A Multiproxy Paleolimnology Study on a Shallow Delta Lake in Northern Canada

Y.Yi[1], R.N. Sinnatamby[2], T. Asada[2], K. Clogg-Wright[1], M. Sokal[2], M. Falcone[1], T.L. Karst-Riddoch[2], S.R. Vardy[2], R.I. Hall[2], B.B. Wolfe[1,3], T.W.D. Edwards[1]

[1]Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada
[2]Department of Biology, University of Waterloo, Waterloo, Ontario, Canada
[3]Department of Geography & Environmental Studies, Wilfrid Laurier University, Waterloo, Ontario, Canada

1. Introduction- Peace Athabasca Delta (PAD)

The Peace-Athabasca Delta (PAD) in northern Alberta, Canada, is one of the largest and most productive inland freshwater boreal ecosystems in the world (~4900 km^2). It has been recognized both by the Ramsar Convention as a wetland of international significance and by UNESCO as a World Heritage Site.

In 1968 the W.A.C. Bennett Dam was constructed for hydroelectric production at the headwaters of the Peace River, exacerbating the effects of dry climatic conditions on river discharge and delta hydroecology during the filling of the reservoir (1968-1971). Absence of major ice-jam flooding 1975-1995 and apparent drying in the delta have fueled concern that flow regulation may also be enhancing the impact of climatic forcing on this system. However, insufficient understanding of the long-term evolution of the delta has limited our ability to separate anthropogenic factors from natural climatic effects.

Herein, we are employing multidisciplinary paleolimnological approaches, integrating physical (structure, texture, mineralogy), biological (diatom, pigments, pollen, plant macrofossils) and geochemical (organic elemental abundance and stable isotope composition) information preserved in lake sediments, to investigate the natural history of the system.

2. Study Site – PAD 9

PAD 9 (58°46.46' N, 111°19.48' W, 208.8m asl) is a small, shallow (ca. 12ha, Z_{max}=0.9m), closed-drainage lake. The lake is located near Lake Athabasca, one of the Great Lakes of northern Canada, and is separated from the western end of Lake Athabasca by an extensive (ca. 70km^2) wetland. While a bedrock outcrop borders the lake in the south, the remaining shoreline is marked by a double fringe of dead willow shrubs with prominent adventitious rooting well above current lake levels, indicative of both lower and higher water levels in the past. Highly productive conditions were observed in a growing season, with abundant *Ceratophyllum*, other aquatic macrophytes and filamentous algae.

3. Sampling

Both short and long cores were retrieved from the current depocenter of the lake in June 2001. Five short cores (~30cm) were collected with a modified KB gravity corer. Three long cores (80-100 cm) were collected with a Russian peat corer. Sediments were sectioned into 0.5cm intervals and preserved at 4°C until lab analysis.

Water samples were collected from the deepest part of PAD 9 for analysis of water chemistry and stable isotopes ($^{18}O/^{16}O$ and $^{2}H/^{1}H$). Measurement of maximum water depth, secchi depth, pH, total dissolved oxygen and conductivity were also performed in situ.

4. Chronology

Chronologies for the PAD 9 cores are based on ^{210}Pb analysis of upper sediments and ^{14}C dating of seeds of emergent macrophytes, preserved at 74 and 78 cm (Fig a). Error bars represent ± 2 SD units.

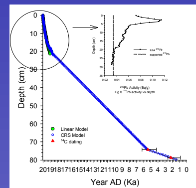
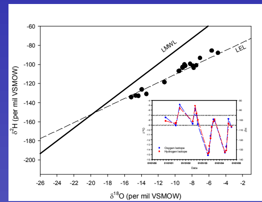


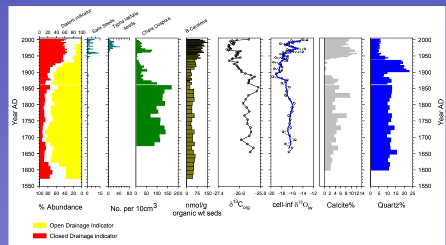
Fig a Depth Vs interpolated age

5. Modern Isotope Hydrology



Stable isotope monitoring of PAD 9 lake water over four years shows strong seasonal dynamics, which is characteristic of shallow lakes in the PAD. In δ^{18}O–δ^{2}H space, lake water samples tightly cluster along a Local Evaporation Line (LEL), suggesting evolution under local climatic conditions. In addition, other significant hydrological events also affected isotopic signatures. For example, 2002 late-summer precipitation events led to depletion in heavy isotopes, and 2003 snowmelt input in early spring caused depletion of lake water (~6‰ δ^{18}O) compared to the previous year.

6. Historical Period



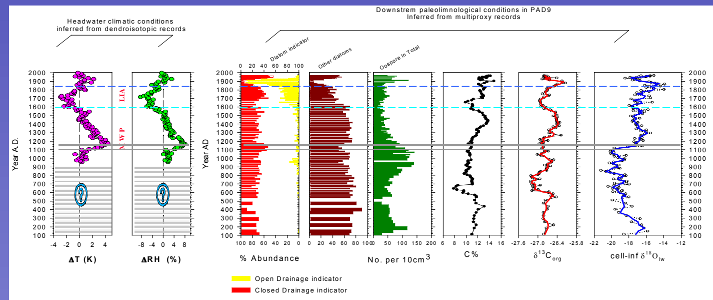
Short cores from PAD 9 clearly demonstrate three phase transitions over the past 400 years, which are also supported by a set of historical maps (1884, 1873, 1971) and maps based on air photos (1927, 1955):

1) Before 1910, PAD 9 was part of a shallow embayment of Lake Athabasca (1884 and1897 maps), indicated by high percent abundance of open-drainage diatom indicators (e.g. *Fragilaria pinnata*), high abundance of *Chara* oospores, and constant cellulose-inferred $\delta^{18}O_{lw}$.

2) Between 1910 and 1930, the peak in quartz content, sharp decline of *Chara* oospores, and the most depleted cellulose-inferred $\delta^{18}O_{lw}$ signals are consistent with a channelized through-flow lake in 1917 map.

3) Since 1930, PAD 9 has progressively become an isolated closed-drainage lake (1927 and 1955 maps), as indicated by the dominance of closed-drainage diatoms (e.g. *Cocceneis placentula*), encroachment of shoreline vegetation (e.g. *Salix and Typha*), and enriched cellulose-inferred $\delta^{18}O_{lw}$ and depleted $\delta^{13}C_{org}$.

8. Last Two Millennia



The extended records from the Russian core allow us to place these historical changes in a long-term context.

- Around AD 1100, the lake-water isotope composition responded strongly to the extreme conditions of the "High Medieval" in the headwater region.
- However, through the Medieval Warm Period (MWP), the lake appeared to be dominated by closed-drainage diatoms, comparable to current conditions in terms of biology, although some ecological proxies including oospores, open-drainage diatoms and $\delta^{13}C_{org}$ did show variation to some extent during the "High Medieval".
- In comparison with the MWP, the lake is dominated by open-drainage diatoms during the Little Ice Age (LIA), possibly reflecting high water levels in Lake Athabasca maintained by sustained snowmelt runoff from the Rocky Mountains.
- The linkages between climate and hydroecology prior to AD 900 remain enigmatic.

On-going efforts to combine lake sediment records with isotope dendroclimatological records, and to develop dual-isotope tracer method for lake water composition (i.e. δ^{18}O and δ^{2}H) will help us further understand the ecological and hydrological responses to climatic forcing in this important northern ecosystem.

7. Historical Maps

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