Danielle Chiasson[1,2,3], Pascale Roy-Léveillée[1,2,3], Najat Bhiry[2,3]

1 CRYO-UL Permafrost Research Laboratory at Université Laval
2 Centre d'études nordiques, CEN Centre for Northern Studies
3 Université Laval

Post-Drainage Evolution of Wolverine Lake, Old Crow Flats, Yukon

A palaeoecological approach to better understand drained thermokarst lake basins after drainage

The Evolution of Drained Thermokarst Lake Basins

Drained thermokarst lake basins (DTLBs) are extremely dynamic and create complex landscapes marked by repeated cycles of permafrost degradation through thermokarst lake formation, and permafrost aggradation following lake drainage. The age of DTLBs can range from decades to thousands of years old and have different morphologies and vegetation depending on their age.

In terms of morphology, young basins have raised margins and depressed centres with remnant ponds, and show uncertain permafrost aggradation in the decades following drainage. Whereas old basins are the opposite, with depressed margins and raised centres. The vegetation of young basins is characterized by a rapid development and mortality of tall willow thickets in its margins, representing an intermediate stage of succession. The vegetation in older basins is either dominated by dwarf shrubs, tussock tundra, or mosses.

While contemporary conditions in DTLBs have been well documented, little is known about the evolution of young basins to old, and there are few paleo-environmental reconstructions of post-drainage basin evolution prior to anthropogenic climate warming. Luckily, DTLBs and their thick peat covers are excellent paleo-archives.

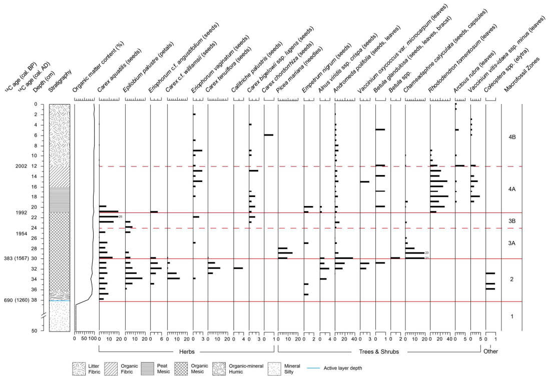


Figure 2. Macrofossil diagram and stratigraphy of a peat core from the centre of Wolverine Lake's drained basin. Macrofossil zones are delineated by solid red lines and their sub-zones by dashed red lines.

Macrofossil Analyses

4 macrofossil zones were identified in the peat cores based on species composition (Figures 2 & 3) and peat characteristics. Each zone represents a major change in vegetation composition and a stage of vegetation succession. Sub-zones represent finer vegetation changes within each zone.

Zone 1 | Margin: Marsh, dominated by aquatic species. Centre: Open water, no species present.

Zone 2 | Margin & Centre: Wet sedge meadow, dominated by hydrophilic sedges. Terrestrial species reflect changes in topography and hydrology.

Zone 3 | Margin: *Sphagnum* bog with a mixture of sedges and dwarf shrubs. Centre: *Sphagnum* bog, with influx of black spruce and ericaceous shrubs.

Zone 4 | Centre: Tundra with tussock-forming sedges, dominated by ericaceous shrubs.

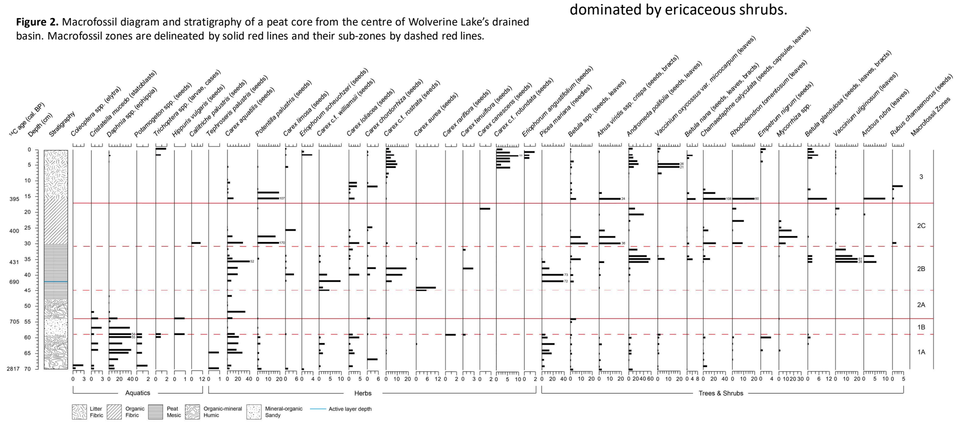


Figure 2. Macrofossil diagram and stratigraphy of a peat core from the margin of Wolverine Lake's drained basin. Macrofossil zones are delineated by solid red lines and their sub-zones by dashed red lines.

Old Crow Flats, Yukon

Old Crow Flats (OCF) is a lake-rich thermokarst landscape spanning 5,600 km^2 within the continuous permafrost zone of the Vuntut Gwitchin Traditional Territory, northern Yukon, Canada.

In 2019, the Vuntut Gwitch'in First Nation declared a climate change state of emergency related to the rapid landscape change in their traditional territory. These changes include increased frequency of catastrophic lake drainage events and widespread willow growth following drainage, contributing to landscape-scale shrubification.

Study Site & Methodology

Wolverine Lake (Figure 1A) is a large thermokarst lake that drained catastrophically prior to anthropogenic climate warming. This makes its drained basin a good candidate for paleo-reconstruction.

Peat samples were collected from the margin and centre of its drained basin (Figure 1B-D) to reconstruct local vegetation succession through radiocarbon-dated macrofossil analyses at 1cm intervals.

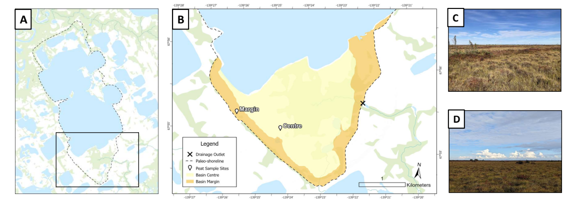
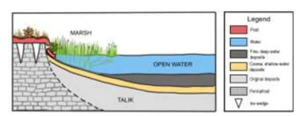


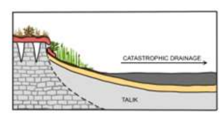
Figure 1. A) Wolverine Lake, its paleo-shoreline, and location of drained basin. B) Peat sample sites within the margin and centre of the drained basin. C) Photo of the margin sample site. D) Photo of the centre sample site.

Conceptual Model of Post-Drainage Evolution



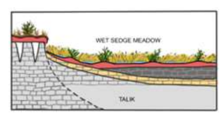
Pre-Drainage | Early-Successional Marsh

Wolverine Lake was a 290 km^2 thermokarst lake undergoing active lake expansion. The margin is characterized by a shallow lakeshore marsh. The centre is open water, too deep for the growth of aquatic plants.



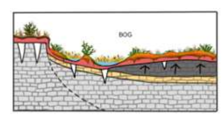
Catastrophic Drainage

Similar basal peat dates from the margin and centre suggest that Wolverine Lake drained catastrophically from the SE corner c. 730 years BP. The partial drainage of Wolverine Lake may reflect differences in lake bathymetry prior to drainage. Permafrost aggradation begins in the exposed basin sediment.



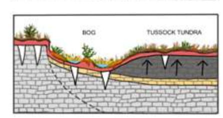
0-400 Years Post-Drainage | Mid-Successional Wet Sedge Meadow

Both the margin and centre are characterized by fen vegetation dominated by hydrophilic sedges. Drier species of dwarf shrubs establish on ridges and mounds of peat. During this post-drainage timeframe, as observed in modern basins, the rapid development of willows is expected. However, there is no evidence of willow species in the macrofossil record of the margin or the centre. Permafrost depth after 300 years = 25m



400-800 Years Post-Drainage | Mid-Successional *Sphagnum* Bog

Surface uplift at the centre (due to aggradational ice) causes differences in topography, hydrology, and vegetation within 400 years post-drainage. The centre is drier and dominated by ericaceous shrubs. The margin is wetter with a mixture of dwarf shrubs on peat ridges and hydrophilic sedges in wet depressions. Permafrost depth after 500 years = 33m



600-800 Years Post-Drainage | Mid-Successional *Sphagnum* Bog | Late-Successional Tussock Tundra

What is observed today at the margin and centre of the basin. The margin remains a wet *Sphagnum* bog, whereas the centre is characterized by drier tussock tundra vegetation. The late-successional tussock tundra stage is reached within 600 years post-drainage, an accelerated rate due to ongoing surface uplift. Permafrost depth after 800 years = 42m

Many thanks / Merci beaucoup / Mahsi' Cho

Vuntut Gwitchin Government
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