Long-term increasing water levels in subarctic fens of the Laforge region, Quebec: timing and potential driving factors

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ABSTRACT
The subarctic fens of the Laforge region possess a microtopography of large pools and narrow strings, implying an imbalance between hydrology and peat accumulation. In this project, we performed paleoecological analyses to determine the timing and nature of the initiation of local wet surface conditions. Tools include testate amoeba and local vegetation analyses combined with radiocarbon dating. A reconstruction of water tables was inferred from amoeba assemblages using a transfer function. Due to possibly important variability within and between ecosystems, a total of six cores from three peatlands are studied.

RÉSUMÉ
Les tourbières minérotrophes subarctiques de la région de Laforge montrent une microtopographie caractérisée par des larges dépressions humides et des buttes étroites, indiquant un déséquilibre entre l’hydrologie et l’accumulation de tourbe. Des analyses paléoécologiques ont été employés afin de déterminer l’installation des conditions humides locales et d’identifier le facteur déclenchant. Les outils paléoécologiques incluent des analyses des thécamoebiens et de la végétation locale, ainsi que des datations au carbone-14. Une reconstitution de la nappe phréatique est obtenue par l’application d’une fonction de transfert aux assemblages de thécamoebiens. Puisque la variabilité pourrait être importante à l’intérieur et entre écosystèmes, on étudie un total de six carottes provenant de trois tourbières.

1 INTRODUCTION
Peatlands are unique ecosystems as they generally accumulate organic matter in a relatively steady way on decadal to millennial timescales. The major part of the global peatlands are found in the northern and boreal regions of the northern hemisphere, covering about 4 million km² (Yu et al., 2010). Peatland development generally coincided with the onset of the Holocene, as arctic conditions or glacier presence prevented large-scale peat accumulation during the Last Glacial Maximum. Organic matter is accumulated as production generally exceeds its decomposition, the decay rates being strongly limited due to typically cold, acidic and anoxic conditions of the submerged peat.

Due to their accumulating nature, peatlands are of importance in paleoecological and paleoclimatological research for two reasons. First, peatlands constitute an important sink of organic carbon as about 50% of the organic matter is represented by carbon. Due to a relatively continuous accumulation and expansion of peat over the Holocene, peatlands have influenced the global atmospheric greenhouse budget by an uptake of CO₂, yet emitting methane (CH₄) (Froking and Roulet, 2007). At present, northern peatlands represent about 30% of the global soil carbon pool (Yu et al., 2010).

Second, determining past variations in local vegetation constitute an effective way to reconstruct water table levels as the vegetation is strongly determined by hydrology. Using multiple records from one or more ecosystems, a reconstruction of past climate regimes may thus be inferred. In many ombrotrophic peatlands, summer water deficit is a driving factor for local water table levels (Charman et al., 2009), although in (sub)arctic regions snowfall may play an additional role.

Besides local vegetation, the analysis of testate amoebae has been developed over the last decades to reconstruct past water table fluctuations in peatlands, as shifts in testate amoeba presence are primarily driven by changes in water level (e.g. Warner and Charman, 1994). As testate amoebae are generally ubiquitous, we may assume that assemblages rapidly respond to changes in local water table. Transfer functions may thus be used to quantify water table levels from past testate amoeba assemblages (Booth, 2008; Charman et al., 2007).

The peatlands in the subarctic Laforge region (54°N/72-73°W) are located close to the peatland distribution limit in eastern Canada, as northwards colder temperatures and thinner snow covers inhibit Sphagnum (peat moss) growth and may cause the installation of permafrost, thereby strongly limiting the accumulation of peat. Due to the proximity of the peatland distribution limit and given important decreases in temperature and changes in precipitation regimes previously referred to as the Neoglacial (Bhiry et al., 2007; Carcaillet and Richard, 2000; Filion, 1984), this region is of high interest considering paleoecological and paleoclimatological reconstructions. At present the peatlands in the Laforge region show an important presence of pools whereas terrestrial sections are highly spatially limited, indicating
an imbalance between hydrology and peat accumulation. As peat accumulation and water balance are nonlinearly related (Belyea, 2009), a driving factor for this “aqualysis” tendency may be difficult to identify. Nevertheless, if multiple records from different peatlands show comparable timing of shifts, this implies that changing climate conditions may have pushed these ecosystems over a stability threshold.

In this study, we use both testate amoeba and vegetation analyses to reconstruct hydrological changes in three subarctic fens of northern Quebec. We specifically aim to identify the onset of the aqualysis process and driving factors.

2 STUDY REGION

The minerotrophic peatland Aeroport (∼3 ha) is located at the eastern, upstream end of the La Grande Rivière watershed near the hydro-electric complex of Laforge-1 (54°06'15"N; 72°13'10"W). The regional mean annual temperature is -4.3°C and mean annual precipitation is 739 mm. The amount of growing degree days above zero is 1400 (NLWIS data; Hutchinson et al., 2009). The region was covered by the Laurentide Ice Sheet until ~7500 cal BP (Dyke et al., 2003), after which peatland development could initiate. Regional initiation of peat accumulation has been found starting ~7380 cal yr BP (Arlen-Pouliot, 2009).

Figure 1. Aeroport fen with coring locations

3 MATERIAL AND METHODS

From each of the three peatlands two peat cores were retrieved. Coring was performed using a Box corer. Cores were wrapped in foil, transferred to rigid cases and transported to the laboratory where they were stored in a cold chamber at 4°C until analysis. Cores were sliced into continuous 1-cm thick sections and subsampled for testate amoeba and vegetation analyses.

Preparation of testate amoeba subsamples (1 cm³) was performed using the method by Hendon and Charman (1997). For each subsample we aimed to identify 150 individuals, although in some cases only 50 individuals could be counted due to the presence of highly decomposed peat and probably poor conservation of the tests. Water table depths were inferred from testate amoeba assemblages using a transfer function for Quebec peatlands (Lamarre, 2010).

Radiocarbon dating was performed using accelerator mass spectrometry on terrestrial plant material. The resulting radiocarbon ages were calibrated and age-depth models were created using Bchron (Haslett and Parnell, 2008).

4 PRELIMINARY RESULTS

For now, we present results from two cores from Aeroport fen. Core Aero1 was sampled near the peatland-forest boundary and core Aero5 was sampled close to the center of the peatland (Figure 1).

Radiocarbon datings of the basal peat shows that peat accumulation started around 5530 and 4260 cal yr BP in cores Aero1 and Aero5 respectively (Table 1).

Table 1. Radiocarbon dating results selected by core

<table>
<thead>
<tr>
<th>Core</th>
<th>Depth (cm)</th>
<th>Lab. code</th>
<th>¹⁴C Age (yr BP)</th>
<th>Age (cal yr BP)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Beta226438</td>
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<td>2010</td>
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<tr>
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<td>UCIAMS39594</td>
<td>3490±15</td>
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<td>4790±60</td>
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<td>TO12796</td>
<td>3830±50</td>
<td>4260</td>
<td></td>
</tr>
</tbody>
</table>

Due to differences in relative position, reconstructed water table depths show important differences (Figures 2 and 3).

Core Aero1 shows very low water tables between 20 and 60 cm beneath the surface during early accumulation history, until ~3000 cal yr BP (Figure 2). Local vegetation analyses confirm dry conditions by the presence of important quantities of *Picea mariana* needles and *Sphagnum fuscum* during this period (not shown). After 3000 cal BP, water tables rise abruptly, reaching the surface around 2100 and 1000 cal yr BP during the late-Holocene, with a slight decrease after 600 cal yr BP.
Holocene water tables from core Aero5 show much more stable values, generally fluctuating between 10 cm depth and the surface over the last 4300 years (Figure 3). The differing trend in water table fluctuations during the period 4300-3000 cal yr BP may be explained by lateral expansion. The position of Aero1 close to the present-day forest indicates that this site became much more humid once the fen developed laterally.

4.1 Future work

Additional testate amoeba analyses, reinforced by reconstructions of local vegetation from the two remaining peatlands, may permit the identification of a distinct climate change ~3000 cal yr BP that may have caused ecosystem scale increases in water tables. Alternatively, if no increase in water table is found around 3000 cal yr BP in the other peatlands, the trend observed in the Aeroport fen may merely be a local trend, possibly the result of hydrological change at the scale of the watershed.

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