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Hydrogeochemistry and Peat Development in a Coastal Cedar-Hemlock Bog-Forest Complex

Introduction

In the Prince Rupert Forest Region of British Columbia (BC), low to mid-elevation coastal cedar-hemlock forest ecosystems have developed hydrological conditions that control the degree of root zone saturation and nutrient supply. Within the North Coast Timber Supply Area, only 6% of the 1.14 million ha land base is considered operable (BCMOF 1994). Opportunities exist to expand into previously uneconomical, lower productivity, lowland coastal forests. Harvesting these forests will alter soil moisture conditions, water table elevation and duration, and nutrient fluxes. A projected rise in the shallow water table may have an impact on peat development and consequently, on forest tree growth. Under such conditions, decreased soil aeration would limit oxygen and nutrient supply in the rooting zone. The success of second-growth forests will also be linked to expected changes in peat development processes both within peatlands and between peatlands and adjacent forests. As peat development progresses, well-drained surficial systems are replaced by poorly drained conditions. The impedance of drainage results in the replacement of forest plant communities by bryophytes with concomitant variation in hydrology and geochemistry.

The plan to harvest lowland stands has created a need to understand the hydrological and ecological processes in these ecosystems. A multidisciplinary collaborative study "Pattern, Process and Productivity in Hypermaritime Forests of Coastal British Columbia" (HyP³) was therefore initiated with the aim of providing some guidelines for the sustainable management of these

forests. This paper is one outcome of HyP³ and presents some preliminary information on the hydrogeochemistry and peat development within a representative bog-forest complex.

Study Area and Methods

The study site is located in the Diana Lake Provincial Park, approximately 20 km southeast of Prince Rupert, BC, and is characterized by hypermaritime conditions with frequent periods of fog. Soil-forming processes are dominated by the accumulation of organic matter and peat. The bedrock geology consists of gneisses and schists.

A 500-m transect was established from a lowland forest, through bog woodland, bog, and into a productive upland forest (Figure 1). The research was conducted from 03 July 1997 to 14 January 1998. Water table depth and hydraulic head data were obtained from a series of wells and piezometers (2.5-cm diameter PVC pipe) installed within each vegetation community. Hydraulic conductivity for each piezometer was determined by the Hvorslev water level recovery method (Freeze and Cherry 1979). Vertical and horizontal (fog) precipitation were monitored continuously using tipping bucket rain gauges. The fog collection apparatus is described in Price (1992). Samples for chemistry were collected from polyethylene manual rain gauges. Throughfall was collected in stainless steel V-shaped 8-m long troughs, at an angle of 10° from the horizontal, emptying into a tipping bucket rain gauge. A similar apparatus using a polyethylene trough was used to sample throughfall for chemistry.

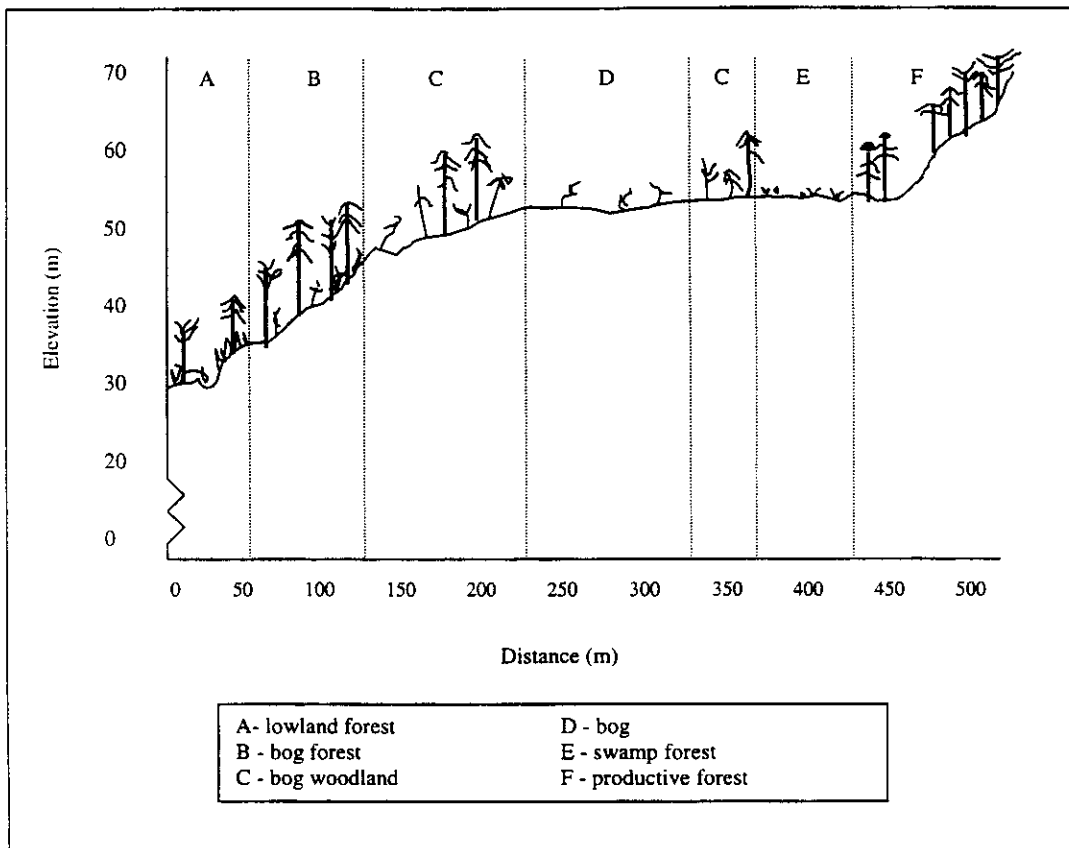


Figure 1. Schematic profile of the bog-forest complex.

Samples for chemical analysis were collected every other month. Groundwater samples were collected from piezometer nests at five sampling stations in each of the five vegetation communities. Soil water was collected in the forest communities using ceramic-cup soil water samplers at 15-, 35-, and 55-cm depths. Samples were field filtered, preserved and stored at 4°C, and later analyzed for pH, electrical conductivity, major ions, alkalinity, reactive silica, and dissolved inorganic and organic carbon.

Borings and soil pits were used to characterize the nature of the unconsolidated mineral deposits overlying the bedrock, the depth of organic matter, and stratigraphic composition of peat in the bog. Seven additional cores within the bog woodland and the bog were taken for detailed analysis of soil bulk density, ash content, and radiocarbon dating.

Results and Discussion

The vegetation communities are in part related to slope and in part related to the peat component in the soil profile. More productive forests occur on steep, well-drained sites. On slopes of lower gradients, peat has accumulated and water tables are relatively shallow. The ability to moderate water table fluctuation is related to the thickness of the unsaturated zone. Water table response to storm events is much more rapid in the bog woodland and bog as compared to the lowland and upland forest systems where response times lag by several days. Vertical hydraulic gradients within the lowland forest (0.001), bog woodland (0.01), and bog (0.004) indicate a weak downward flow of water. The rate of flow through the organic soils depends largely on porosity. Undecomposed surface peats have specific yields of 0.05 - 0.08 cm³/cm³ and allow rapid water movement. As indicated

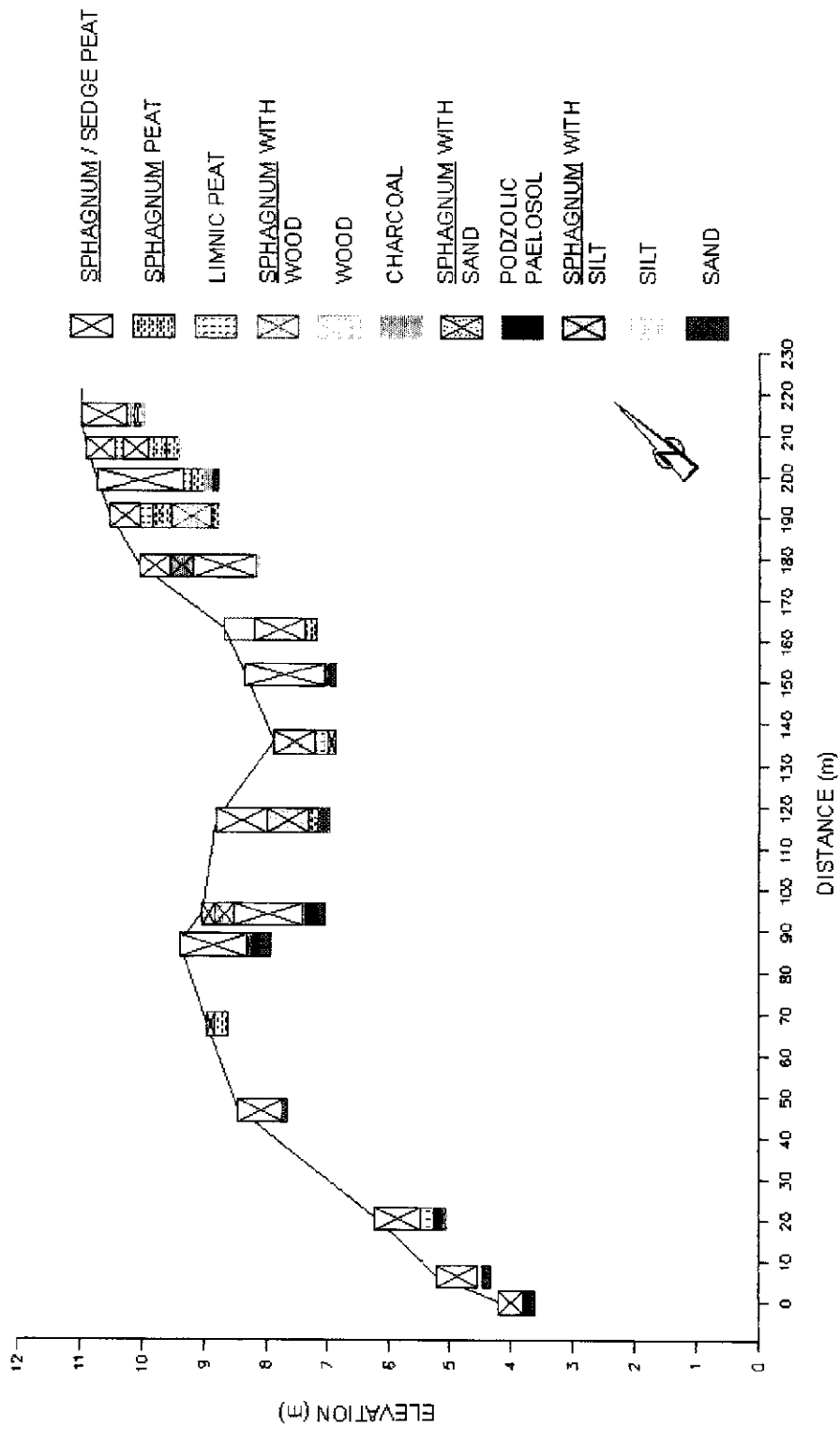


Figure 2. Stratigraphic profile of the bog and bog woodland communities in the bog-forest complex.

by specific yields ($0.12 - 0.58 \text{ cm}^3/\text{cm}^3$), the more decomposed peats permit little water movement. The rate of water movement depends largely on the peat material found in the organic profile. Hydraulic conductivities were found to cover a range of values ($5.1 \times 10^{-7} - 2.7 \times 10^{-4} \text{ cm s}^{-1}$). Hydraulic conductivity in the lowland forest, bog forest, bog woodland, and bog averaged 9.3×10^{-5} , 3.1×10^{-5} , 4.7×10^{-6} , and $1.7 \times 10^{-6} \text{ cm s}^{-1}$, respectively.

As the peat component in the soil profile increases, the pH of soil and ground water decreases. This acidification is due to microbial activity and the cation exchange capacity of *Sphagnum* species. The predominant major anion and cation in ground and soil water solution were Cl^- and Na^+ , respectively. The absence of sulphate and nitrate could be related to forest uptake and redox processes under the high water table conditions. The dominant base cations are Mg^+ and Ca^+ . The influence of base cations increases with depth, reflecting the influence of mineral soil and ground water discharge. Further sampling is required before geochemical patterns can be clearly established.

In the central part of the bog, peat formation began 11 000 cal y BP and has progressed downslope laterally at rates varying from 0.5 to 6.8 cm y^{-1} and vertically at a rate of 0.15 ± 0.01 (SE) mm y^{-1} . Paludification seems to have been the primary mode of peatland development. The upper layers of the stratigraphic profile, comprising the bog and bog woodland complexes (Figure 2), are composed primarily of *Sphagnum* and *Sphagnum*/sedge peats underlain in many places by

woody peat with charcoal. Podzolic paleosols, indicating a former forest component, were also present in some cores at the peatland-underlying mineral contact. Linnic peats at the northern edge of the bog may indicate former open water wetlands. The depth of the peat is greater along the northern edge and in the middle of the peatland compared to the shallower bog forest area to the south. Ash content (7.1 ± 0.9 (SE) % of dry matter) and long-term rates of carbon (C) accumulation (6.3 ± 0.6 (SE) $\text{g m}^{-2} \text{ y}^{-1}$) are substantially lower in comparison to published data from boreal peatlands (Ovenden 1990, Tolonen and Turunen 1996). Variation in C accumulation rates indicate horizontal carbon flow in the mineral subsoil. Considering the C accumulation densities in each vegetation community, only the average C density for the mineral subsoil of the bog forest differed significantly compared to the bog ($p=0.011$). The accumulation of C in the bog forest may indicate transport from further upslope; however, the origin of this C will not be known until C-14 dating is complete.

Although the data are preliminary, this study will contribute insights into bog-forest complexes that will be used to develop management guidelines for the hypermaritime forests of BC. Future research will more closely examine the interaction between the hydrological system, geochemical processes, and peat development.

Acknowledgements

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