shows the water, vegetation and landform conditions associated with each class (3).

The saturated conditions are modified for farming by drainage works, but the precipitation loading placed upon these works varies in different macroclimatic zones, being heaviest in Maritime climates.

Climatic factors are accommodated in classification and mapping at two levels, the primary stratification of the legend by climatic zone and the Family level of the taxonomy.

TABLE 2. MOISTURE SUBCLASSES AS APPLIED TO ORGANIC SOILS

Moisture Regime	Aqueous	Aquic			Moist Soils	
Classification	Aqueous	Peraquic	Aquic	Subaquic	Perhumid	Humid
Descriptive Condition	Free surface water	Saturated for very long periods Very poorly drained	Saturated for moderately long periods Poorly drained	Saturated for short periods Imperfectly drained	Moist with no significant seasonal deficit Imperfectly to moderately well drained	Moist with no significant seasonal deficit Moderately well drained
Suggested Criteria						
Saturation period	Continuous	Very long	Long to moderately short	Short to very short	Very short	Very short to insignificant
(months)	11.5–12	>10	4–10	<4	<2	<0.5
Moist period	Insignificant	Very short	Short to moderately long	Long to very long	Long to very long	Very long
(months)	<0.5	<2	2–8	8–11.5	8–11.5	>11.5
Associated Native Vegetation	Hydrophytic Nymphaea Potamogeton Scirpus Typha, Phragmites Drepanocladus	Hydrophytic Scirpus Typha Carex Drepanocladus Feather mosses Tamarack	Hydrophytic to mesophytic Wet forest black spruce, mixed feather and sphagnum mosses Ericaceous shrubs	Hydrophytic to mesophytic Wet to very moist forest black spruce, sphagnum Ericaceous shrubs	Mesophytic Moist forest black spruce, mixed sphagnum and feather mosses Ericaceous shrubs, lichens	Mesophytic Disturbed species Cultivated species
Associated Peat Landform	Wetlands, marsh, floating fen, collapse scars	Flat fens, patterned fens, spring fens, swamps	Blanket bogs, transitional bogs	Domed bogs, plateaus	Frozen plateaus, frozen palsas, frozen peat polygons	Drained peat land Folisols

2. LANDFORMS

The landforms of the organic terrain influence ease of drainage, as on a markedly domed bog versus a level fen. A gently sloping surface may be optimum for water control. Surface roughness may have to be smoothed, so it is important to identify it. The surrounding topography can contribute to the loading on the drainage scheme and constrain design of outfall disposal. Thickness of the deposit and the nature of underlying mineral material may influence drainage design; they are also a consideration in long-term plans for possible continued use after the peat has disappeared.

Landform factors are accommodated in classification and mapping partly by their association with dominant Subgroups, but should be inserted as definitive differentiating criteria for map units in a separate component of the legend. The provisional classifications currently in use will soon be finalized to expand the scheme in the Canadian System of Soil Classification (3).

3. HYDROLOGY

Ability to regulate the zone of saturation is crucial in evaluating the organic soil. The saturated zone is to be maintained high enough to minimize subsidence, wind erosion and dessication of the seedbed, but low enough to minimize anaerobic conditions in the root zone and difficulties of vehicle traction. Especially in dry climates, maintenance of sufficient moisture in the crop root zone in late summer may be difficult without carefully controlled drainage and subirrigation installations.

Maintenance of the saturated zone at a depth of 60-90 cm is good practice for established vegetable crops, a little more for grain and less for forage. 85 cm has been recommended for vegetables in Newfoundland, but this would vary according to type of soil and degree of decomposition (2).

Evaluation of this factor on peatlands in their natural state involves much uncertain prediction, and is a separate process from the evaluation of the degree of control on the water table in developed peatlands.

Successful control of water requires some understanding of its source; the position on the landform; the kind of peat and its degree of decomposition as they affect permeability; and the depth and character of underlying mineral soil. One hopefully proceeds to a drainage design having optimum spacing of ditches, tiles or mole drains (generally closer than on mineral soils) with least impedance to cultivation. However, evaluation of drainability poses some problems.

Well-graded drainage outfalls are critical and their configuration should be strongly related to landform. Their efficiency may decline with time as the surface subsides and ditch grades change. Tile drains are gradually exhumed. There is some uncertainty as to the longevity of mole drains in different kinds of peat.

It is generally held that fibric peat is the most permeable and humic peat the least, but other factors such as layering of Phragmites and dessication cracks in humic peat may complicate the picture. The mesic state of decomposition may be the optimum for drainage control; it lacks the extremes of low permeability and water retention at high suctions in more decomposed material, and possible excessive withdrawal of water that may occur on more elevated areas of fibric sphagnum peat (this latter, however, is questionable).

The influence of the mineral substratum is no simple matter. A sandy substratum could facilitate drainage, but more often than not the organic deposit is in a discharge zone that readily replenishes water supply. A slowly permeable clay, on the other hand, may hinder drainage to a regional drainage network, but it may also restrict the rate of groundwater discharge into the peatland.

The presence of ponds (flashets, flarks) on the peatland presents problems for development. They may be too numerous, deep or otherwise impractical to drain, and remain as an impediment.

Permafrost attains its maximum southern extent in organic soils, but is not known to be a factor in their use for agriculture.

In classification and mapping, the water table and drainability are (with a few exceptions) not characterized explicitly, but inferred from the landform class, the soil Subgroup and the soil climate component of the soil Family classification. (The proposed new classification of soil water regime (SWIG) would strengthen the differentiation of map units.) The influence of a mineral substratum on water regime is handled at the Subgroup level (depth), and the Family level (particle size) of the taxonomy, and in the landform component of the mapping unit. The landform class should also accommodate occurrence of ponds on the peatland surface. Permafrost is well characterized at the taxonomic Great Group level and in the landform class.

4. SOIL PHYSICAL ATTRIBUTES

(i) Degree of decomposition

This criterion receives much emphasis in the taxonomic classification of peats, mainly because of good correlation with a whole suite of other properties that influence productive potential, viz., density, hydraulic conductivity, water holding capacity, the capillary rise of water in the rooting zone, strength to support traffic, tilth of the seedbed, cation exchange capacity and nutrient availability.

Putting it all together, mesic peat with 10 to 40% content of rubbed fibre appears to be the optimum. But in this dynamic environment, cultivation itself reduces a fibric surface to the mesic state, which of course is one reason the taxonomy attaches least importance to the surface tier.

In classification and mapping the decomposition state in the control section is the cornerstone of the Great Group and Subgroup classification, and for the surface tier it is accommodated at the Family level.

(ii) Presence of woody layers

Stumps and logs are a physical hindrance to reclamation and cultivation. There is some disagreement about what constitutes unacceptable quantities (see Appendix 2), and the hardness of the wood has to be considered, as well as the depths at which it is found.

Wood content is a differentiating criterion at the series level in the taxonomy.

(iii) Depth and kind of mineral substratum

Mineral soil within the control section (1.6 m), if it is of no intrinsic value for farming when exhumed, obviously renders reclamation questionable. With mineral soil at 1.6 m, a good organic rooting zone will peter out after about 20 years even under good management; hence, questions of amortizing the costs of development and maintenance enter the picture. Because of the initial subsidence when drained, a depth of 2 m might be a more realistic threshold for decisions on development.

A loamy stone-free substratum may offer prospects of continued farming, but after consideration of the new drainage grades that will then exist, the operator might do better in aquaculture.

Depth of the mineral layer up to 1.6 m is a Subgroup criterion, but beyond that differentiation is on an ad hoc basis, best keyed to the landform class. Particle-size is handled at the Family taxonomic level and mineralogical composition and other characteristics at the Series level.

(iv) Density and compaction

The denser peat materials have more bearing strength for machinery, other things being equal. But resistance to shear is also related to the strength of the mesh of fibres, and fibric materials are generally less dense. This again points to certain mesic materials as being optimum; their density is commonly in the range 0.075 to 0.2 g/cm^3.

Materials denser than this may be conducive to preparation of a tight seedbed, but may also form semi-permanent clods upon drying that are difficult to wet and break down. Less dense fibric materials may be difficult to compact sufficiently for a good seedbed.

In classification, density is a definitive criterion for Soil Series.

(v) Mineral content

Mineral material incorporated in organic soil, whether air- or water-borne, increases potential nutrient supply, density and in some cases trafficability, but frequently reduces permeability and therefore drainability if it is clay or silt. The interactions are complex, and the history of muck farming might indicate a net benefit from admixture of mineral soil. However, the gains are probably outweighed by the loss of some advantageous physical attributes of purely organic soils.

Mineral material occurring as distinct layers is accommodated as Cumulo Subgroups in the taxonomy; intermixture with organic material, on the other hand is a Series separator. A surface mineral layer is a Family separator.

(vi) Hydraulic conductivity

This far down the list of physical attributes used for evaluation of organic soils, many interactive parameters have already been covered, including those related to hydraulic conductivity. Hydraulic conductivity is obviously significant for drainage and maintenance of a moist surface for germination and resistance to wind erosion.

Soil physicists have great difficulty making reproducible field measurements of conductivity in the saturated state and the methodology for "undisturbed" laboratory samples and for unsaturated conductivity is even more tenuous. The task is probably no easier for organic soils than for mineral soils, and we have minimal data for evaluating this factor. The system of soil classification for Canada cites hydraulic conductivity values over > 6 cm/h for fibric material and < 0.1 for humic material, but these are of uncertain provenance (3). Fibric sphagnum peats have been observed to be very slowly permeable, much slower than forest peats, especially those containing logs.

It is not difficult to envisage scope for a whole field of research in this most important aspect of organic soils. Hydraulic conductivity is not used as a criterion in mapping and classification, and is inferred from other attributes (by those with special insight).

5. SOIL FERTILITY

(i) Inherent fertility is of little use in evaluating undeveloped organic soils; differences between soil types are miniscule beside the requirement of added nutrients for cropping. The nutrient status might be of some pertinence in evaluating a cultivated peat. Rayment's recommendations for forage on newly reclaimed mesic peat in the Avalon Peninsula are 60 kg N, 50 kg P and 90 kg K per hectare (2). For many vegetables, 340 kg N, 110 kg P and 280 kg are required. The annual requirement for N and P drops, but it remains high for K.

The requirement for the micronutrients boron, molybdenum, copper and zinc (according to Rayment) together amounts to 22 kg/ha at first cultivation. Copper has special significance in suppressing certain enzymes, and at 250 ppm markedly inhibits decomposition and subsidence of peat (4).

It is important to know the cation exchange capacity in regard to the response of the soils to fertilization. CEC increases markedly with degree of decomposition.

(ii) Soil reaction (pH) is commonly but not universally very low on most undeveloped organic soils. While crops can tolerate a lower pH on organic soils than on mineral soils, the surface pH of 3.5 to 4.0 common on most Newfoundland soils demands 7 t/ha of lime in the first year of vegetables, according to Rayment, and 2 to 3 t for forage, with supplements in succeeding years (2).

(iii) Presence of sulphur in some organic soils, such as on marine marshes, affects their evaluation for agriculture. The sulphur can become toxic after liming or draining. On other organic soils, evaporation in summer can enrich the surface with salts from saline substrata or seepage, a problem enhanced by strong groundwater discharge. It is possible that toxicity levels are higher on organic soils than on mineral soils, and once again one should guard against using the same criteria in the absence of more data.

Fertility is not a criterion in classification, and mapping systems, but if significant it could be accommodated as a map unit phase. A pH of 4.5 ($CaCl_2$) separates euic and dysic Families in the taxonomy, and calcareousness is a recommended Series criterion. There is no provision for sulphur content such as the sulphurous families of mineral soils, nor salinity, but they could be accommodated as phases.

6. BOTANICAL COMPOSITION

The chief reason for characterizing the botanical composition of the peat material is not so much direct evaluation for cultivation, but for the derived attributes with which it is associated such as landform, chemical and physical composition and rate of subsidence. In theory its importance is equivalent to that assigned to lithology in characterizing mineral soils.

Forest peat tends to be more productive than sedge peat, with sphagnum materials the least of the three, but other factors can interfere. Sedge peat at any stage of decomposition has a high rate of subsidence.

Floristic composition is a criterion for differentiating soil series, and sphagnic, silvic and fennic surface layers are criteria for separation at the soil Family level of classification.

7. SURFACE VEGETATION

A tree cover raises the cost of clearing organic soil for cultivation, but with the right equipment the energy required may be less than on mineral soils. On open peatlands the proportion of the land actually available for the first crop, ie. between ditches, may be substantially more than that commonly left between windrows on cleared mineral soils. Under prevailing practices in the Atlantic Provinces much of the valuable surface soil ends up in the windrow, helping to prolong its occupance of one quarter of the potential new farmland.

Vegetation communities provide useful indications of landforms, hydrology and nutrient status. They are used in conjunction with landform in the basic separation of map units, but are not a taxonomic criterion.

In the foregoing discussion of factors used to evaluate organic soils for agriculture, I have indicated how they are currently accommodated in the Canadian System of Soil Classification and mapping systems. I would like to emphasize that there are additional avenues open to the mapper. Most of the factors can be accommodated as special phases of any taxonomic or mapping unit, provided that the procedure is properly correlated.

This is not true of the next few factors of evaluation.

8. ECONOMIC AND SOCIAL FACTORS

The evaluation of organic soils for agricultural use cannot proceed far without a thorough assessment of the difficulty and costs of development. Economic feasibility also takes account of the availability of processing facilities and markets for the products. Clichés like this have to be reiterated in view of the chequered and limited experience with peat soils in the Atlantic Region. Some of us have seen co-operative farmers toiling in the black earth between clogged ditches, wondering how to dispose of forked carrots and chickweed.

Success with organic soils involves some special skills, techniques and equipment, and a hefty capital investment. The capacity to assemble and upgrade management skills, and to organize co-operative use of specialized machinery, must enter the evaluation process at some point.

Lastly, realistic development goals in the agricultural sector must be reviewed in relation to competing demands from other sectors, the peatmoss industry, forestry, wildlife and energy.

C. Incorporating evaluation factors in an interpretation framework

It will be assumed that an interpretive framework must satisfy two conditions, viz:
(i) rate the soils relative to each other
(ii) display all the constraints in a manner that enables a user to make his own evaluations of suitability.

Ranking in arbitrary classes of good-fair-poor may be optional, but those who regard such rankings with distaste must acknowledge that many of their clients, such as planners, do not.

1. THE C.L.I. APPROACH

Following the Canada Land Inventory scheme for mineral soils (5), the soils are ranked in seven classes by degree of limitation on their use, with the kinds of limitation, tailored to organic soils, identified in subclasses.

This approach has been used in Ontario (6) and British Columbia (7), and perhaps elsewhere. Excerpts from the Ontario scheme are in Appendix 1, omitting details of the definitions of the ten subclasses: inundation, excess water, permeability, depth, fertility, climate, presence of logs, surface roughness, permafrost and salinity. In this scheme there is plenty of scope for disagreement on the relative significance ascribed to individual factors, such as a 5 cm layer of aquatic peat in a profile.

A useful concept of the difficulty of development of undeveloped peatlands was grafted on to this scheme, in recognition of the variability encountered in nature and whether reclamation is a minor or major undertaking. Again seven classes were used (Appendix 1).

2. THE ONTARIO PENALTY POINT APPROACH

This is an outgrowth of the CLI scheme in which various degrees of each constraining factor are assigned "penalty values" (8). Summing the values for all applicable factors and subtracting from one hundred gives an index number (Appendix 2). It is then possible to assign ranges of the index number to each of the seven CLI classes. These were named "suitability groupings" when presented to the Americans at their 1973 Soil Survey Work Planning Conference (9). The scheme was subsequently used successfully, with a few modifications, in the Roseau River Survey in Manitoba (10).

The numerical values you will note in Appendix 2 are again subject to adjustment for local conditions and biasses. They lend precision to the CLI groupings, so that a soil in the range 40 to 50, for example, is slotted into Capability Class 4. However much you may dislike this kind of numerical approach, I would contend that it has the distinct advantages of being flexible, conceptually simple and easy to explain to the user, qualities not universally characteristic of soil survey.

The development difficulty ratings (in three or seven classes), are used in conjunction with this method. They could probably stand some tightening of definitions, for example, in what constitutes minor versus major reclamation. This could be done fairly easily for local conditions.

Whereas Canadians fitted the index numbers to their Capability Classes, the Americans went off on their own traditional tangent and slotted the land factor ratings into good fair and poor classes for specific crops (Appendix 2, p. 45). Although it is not explicitly stated, it is apparent that one deleterious factor, such as depth to water, pre-emptively places a soil in the poor class, alongwith a soil having that constraint plus perhaps two others. The two soils are clearly not equivalent. Moreover there are regional differences of opinion as to what, in a given region, constitutes good, fair or poor.

3. SOIL POTENTIAL RATINGS

Dissatisfaction with what is perceived as a very negative approach of "limiting factors" led the Americans to develop a new approach to soil interpretations, Soil Potential Ratings. This aims to provide more realistic evaluations on a local basis, and the application is seen at its best in areas where the best soils available for a particular land of land use may be portrayed as "poor" for that use according to some national scheme. Soil Potential is used for all kinds of interpretations, including engineering uses of soils.

The approach has been tested on a few survey projects in the U.S.A., but not in Canada. The ratings are prepared in co-operation with technical experts in the appropriate field and I wish to emphasize that they are established on a local basis for local needs; the criteria may vary from one area to another. The ratings are for planning purposes, and as with all interpretations from soil surveys, are not designed to supplant the site investigation prior to any development.

"Soil potential ratings are classes that indicate the relative quality of a soil for a particular use compared with other soils in the same area" (11). The Soil Potential Index (SPI) is a numerical rating of soil suitability derived as follows:

$$SPI = P - (CM + CL)$$

where P is an index of performance or yield as a locally established standard,
CM is an index of costs of corrective measures to minimize the effects of soil limitations
CL is an index of costs resulting from continuing limitations.

The standard chosen for P is commonly higher than the average for the area, usually close to the maximum. CM represents the costs over and above those of a standard defined management system that is followed on the best soils in the area. Therefore when P = 100 (if 100 is chosen to represent the standard yield), CM = 0.

Continuing limitations (CL) are of three types:
(i) poor performance (eg. crop yield), small fields probability of failure of structures, etc., after all reasonable measures have been taken.
(ii) annual maintenance costs.
(iii) offsite damage, eg. from sediment.

It seems to me that the CL index corresponds closely to the penalty value in the Ontario Scheme. It may be very difficult to estimate realistically. Not the least of the difficulties is ascribing an annual value to infrequent major yield depression or crop failure. The terms in the equation must all be reduced to a common basis, either annual value or a value for some longer time-span. SPI can be calculated for each map unit, and the soils of an area grouped according to certain ranges of the index.

To illustrate how it works, I have prepared worksheets on the US model for obtaining a Soil Potential Index for forage on two more or less hypothetical organic soils in Newfoundland. They roughly correspond to a soil in map unit 06F6, a mesic sedge-sphagnum peat (Table 3) and map unit 02F6, a fibric sphagnum peat (Table 4) from the Avalon soil map (2).

The list of evaluation factors (column 1) is not necessarily complete, being for illustration purposes only; it is naturally the same for both soils. Climate is omitted in this local context, but microclimate might well have been included. "Soil and site conditions" (column 2) for the map unit should come from the map unit description, but I have taken liberties. "Degree of limitation" (column 3) was left blank because of some personal antipathy to slight-moderate-severe. "Effects on use" (column 4) relate to the corresponding soil conditions and corrective measures but in these examples do not include everything that might have been included.

Each corrective measure (column 5 and 6) has a cost attached (rounded to the nearest 1980 dollar.) and reduced to an annual cost by 10-year amortization (in brackets). The index number in this case is an arbitrary 10% of annual cost; a percentage of crop value has also been used in other applications of the method.

Continued reduced yield is treated as a continuing limitation (columns 7 and 8), and if it cannot be attributed to any particular evaluation factor it can be entered as a single unconnected value, as in Tables 3 and 4. In this case, the continuing reduced yield was taken as 7 t/ha from two cuts compared to a local performance standard of 10 tons (expressed as a performance index of 100). It could have been calculated as a straight percentage reduction, but it is better to relate the reduced value of the crop to the maximum range in the area, in order to arrive at an index of reduced yield. Thus:

$$\text{Reduced Yield Index} = \frac{(\text{Top yield for area - actual yield}) \times 20}{800} \times 100$$

The value of hay is assumed to be $20/tonne. The 800 is the difference in value between high and low yields in the area ($100) plus the cost of "a high degree of corrective measures" ($700). This kind of formula was used for testing soil potentials for pear production in Oregon.

Table 3 WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Forage Area: Avalon

Mapping Unit: 06F6 Mesic sedge-sphagnum peat-transitional bog.

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures: Kinds	Corrective Measures: Index	Continuing Limitations: Kind	Continuing Limitations: Index
Degree of decomp.	mesic		seedbed	cultivation methods	-	special methods $10	1
Bearing strength	low		traffi-cability	special cultivation methods $200 (20)	2	Ditto $20	2
Depth to water	20 cm		rooting subsi-dence	Ditching $200 (20)	2	Maintenance $20	2
Flashets	3%		obstacle	Drainage-some filling $100 (10)	1	Obstacle	1
Fertility	low		low yields	N, P, K, lime, etc. $153	15	Maintenance $80	8
Surface roughness	1 m mounds		field ops.	Smoothing $60 (6)	1	-	-
Depth to mine-ral layer	>1.6m		Dura-tion of use	None	-	-	-
Presence of logs	< 1%		obsta-cle	None	-	-	-
						Reduced yield	8
				Total	21	Total	22

NB Performance standard
= 10 tonnes/ha
= 100 index

Costs of corrective measures amortized over 10 years

100 (Performance Standard Index) - 21 (Measure Cost Index) - 22 (Continuing Limitation Cost Index) = 57 (Soil Potential Index[1])

1. If performance exceeds the standard increase SPI by that amount.

Table 4 WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Forage Area: Avalon

Mapping Unit: 02F6 Fibric sphagnum peat - domed bog.

Evaluation Factors	Soil and Site Condi- tions	Degree of Limitation	Effects On Use	Corrective measures: Kinds	Corrective measures: Index	Continuing Limitations: Kind	Continuing Limitations: Index
Degree of decomp.	Fibric		Seed-bed, subsi-dence etc.	cultivation methods	-	special methods $80	2
Bearing strength	low		traffi-cability	spec. cult. methods $300 (30)	3 3	Ditto $20	2
Depth to water	20 cm		rooting subsi-dence	Ditching $200 (20)	2	Maintenance $20	2
Flashets	3%		obstacle	Drainage-some filling $100 (10)	1	Obstacle	1
Fertility	low		low yields	N,P,K, lime, etc. $150.	15	Maintenance $80	8
Surface roughness	0.5 m mounds		field ops.	Smoothing $30 (3)	0.3	-	-
Depth to mine-ral layer	>1.6 m		Duration of use	None	-	-	-
Presence of logs	< 1%		obstacle	None	-	-	-
						Reduced yield	11
N.B. Performance standard = 10 tons/ha = 100 index				Total	21	Total	26

Costs of corrective measures amortized over 10 years.

100 (Performance Standard Index) - 21 (Measure Cost Index) - 26 (Continuing Limitation Cost Index) = 53 (Soil Potential Index[1])

1. If performance exceeds the standard increase SPI by that amount.

With worksheets completed for all the soils, their SPI's can be tabulated and checked against actual experience with the soils. In the examples used here the mesic peat has an index of 57 compared with 53 for the Fibric peat.

Details on the methodology with examples of its application are available from LRRI.

It is difficult to evaluate the soil potential approach without trying it in real situations. For many interpretations, and perhaps including those of organic soils for agriculture, the estimates of costs of development and evaluation of continuing limitations may be so tenuous as to be worthless when the variability within map units is taken into account. However it seems reasonable to expect any development proposal to furnish such estimates of costs before it is given the least consideration. Why should we expect any less in the interpretation of surveyed soils?

We are only just at the point of starting to measure on a statistically sound basis the variability of map units, and thereby the relative reliability of interpretations. Applied to organic soils this effort will hopefully generate enough data to bring the treatment of organic soils into line with that of mineral soils during the course of soil surveys in Canada.

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Appendix 1

The CLI approach

Capability classification of organic soils for agriculture
(Extracted from Leeson, B. et al pp. 27-34)

The organic soil capability classification for agriculture is an interpretation of the agricultural potential of organic soils from information gained by studying the morphology and physical and chemical characteristics of organic soils. The capability classification is developed from and depends on the properties of organic soils. The potential of organic soils for the production of vegetable crops has been of particular concern in the formulation of this system. The classification is comprised of seven capability classes and each soil area is given two ratings. The first rating indicates the agricultural potential of the soil according to any hazards which reclamation is unable to remove and which therefore constitute a continuing limitation to agricultural production. The second rating is a "development difficulty rating" which indicates the relative amount of reclamation which is necessary before the full potential of an area for agriculture can be realized.

Agriculture Capability Classification

The agriculture capability of the soils are rated in classes from one to seven according to the degree of continuing limitation which the presence of particular hazards may have on the production of agricultural crops. The capability class is a group soils which have the same potential for production of agricultural crops. The degree of limitation becomes progressively greater from class one to class seven and the agriculture potential becomes correspondingly less from class one to class seven. Classes one, two and three are considered capable of sustained production of vegetable crops. Class four soils are marginal for sustained production of vegetable crops. Class five soils are not suited to production of vegetable crops but may respond favourably to management for forage and pasture purposes. Class six soils are not suited to the successful establishment of any crops other than indigenous* species. Class seven soils possess no potential for the production of useful agricultural crops. Organic soils which have been reclaimed will be classified according to their continuing limitations only.

Development Difficulty Classification

Organic soils in the native unreclaimed state will be given a "development difficulty rating" from one to seven. This second rating is proposed because it is recognized that although two separate soils may have similar agriculture capability according to continuing limitations, the extent of necessary reclamation of one might be greater than the other. By considering the present state of a soil some estimation of the relative degree of difficulty which may be encountered in the development of the soil can be postulated. Such information can be useful in comparing alternative land uses.

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* Indigenous species are those plants which are native to the area and become established by volunteer growth and perpetuate themselves without management.

Minimum difficulty will be encountered in overcoming hazards present in soils rated one, two or three. Only minor reclamation is required. Minor reclamation is considered to be those operations which can be carried out by a single operator and which do not require co-operation between adjoining operators. Such operations would include levelling rough surfaces, removal of surface woody layers and land clearing.

Soils rated as four require major reclamation but when the agriculture capability of the soil is high (class one, two or three), reclamation is usually warranted. Major reclamation is considered to be those operations which require co-operation between adjoining operators or which may require outside financial assistance. Such operations could be drainage, construction of dams or levees and correction of very low (<3.5) or very high (>7.6) pH.

Hazards present in class five soils require major reclamation schemes which will be warranted only where the agriculture capability of the soil is class one, two or three and where high value crops can be produced.

Soils rated as six can be developed only with very large reclamation projects. Major reclamation is seldom warranted here because the hazards are so serious that they constitute some continuing limitation which reduces the agricultural capability.

The most serious hazards which occur in soils rated as seven can be overcome only by very intensive development on a major scale. It is unlikely that such development is warranted.

The Capability Subclass

The capability class and the development difficulty class are further subdivided into subclasses. A subclass is a group of soils with similar kinds of limitations or hazards. The capability class and the development difficulty class categorize soils having the same relative degree of limitation or hazard. The subclass is designated by a symbol which indicates the specific hazard or limitation present.

Capability Classes

Class 1

Class 1 soils have no limitations which restrict their use for the production of agricultural crops. These soils, at an intermediate (Mesic) stage of decomposition have no drainage, topographical, salt or pH limitations which reduce their agricultural potential. They are deep, not liable to crop damage from overflow and are located in climate category i where optimum crop production is favoured.

Class 2

Organic soils in class 2 have one limitation which restricts their use for agriculture in a minor sense. This limitation may cause lower crop yields but does not pose a threat of crop loss under good management. They have a high to medium productivity for a wide range of crops. One of the following limitations prevents them from being class 1 soils:

- soft wood <3 inches thick in the upper 5 feet of the profile
- climate of category ii, or localized climatic conditions posing minor threat to crop
- pH 4.5 - 4.0
- depth of profile between 5-6 feet
- layer of loam >2 inches and <12 inches thick in the upper 60 inches of the profile
- mounds, hummocks, ridges, plateaus <1 foot high or, holes <1 foot deep (do not constitute a continuing limitation - used for assessment of development difficulty).

Class 2 soils are mesic soils with hydrologic characteristics which do not retard drainage, create droughty conditions or lessen the likelihood of obtaining maximum crop yields. They have no salinity or permafrost problems and the climate category i or ii is suitable for a wide range of crops.

Class 3

Organic soils in this class have moderately severe limitations that restrict the range of crops or that require special management practices. With good management these soils have a medium to high productivity for a fairly wide range of crops.

Their limitations to agriculture may be a combination of two of the hazards outlined in class 2 or one of the following:

- 1-5 foot depth of the profile is in an advanced stage of decomposition - Humic
- climate of category iii, or local climatic conditions pose a threat of some minor crop damage but no crop loss
- pH of 4.0 - 3.5 or pH 7.0 - 7.5
- overflow frequent or intense enough to cause minor crop damage but no crop loss
- 4 to 5 feet of organic soil underlain by loam or sand
- aquatic muck >2 inches thick in the 60 inch to 36 inch depth
- soft wood >3 inches thick; or hardwood <2 inches thick in the 20 inch to 60 inch depth of the profile
- layer of sand >2 inches and <12 inches thick in the top 60 inches of the profile
- minor effect by salinity
- mounds, hummocks, ridges or plateaus 1 to 2 feet high; or holes 1 to 2 feet deep

Class 4

Soils in class 4 have limitations which severely restrict the range of crops or which require special development and management practices. Even with intensive development and a high level of management the productivity of crops will be medium to low. Only specially-adapted crops will produce high yields. Reclamation and management costs will be high and warranted only where high value crops can be produced.

Class 4 soils may have two or more of the limitations which characterize class 2 and 3, or one of the following:

- inundation or excess water occurring frequently enough to cause moderate crop damage and the slight possibility of one crop loss within the protected period *
- organic material in the 1 foot to 5 foot depth of the profile is undecomposed - Fibric
- profile of organic material is 3 to 4 feet deep underlain by loam; 4 to 5 feet deep underlain by clay, marl or sand; or 5 to 6 feet deep over bedrock
- a pH <3.5 or pH 7.6 - 8.0
- climate of category iv or local climate such to shorten the growing season or cause moderate crop damage
- hardwood 2 inches or less in thickness in the upper 20 inches of the profile or hardwood 2 inches to 12 inches in thickness in the 20 inch to 60 inch depth of the profile
- the presence of salts such as to reduce the yields of all vegetable crops and severely restrict the range of all crops
- permafrost below the 5 foot depth and unaffected by cultivation
- mounds, hummocks, ridges or plateaus >2 feet high; or eroded holes >2 feet deep
- layer of clay or marl >2 inches thick in top 60 inches of the profile
- aquatic muck >2 inches thick in the 36 inch to surface depth.

Class 5

Class 5 soils have such severe limitations that they are restricted to the production of perennial forage or other specially adapted crops. They may be improved for the production of these crops but it is not feasible to undertake large scale reclamation for the establishment of other crops where the reisk of crop loss is high and the probable productivity of the crop low. Limitations to agricultural production might be:

- frequent inundation or excess water causing crop loss once within a protected period
- organic layer is 2-3 feet deep underlian by loam; or 3-4 feet deep underlain by sand, clay or marl; or 4-5 feet deep underlain by bedrock
- pH >7.6
- climate of category v, or local climatic conditions causing likelihood of crop loss
- hardwood >2 inches thick in the upper 20 inches of the profile
- salts are so concentrated that vegetable crops will not survive. Only salt-tolerant native species will thrive.

Class 6

Class 6 soils are capable of producing only indigenous crops and improvement practices are not feasible. The naturally occurring vegetation may have some limited agricultural use such as graxing. Limitations which may be present and which may be so severe so as to exclude the practicality of agricultural development are:

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* Protected period is chosen as an arbitrary interval within which time one total crop loss will not bankrupt an agriculture operation. This period would vary for different crops, depending on the value of the crop. More than one crop loss will cause bankruptcy.

- excess water and overflow occurring so frequently that if crops could be established the loss of the crop is likely two or more times within the protected period
- profile is 1-2 feet of organic soil over loam; or 2-3 feet of organic soil over sand, clay or marl, or bedrock occurs in the 3-4 foot level of the profile
- soils are so salty that the successful maintenance of any plants other than the native salt-tolerant species is impossible
- permafrost occurs within the upper 5 feet of the profile during the growing season

Class 7

Organic soils in class 7 have no capability for agriculture. These soils have such severe limitations that any improvement or development for agriculture is impractical. Limitations may include:

- organic soils less than 1 foot deep; or organic soils 1-2 feet deep and underlain by sand, clay or marl; or bedrock occurring in the upper 36 inches of the profile
- climate category vii
- wood so prevalent in the profile that it excludes any possible development for agriculture
- salt problem is so severe that no useful plants can exist
- permafrost influence is so severe so as to exclude any possible agricultural development.

Appendix 2

The Ontario Penalty Point Approach

A suitability grouping of organic soils for agriculture (Hoffman D.W. 1970 and US Organic Soils Task Force 1973 references #8 and 9).

Assumptions

1. Suitability ratings for drained conditions assumes continued subsidence rates of 3/4 inch to 2 inches annually; hence for continuous use the thicker organic materials are the most suitable.

2. The organic suitability grouping is an interpretative classification designed to assess the limitation of individual organic soils to development for and production of crops.

3. Good soil management, including drainage, control of subsidence, wind erosion, crop growing and conservation practices that are feasible under a mechanized system of agriculture are assumed.

4. The soils within a suitability class are similar with respect to the degree of soil limitation but not necessarily similar with respect to the kind of limitation. The subgroup provides information on the kind of limitation or hazard and the group indicates the intensity of the limitation. Organic soils in group 1 have the least number of soil limitations and group 7 have the most severe.

5. Organic soils which have been reclaimed and developed for agriculture are classified according to any continuing limitations which may affect the production of agricultural crops. Soils in the natural state will be classified not only for the agriculture capability but also will be classified according to the apparent degree of difficulty in reclamation and development.

6. The location, distance to market, efficiency of transport, financial state of the market, farm size and sociological influences do not constitute criteria for suitability groupings.

7. Suitability groupings, suitability definitions and penalty figures are subject to change as new information and methods concerning the manipulation of organic soils become available.

A SUITABILITY GROUPING OF ORGANIC SOILS FOR AGRICULTURE [1/]

A. Physical Features Used To Determine Organic Suitability Grouping.

Factor	Penalty Factors
SOIL TEMPERATURE	
Isohyperthermic	0
Isothermic	0
Hyperthermic	0
Thermic	0
Mesic	0
Isomesic	0
Frigid	25 (20) [2/]
Cryic	60
Pergelic	90
WATER CONTROL	
Adequate	0
Marginal	35
None	55
COARSE FRAGMENTS (Wood > 4" dia.) (Volume % within depths of 51")	
<1%	0
1-5% (1-25%)	20
>5% (25-50%)	50
MINERAL OR LIMNIC LAYERS (Thickness within depths of 51")	
<2"	0
2-12"	20
SALINITY (mmhos/cm) (Water at 5 cm tension)	
0-4	0
4-8	20
8-16	50
>16	75
WOOD LAYERS (Thickness within depths of 51")	
<3"	0
>3"	20

1/ This proposed grouping of organic soils follows "A Guide For Capability Classification of Organic Soils", prepared by the Dept. of Soil Science, Ontario Agricultural College, University of Guelph, Guelph, Canada.

2/ Values in parentheses are changes suggested by U.S. Organic Soil Task Force (1973)

Factor	Penalty Factors
THICKNESS OF ORGANIC MATERIALS	
>72"	0
52-72	10 (15)
36-52	20 (15)
<36	40 (35)
UNDERLYING MATERIALS (Within depths of 51")	
Loamy	0
Clayey	10 (5)
Sandy	20 (10)
Diatomaceous earth	20 (15)
Coprogenous earth	25 (15)
Marl	30 (15)
Skeletal	40 (30)
Rock or fragmental	50
SULPHUR (Weight % within 40")	
<0.4	0
0.4-.75	50
>0.75	75
SLOPE (Percent)	
<6	0
6-12	20
>12	50

B. Organic Suitability Grouping.

The ten soil features under A above have penalty values assigned to each subdivision of the soil feature. As a guide to proper suitability grouping, add up the penalty numbers for the soil features applicable and subtract this figure from 100. Using this figure, determine the suitability grouping from the guide below:

SUITABILITY GROUPS FOR AGRICULTURE

1	85-100
2	70-80
3	55-65
4	40-50
5	25-35
6	10-20
7	0-10

Organic Soil Groups

Group 1 (85-100) -- Organic soils of this group have no water, topographical or pH limitations, and are deep and level. They are located in areas having mesic or warmer soil temperatures.

Group 2 (70-80) -- Organic soils in group 2 have one limitation which restricts their use in a minor way. The limitation may be soil temperature, coarse fragments, wood layers, salinity depth or slope.

Group 3 (55-65) -- Organic soils in this group have moderately severe limitations that restrict the range of crops or that require special management practices.

Group 4 (40-50) -- Organic soils in this group have limitations which severely restrict the range of crops or which require special development and management practices.

Group 5 (25-35) -- Organic soils of this group have severe limitations that restrict the production of perennial forage or other specially adapted crops. Large scale reclamation is not feasible.

Group 6 (10-20) -- Organic soils in group 6 are capable of producing only indigenous crops and improvement practices are not feasible.

Group 7 (Less than 10) -- Organic soils of this group have no potential for agriculture.

Organic Subgroups

Subgroups may be designated as needed to indicate the kind of limitation. For example, if the only limitation a soil had was climate, a designation of 2c could be used or if depth was the limiting factor 2d or 3d could be used to indicate that depth was the limitation.

Explanation of Soil Features

SOIL TEMPERATURE -- refers to the soil temperature classes as defined in Soil Taxonomy.

WATER CONTROL -- refers to ground water level and flooding.

Adequate: Water control system must provide drainage for optimum crop yields and a water table sufficiently high to prolong the life of the soil.

Marginal: Water control less than adequate. Yields reduced because of poor water control and choice crops reduced.

None: No control measures for control of groundwater or flooding.

MINERAL LAYERS -- refers to soils in Fluvaquentic or Limnic subgroups and soils having Fluvaquentic or Limnic characteristics included in other subgroups as defined in Soil Taxonomy. This soil feature is not used in rating soils with mineral or limnic layers greater than 12 inches thick within depths of 51 inches. (Terric subgroups or Limnic subgroups with Limnic layer greater than 12 inches thick).

THICKNESS OF ORGANIC MATERIAL -- penalties for thinner soils are related to the eventual destruction of the resource by subsidence.

UNDERLYING MATERIALS -- refers to soils in lithic, limnic, or terric subgroups where the underlying materials are greater than 12 inches thick and soils in terric subgroups that have fragmental or sandy or sandy-skeletal particle-size classes. Penalties for underlying material are related to reclamation as the organic soil subsides and is destroyed.

Development Difficulty Rating*

It is possible that two separate soils may have similar suitability ratings for agriculture but one may be more difficult to reclaim than the other. A development difficulty rating from 1 to 3 is proposed for all organic soils in an unreclaimed state. Brief definitions of the development difficulty groups follow:

Group 1 -- only minor reclamation is required. Minor reclamation is considered to be those operations which can be carried out by a single operator.

Group 2 -- major reclamation is required but is warranted when soils potential is high. Major reclamation is that requiring cooperation between adjoining operators or outside financial assistance or both.

Group 3 -- major reclamation is required and seldom warranted.

*this Development Difficulty Rating follows the system prepared by the Department of Soil Science, Ontario Agricultural College, University of Guelph.

Physical Features Used to Determine Development Difficulty Rating*

Vegetative Cover

0 - Light (grasses, reeds, etc.)

20 - Moderate (Brush, small trees)

35 - Heavy (numerous large trees)

Excess Water And Flooding

0 - None

35 - Frequent

65 - Extreme

Surface Roughness

0 - None

35 - Holes and mounds, 1-2 ft.

50 - Holes and mounds, > 2 ft.

Coarse Fragments
(Wood > 4" diameter volume % within depths 51")

0 - < 1%
20 - 1 - 5%
50 - > 5%

Wood Layers
(Thickness within depths of 51")

0 - <3"
20 - >3"

Underlying Materials
(within depths of 51")

0 - Loamy
10 - Clayey
20 - Sandy
20 - Diatomaceous earth
25 - Coprogenous earth
30 - Marl
40 - Skeletal
50 - Rock or fragmental

To determine the development difficulty group add up the penalty numbers for the features applicable and subtract this figure from 100. Using this figure, determine the group from guide below:

Group 1	>55
Group 2	40 - 50
Group 3	<50

Recommendations for site development should be based on both the development difficulty rating and the suitability grouping for the soil after development.

*Physical features used and penalty figures assigned are subject to change as new methods and more information as result of testing becomes available. See reference no. 9.

Sample Guide Sheet for grouping soils
into three grades of suitability (USDA)
(See reference no. 9)

Guide Sheet 1 Suitability ratings of Soils for Onions, carrots, radishes, parshnips, cole crops, sugar cane, celery, lettuce, spinach, etc. and for production of sod.

Item affecting Use	Degree of Soil Suitability Good	Fair	Poor
Climate	Mesic Hyperthermic 1/	Thermic Frigid	Cryic
Depth of Organic Materials	>51"	36"-51"	<36"
Reaction 2/ pH	5.0 - 6.0	4.0 - 5.0 6.0 - 7.0	<4.0 >7.0
Depth to Water 3/	28 - 32"	32 - 36 24 - 28	<24" or >36"
Underlying Mineral Materials	Loamy	Clayey, sandy, diatomaceous	Marl, bedrock, skeletal
Woody Fragments >4" diameter	<1%	1 - 5%	>5%
Salinity 4/	0 - 4 mmhos/cm	4 - 8 mmhos/cm	8 - 16 mmhos/cm
Degree of Decomposition	Humic or mesic	Fibric	--
Sulphur	None	None	None
Mineral Layer (2 - 12" thick)	None	36 - 51"	16 - 36"

1/ Winter only

2/ Reaction may be controlled to a degree through the use of lime or sulphur.

3/ Maximum depths

4/ Some adjustment for variable crop tolerance is necessary.

Guide Sheet 2 Suitability rating of Soils for Cranberries

Item affecting Use	Degree of Soil Suitability Good	Fair	Poor
Climate	Mesic	Frigid	Warmer than mesic
Depth of Organic Materials	>51"	36 - 51"	<36"
Underlying Material	Sandy	--	--
Reaction (pH)	3.0 - 4.0	4.0 - 4.5	>4.5
Depth to Water 1/	0 - 20"	--	<20"
Woody fragments	<1%	1 - 5%	<5%
Decomposition	Fibric or mesic	--	--

Footnotes - Remarks

1/ Water control essential to include flooding.

THE AGRICULTURAL USE OF ORGANIC SOILS IN NEWFOUNDLAND

A.F. Rayment and H.W.R. Chancey

Dating from the early settlement period, Newfoundland peat soils have probably been utilized in garden culture, either <u>in situ</u> or as a peat moss removed for composting or litter or direct application to the land; certainly its use in compost heaps was commended in the mid 19th century (12). In the mid 1930's the first attempts were made to initiate extensive deep peat drainage projects for agricultural production in the vicinities of Harbour Grace, Markland and Colinet (1). Though no continuing production was reported, a good grass sod was observed in a small portion of the Colinet area in the mid 1950's and remains to this time. Curtailment of drainage work with the advent of Work War II resulted in deterioration of most of the project. The possible use of peatlands for agriculture and particularly for grassland production was examined by the Newfoundland Royal Commission on Agriculture, and it was based on their report of 1954 that the first phase of basic research was entered (13). After concerted efforts over a twenty-year period by the federal agriculture and forestry departments in the area of research, and by the corresponding provincial departments in development phases, time was ripe to consolidate information. This came in the form of a seminar held at Memorial University of Newfoundland campus in 1977 (2). Most of the agricultural research data was obtained at the Colinet Peat Sub-station, of the Agriculture Canada Research Station at St. John's. However, there was ample opportunity for observation of a wide variety of peat types and climatic conditions across the island on the various provincial projects.

The first consideration was drainage. Based on experience from Ireland, where climatic conditions were not unlike those of Newfoundland, the basic drainage instituted by Mr. J. V. Healy in provincial projects was by open ditches 0.6 m deep, spaced 15.25 m apart. Research results confirmed the fact that such a spacing was required to substantially lower water tables in wet years, but that a spacing of 23 m to 45 m could be tolerated by forage crops (7). Ditch depths ranging 0.6 to 1.2 m did not significantly affect water tables or crop yields, except that deeper ditches remained more effective after a prolonged period (over 10 years) without maintenance. Due to surface contours, a spacing of not greater than 23 m was adopted for forage production (hay or pasture) throughout the island. Observations on these various provincial projects did not indicate any instances of over-drainage, and the system was satisfactory in most cases, provided it was properly serviced according to the following specifications: 1) free outlet of drains to a catchment ditch or natural waterway; 2) the use of a perimeter ditch, where necessary, to intercept inflow of water from higher elevations; 3) the use of a central waterway for bogs heavily ponded in the middle; 4) the use of supplementary mole drains, especially for locations of low hydraulic conductivity and high precipitation; 5) provision that small ponds be either back-filled or fenced off; 6) the provision for reinforced road access to each field, to avoid crossing of open ditches with vehicles; 7) provision for regular cleaning of open ditches.

Concurrent research on vegetable crops showed that they mostly could also be grown with a wide ditch spacing, provided they were grown on ridges (4). However, it was also apparent that the absence of a sod made machinery support the most critical criterion for the drainage of vegetable land. Recent experiments in the Colinet area show good crop response and ground consolidation through a close spacing of drains (7.6 m), together with supplemental mole drains spaced 1.5 m apart (6). Even in an extremely wet season, root crop production was quite good in culture on the flat, though ridges were still beneficial. Nevertheless, it seems likely that machinery support would be a problem under the very wet conditions often prevalent during the harvest season, and therefore that development of special flotation machinery for vegetable work in the province would be desirable. This might not only reduce the need for extremely intense drainage inputs, but would also reduce soil subsidence and should expand the range of peat sites suitable for vegetable crop production.

Current research is also being conducted on the use of drain liners for closely-spaced covered drains in vegetable crop culture. To date, it seems that perforated, corrugated, plastic pipe is as good as the previously used Norwegian system of wooden slabs supported by cross members, and has the added advantages of greater durability and a more continuous flow (is less subject to alternate silting and flushing). Embedding the pipe in sawdust was not different from wrapping it in fibreglass.

New techniques are being employed to determine the effectiveness of drainage treatments: water outflow from individual drains is measured by the use of totalizing tipping bucket water meters; oxygen sensors to evaluate aeration patterns induced by different drainage systems have been a contribution from the St. Jean Station, Quebec; also, they have helped set up procedures for monitoring nutrient run-off in drainage waters.

The second major area of investigation was that of soil fertility requirements. Early experiments showed that forage could be established with a relatively low 2.24 tonnes of limestone per ha, though at this level stands deteriorated to a moss cover within 6-8 years while higher rates maintained good grass stands much longer. The highest rate of limestone of 20 tonne/ha, when rotovated in to a depth of ca. 15 cm, raised the pH from 3.7 H_2O to about 6.8 to 7.1, depending on the fertilizer used with it.

Deficiencies of the major nutrients and limestone were examined in forage crops in isolated field check plots (5) while various combinations of initial and maintenance N, P and K were evaluated for their effects on the yield and ecology of grass-clover mixtures (9). In order to get optimum yields while maintaining a high legume content, a fertilizer low in nitrogen but high in phosphorus and potassium (5-20-20 at 1120 kg/ha) in the seeding year was followed in subsequent years by one low in nitrogen and phosphorus, but higher in potassium (10-10-40 at 560 kg/ha). After the clover had dropped below 50%, usually in two or three years, it was better to force the grass by using a fertilizer high in nitrogen and potassium (15-5-15) at 7.50 kg/ha.

There was little or no evidence of forage crop responses either in yields or visual appearance to a fritted trace mixture. However, there were problems arising in grazing sheep which suggested trace nutrient deficiencies. Animal responses were obtained from direct supplementation by copper and cobalt, but there were further questions regarding the impedence of copper assimilation by the animal as a result of an antagonism by molybdenum (11). Forage analysis indicated significant increases of copper, molybdenum and zinc through their application with the fertilizer in a fritted trace mixture, and recent research has been directed toward specific evaluation of the best Cu:Mo ratio in fertilizer to produce a desirable plant content.

Fertility research was also conducted on various vegetable crops, starting in virgin peat and over the years including such crops as rutabagas, potatoes, carrots, cabbage and cauliflower. Nitrogen requirements on virgin peat were extremely high, in excess of 300 kg N/ha, while phosphorus requirements were somewhat less (between 200 and 300 kg P_2O_5/ha) and potassium requirements, though not critical except perhaps for cabbage, followed at the same range as nitrogen. On previously cultivated peat, the requirements for nitrogen and phosphorus were considerably reduced, while the need to maintain high levels of potassium became more critical (i.e. foliar symptoms became apparent at higher levels of application). The requirements for limestone as they interacted with phosphorus source and water table were matters of intensive greenhouse lysimeter and field studies, using rutabagas, carrots, radish and oats as indicator crops (2,8).

While finely ground Florida rock phosphate was conducive to early growth on virgin peat, eventual phosphorus deficiency was normally a problem except for a short season crop-like radish. However, especially good results were obtained from rock phosphate on most crops when planted on a previously cropped peat (grass sod).

The need for trace nutrients was early apparent in vegetable crops, especially boron and molybdenum as indicated by various cole crops and also copper in carrots. The need for these elements was normally filled by application in the form of a fritted mixture, though special additions of boron were recommended for rutabagas, and sometimes molybdenum became a problem in cauliflower, without adequate pH adjustment through a sufficiently advanced (6 month) pre-planting application of limestone.

There has been considerable testing of named varieties and cultivars over the years. Besides single row observations on a wide variety of forage grasses and legumes, replicated trials of mixtures for hay and pastures, and of pure alfalfa and red clover varieties have been conducted. The grasses timothy and reed canarygrass were outstanding in performance for hay production; while Kentucky bluegrass was indicated as a useful addition for hay production. Tall fescue and reed canarygrass both showed good agronomic properties for pasture, but alkaloids posed a problem for lamb production. Breeding programmes for these species are being monitored for new low alkaloid varieties. Of the legumes, red alsike and white clovers were well adapted, while alfalfa and birdsfoot trefoil responded to improved drainage conditions. Rhizoma was outstanding in the alfalfa varieties (3).

Many years of vegetable trials were conducted, using paired rows, one ridged and one flat, covering a wide range of crops and cultivars. The following crops were well adapted to peatland conditions; celery, carrot, radish, seed potatoes, kale, Brussels sprouts, early cabbage, cauliflower, broccoli, rutabaga and turnip. Others which were less intensively tested, but which nonetheless produced satisfactory results were beans, peas and spinach. Problems encountered in some other crops were thick necks in onions and scabbing and ringing in beets. Also, replicated trials have been conducted on potato and carrot varieties. The carrot variety Spartan Early was one of the better ones for peat soils, producing a long root, relatively free from green shoulder.

Even though most of the problems limiting the growth of crops have been solved, there remains the difficulty of putting together the appropriate machinery package. The tendency has been to approach the problem from the individual standard piece of farm equipment, modified for use on peat soils, rather than consideration of a total system specially tailored to local peat conditions.

For instance, in the area of forage harvesting, a wide range of equipment, including tractors, mowers, balers, flail harvesters and forage trailers have been successfully modified for use on peat soil. Later attempts have been made to put together a system which allows field air drying of small stacks (FASST System) (2) which holds considerable promise, but is still too weather dependent to be a total success in all years. A system built around the large, round bale, either for silage or field aerating might well hold possibilities for greater versatility.

Considerable input has recently been put into a vegetable production system through contracting out to the "Peat Engineering Design Group" of Memorial University of Newfoundland. Vegetable production systems have additional flotation problems over forage systems, as there is no sod to bind the soil surface together. Furthermore, harvesting of most horticultural crops occurs in the fall when conditions are wettest. The first problem of seeding has essentially been solved by the development of a ridger-seeder that simultaneously performs these operations (10). However, the resulting machinery train, including a special articulated tracked tractor, a self-supporting ridger with packers and precision seeders, requires a large turning radius and is difficult to line up. As this operation does not require a great deal of power, the eventual answer might be a self-propelled unit.

Similarly, where row cultivation is not very practical under moist peat conditions, spraying equipment mounted on a light weight flotation tractor may provide a solution. For crops for which there is no suitable registered herbicide, crop shields are available for the use of non-selective herbicides.

A start in the area of harvesting has been made in the adapting of carrot harvesting gear to special flotation wheels, and the development of a special trailer to go with it. As the harvesting head is well off-set from the power unit, there is an ample latitude for the use of tracked tractors.

Besides the obvious need to modify existing equipment or for new machinery developments for harvesting specific crops, there is also a need for special cultural methods such as for excavating slit ditches and for deep plowing. A ditcher recently developed by the Peat Engineering Design Group would seem to be fairly readily fitted with a blade suitable for producing slit ditches. With respect to plowing, there are many specialized deep plows available in both Europe and America; however, it remains to select one which fulfills the specific tasks to suit local conditions.

That a wide variety of crops can be grown on most Newfoundland peats well within economic inputs of lime and fertilizers there can remain no doubt. Even on the more difficultly drained peats, most crops can be grown by installation of intensive drainage systems. However, the high capital investment needed to install the more permanent perforated pipe drains in an intensive system would have to be equated against the value of the crop and the other advantages which may be inherent in the utilization of a certain bog at a certain location. It is also considered that machinery requirements need to be tailored to the individual enterprise, considering such factors as size of operation; specialization of operation, etc. It is likely that the success of the individual enterprise will depend largely on the ingenuity of the manager to acquire, modify and adapt the correct mechanical system for his operation.

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FIELD TRIP AND PHOTO INTERPRETATION EXERCISE

Charles Tarnocai

Six sites located on the Avalon Peninsula were visited during the field trip. Peatlands associated with these sites are characteristic of the peninsula. Aerial photo stereopairs and triplets (Figures 1-5) showing the peatlands on these 6 sites were prepared and used for the photo interpretation exercise.

Each person attending the workshop received a set of these six photographs on which the sites (1-6) were identified. During the indoor part of the photo interpretation exercise these sites were examined under stereoscopes and peat landforms, soils, vegetation and drainage were identified. The peatlands were also examined along a transect at some of these sites and peat landforms, soils, vegetation, and drainage were identified along the cross-sections which were drawn.

During the field trip each of these sites was visited and the results of the photo interpretation were verified with the ground truth and, if necessary, corrections were made. In addition, different sampling techniques were demonstrated.

At every site the following peatland components were examined:

1. Peat landforms and associated photo patterns.
2. Identification and description of vegetation and associated photo patterns.
3. Identification of peat materials.
4. Determination of fiber content.
5. Description of organic soil profile.
6. Ground truth collection on one of the traverses interpreted on peatland associated with site 3 and generation of a surveyed cross-section using an abney and measuring tape to determine the length and surface topography and peat augering to determine the depth and type of peat materials.

The aerial photographs of sites 1 to 6 and a brief description of these sites are given in Figures 1 to 5.

Figure 1. Basin bogs (site 1) are common in areas of hummocky moraine with poor drainage as is shown on the aerial photo stereopair below. The surface of these basin bogs is level and they have developed in topographically confined basins where the peat is generally deepest in the centre. The description of site 1 is as follows:

Site Description

Location:	Lat. $47^{\circ}21'40''$N, Long. $53^{\circ}02'40''$W
Air Photo No.:	A19592-154, 155
Elevation:	235 m
Peat Landform:	Basin Bog
Slope:	0%
Peat Material:	Sphagnum and Scirpus-moss peat
Drainage:	Very poor
Vegetation:	*Scirpus caespitosus* - moss
Soil Classification:	Terric Fibric Mesisol

Soil Profile Description

Of	0-30 cm	Undecomposed sphagnum peat
Om	30-115 cm	Moderately decomposed Scirpus-moss peat
R	115 + cm	Bedrock

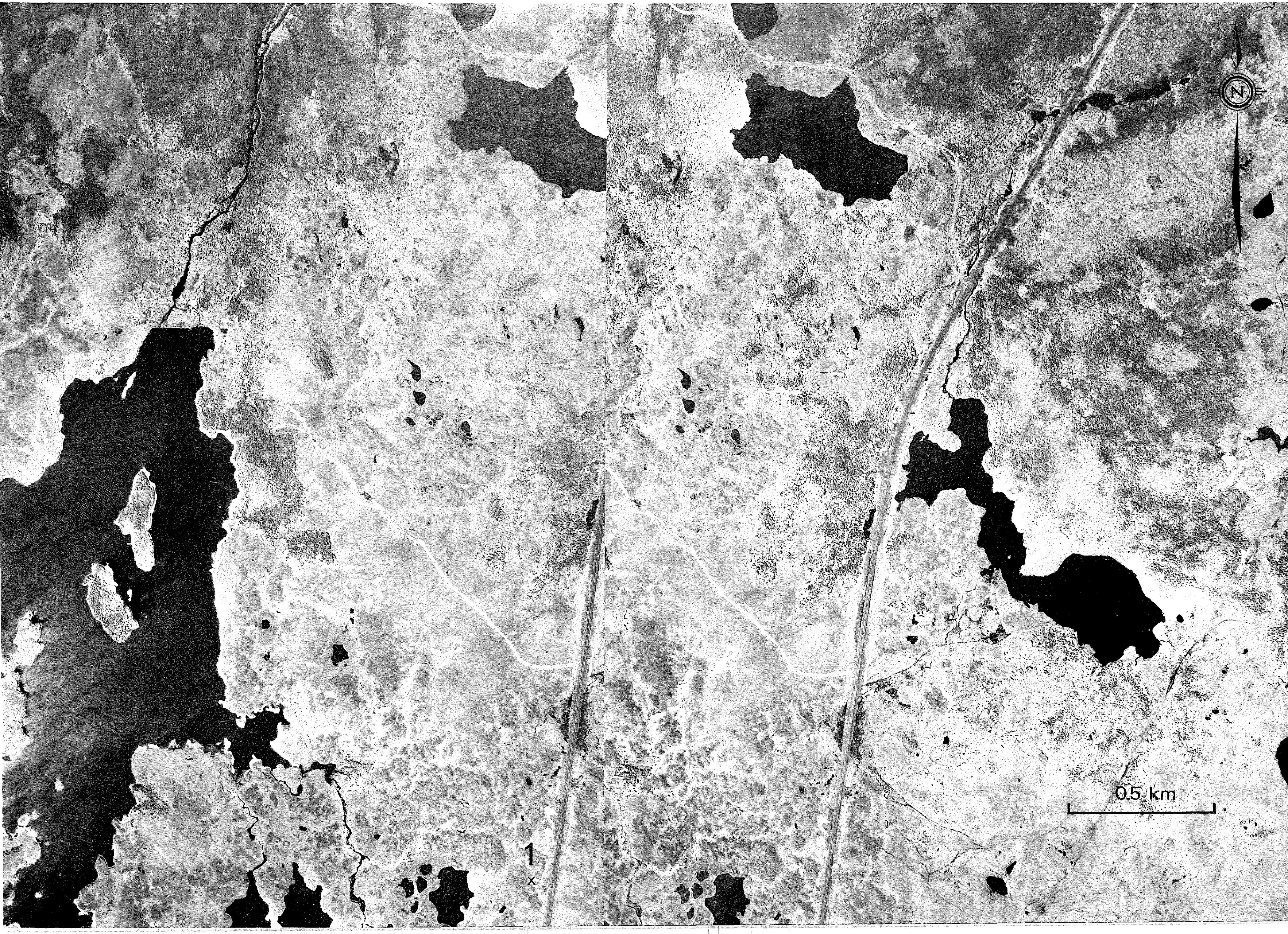

N
0.5 km
1

Figure 2. Atlantic ribbed fens (site 2) are found on the exposed upland regions. They are associated with very shallow peat and an abundance of pools which vary in shape and size. The surface pattern, as is shown on the aerial photograph below, is characterized by a sub-parallel pattern of ridges and furrows. These fens are very often situated on slopes. The description of site 2 is as follows:

Site Description

Location:	Lat. $47^{\circ}21'30''$N, Long. $52^{\circ}59'25''$W
Air Photo No.:	A19592-120, 121, 122
Elevation:	220 m
Peat Landform:	Atlantic Ribbed Fen
Slope:	12%
Peat Material:	Sedge-moss peat
Drainage:	Very poor
Vegetation:	*Carex sp.*
Soil Classification:	Rego Gleysol, peaty phase

Soil Profile Description

Om	30-0 cm	Moderately decomposed sedge-moss peat
Ah	0-6 cm	Loamy sand
Cg	6-20 cm	Loamy sand

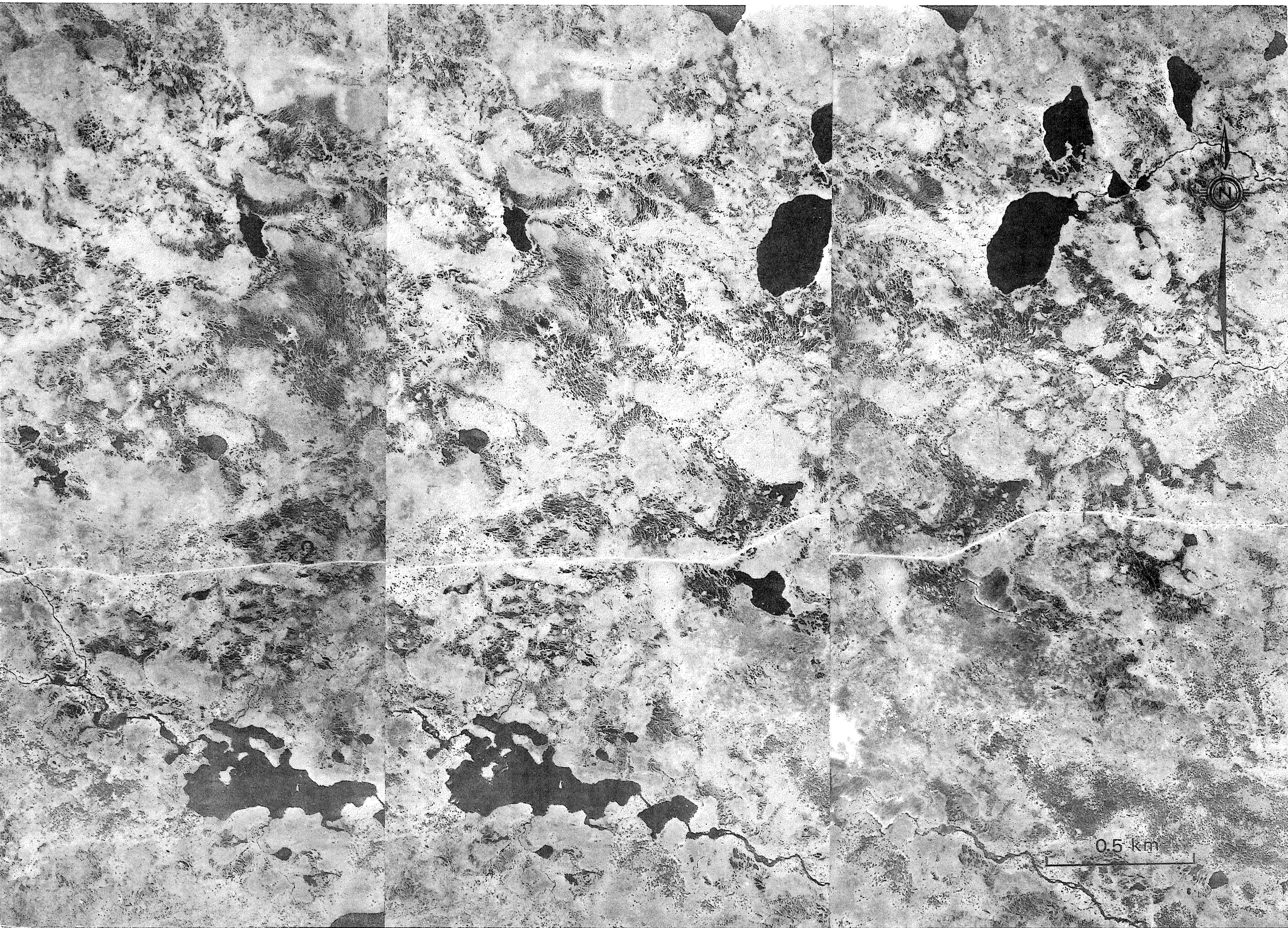

N
0.5 km

Figure 3. Aerial photo triplet showing a domed bog (site 3) and a stream fen (site 4). The domed bog (site 3) is slightly elevated above the surrounding fen. The stream fen (site 4) is situated along the small river and its hydrology is controlled by the water level of the stream. The descriptions of these sites are as follows:

SITE NO. 3

Site Description

Location:	Lat. 47°25'55"N, Long. 53°20'50"W
Air Photo No.:	A19579-168, 169
Elevation:	75 m
Peat Landform:	Domed Bog
Slope:	2%
Peat Material:	Sphagnum and woody-sedge peat
Drainage:	Poor
Vegetation:	Ledum groenlandicum, Sphagnum spp. Empetrum nigrum, Scirpus spp. and Cladonia spp.
Soil Classification:	Typic Mesisol

Soil Profile Description

Of	0-40 cm	Undecomposed Sphagnum peat
Om_1	40-90 cm	Moderately decomposed Sphagnum and Scirpus peat
Om_2	90-210 cm	Moderately decomposed woody-sedge peat
Om_3	210-290 cm	Moderately decomposed woody-sedge peat
Om_4	290-320 cm	Moderately decomposed woody-sedge peat
IICg	320 + cm	Sandy loam till

SITE NO. 4

Site Description

Location:	Lat. 47°27'25"N, Long. 53°22'03"
Air Photo No.:	A19579-167, 168
Elevation:	110 m
Peat Landform:	Stream Fen
Slope:	0%
Peat Material:	Sedge peat
Drainage:	Very poor
Vegetation:	Carex spp., and some Sphagnum spp.
Soil Classification:	Terric Fibric Humisol

Soil Profile Description

Of	0-30 cm	Undecomposed Sphagnum and Scirpus peat
Oh	30-100 cm	Well decomposed sedge peat
R	100+ cm	Bedrock

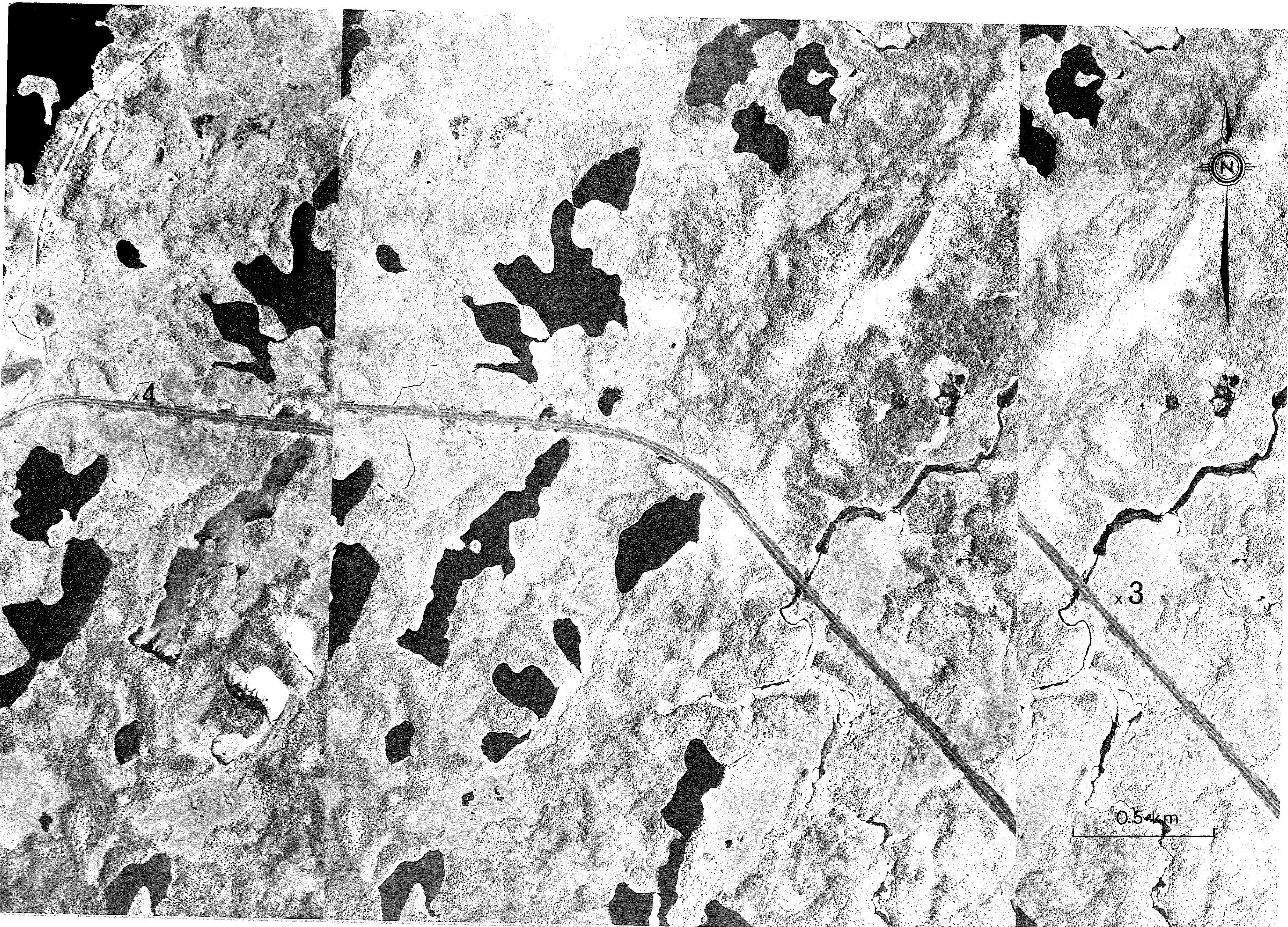

N
x4
x3
0.5 km

Figure 4. Domed bogs (site 5) shown on the aerial photograph below are characterized by convex surface topography. They are treeless in Newfoundland and usually have pools or wet depressions. The description of site 5 is as follows:

Site Description

Location: Lat. $47^{\circ}26'50''$N, Long. $53^{\circ}26'45''$W

Air Photo No.: A19579-164, 165

Elevation: 80 m

Peat Landform: Domed Bog

Slope: 3%

Peat Material: Sphagnum peat

Drainage: Poor

Vegetation: Lichen-Sphagnum-Scirpus-Ericaceous

Soil Classification: Typic Fibrisol

Soil Profile Description

Of_1	0-40 cm	Undecomposed Sphagnum peat
Of_2	40-300 cm	Undecomposed Sphagnum and Scirpus peat
Om	300-350 cm	Moderately decomposed Scirpus and Sphagnum peat
IICg	350 + cm	Loamy sand till

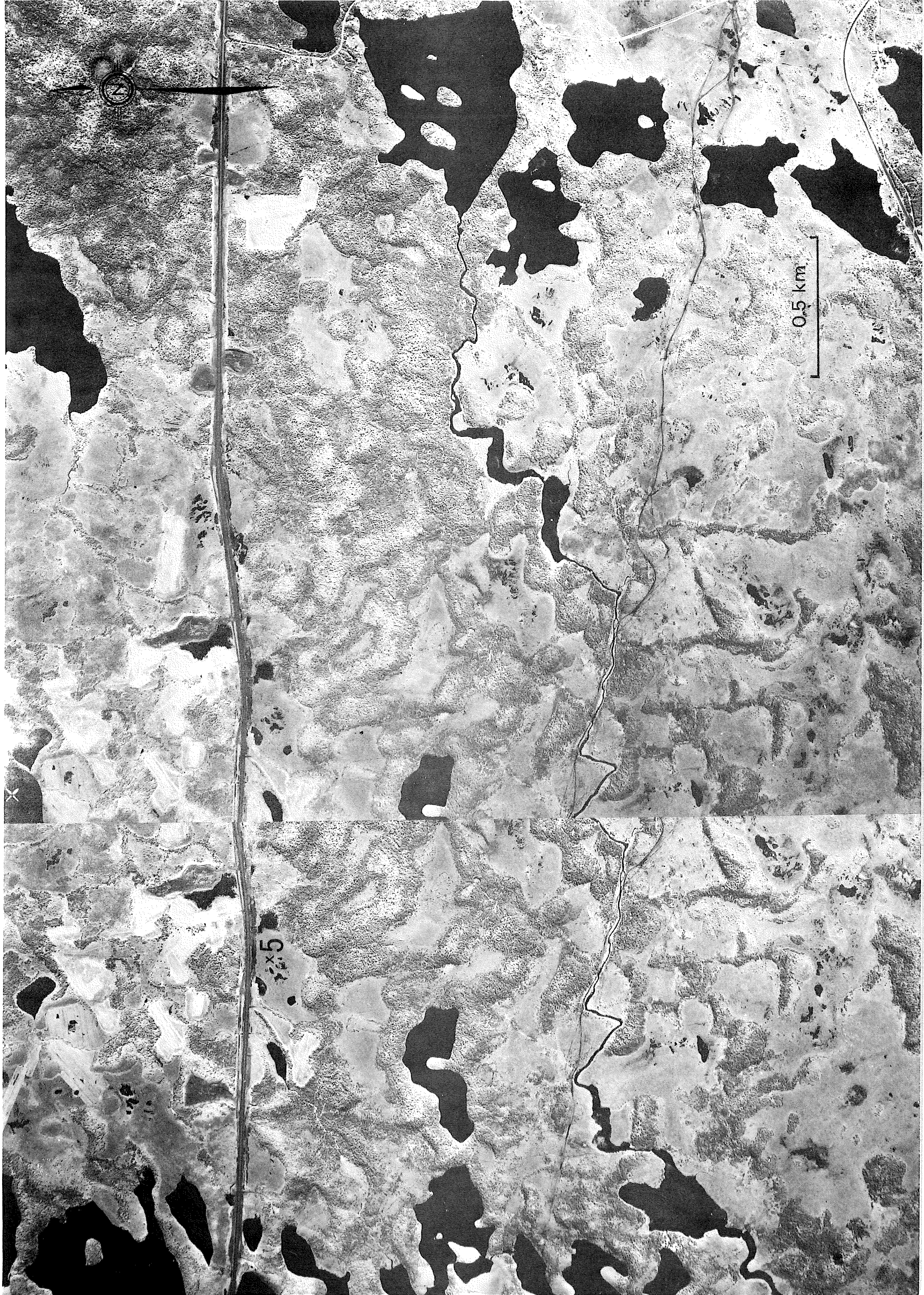

0.5 km
x5

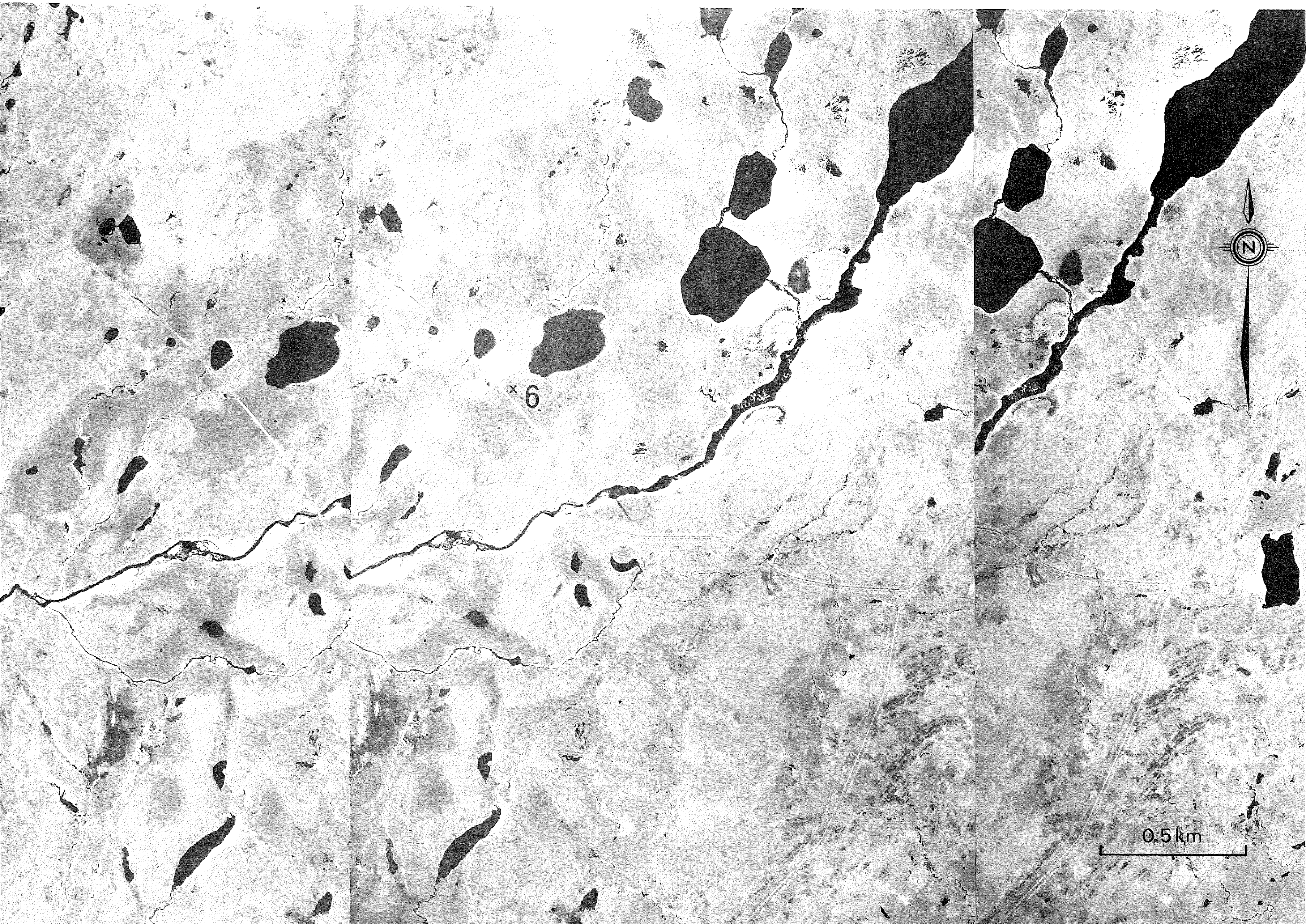
Figure 5. Blanket bogs (site 6) cover large tracks of terrain. They often extend over the landscape (both valleys and hills) for several kilometers. They are treeless and have relatively few ponds. On aerial photograph the blanket bogs are associated with a dark grey photo pattern (see the site 6 location). The description of site 6 is as follows:

Site Description

Location:	Lat. 46°42'45"N, Long. 53°29'35"W
Air Photo No.:	A20056-57, 58, 59
Elevation:	140 m
Peat Landform:	Blanket Bog
Slope:	2%
Peat Material:	Scirpus-Sphagnum peat
Drainage:	Poor
Vegetation:	Scirpus- Sphagnum
Soil Classification:	Terric Fibric Mesisol

Soil Profile Description

Of	0-40	Undecomposed Sphagnum and Scirpus peat
Om	40-145	Moderately decomposed Sphagnum and Scirpus peat
IICg	145 +	Sandy loam till



N
6
0.5 km

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