Proxy development and calibration in the Canadian Arctic

Marie-Claude Fortin & K Gajewski

Laboratory for Paleoclimatology and Climatology
Ottawa-Carleton Institute of Biology
University of Ottawa
Ottawa, Ontario, K1N 6N5, Canada

mfort011@uottawa.ca gajewski@uottawa.ca

Abstract

In the Canadian Arctic, several proxy-climate records are being used to quantify Holocene climate variability, including microfossils (pollen grains, chironomid head capsules, diatom valves) and sediment parameters such as biogenic and organic content. Modern datasets have been developed for these parameters and used in modern calibration exercises. However, the size and geographic extent of the modern-calibration set, the availability and preservation of fossil material as well as difficulties in understanding the relationship between fossilised organisms and their environments can all significantly affect the resulting environmental reconstructions. In some cases, surprising results have been generated when seemingly robust calibration models have been applied to Arctic lacustrine sediment cores. The status of modern datasets for pollen, diatoms, chironomids and BSi will be discussed and applications in several cores presented. The various proxies can be compared to serve as checks on each other.

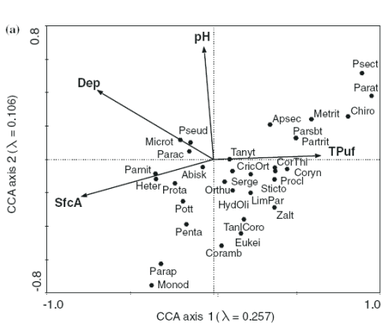
Introduction

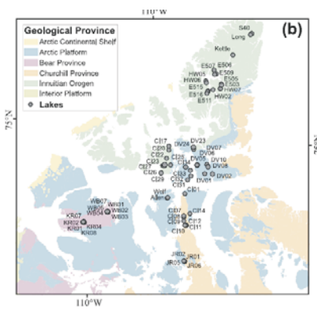
Recent work has greatly expanded our knowledge of the postglacial environments of the Canadian Arctic (Gajewski & Atkinson 2003). Multi-proxy, high-resolution analyses of several Holocene cores document climate variability of several time scales. Geographic arrays of modern samples are essential to permit the quantification of past environments though transfer function and modern analogue techniques.

Results: New calibration data from the Canadian Arctic

In the past few years, we have obtained modern sediment samples and water chemistry information (Hamilton et al 2001) for sites across the Canadian Arctic. In addition, a GIS-based empirical climate model (Atkinson & Gajewski 2002; Atkinson et al 2000) provides high resolution temperature estimates for all sites.

These samples provide the basis for the interpretation of sediment assemblages from arctic environments. All data are available on the Internet for paleoenvironmental reconstructions.

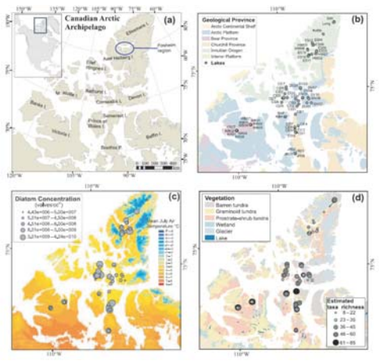




Chironomids

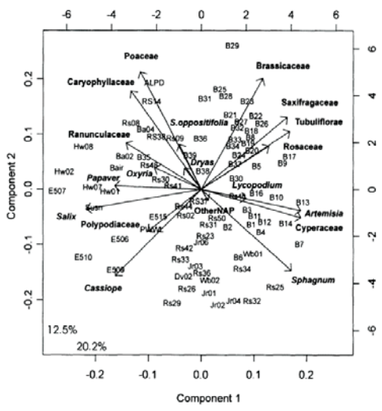
Chironomids have wide distributions (Gajewski et al 2005; Barley et al 2006; Fortin in prep) and are affected by conditions within the lake as well as climate.

A dataset of modern diatom samples from the Canadian Arctic (Bouchard et al 2004) showed the importance of water chemistry in determining diatom abundance, and also that greatly difference assemblages are found in nearby lakes. Taxonomic (Paull et al 2008) and taphonomic (Gajewski 2008) issues need to be carefully considered.



Diatoms

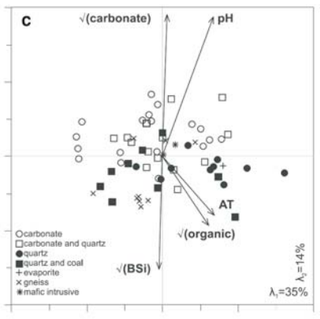
Pollen

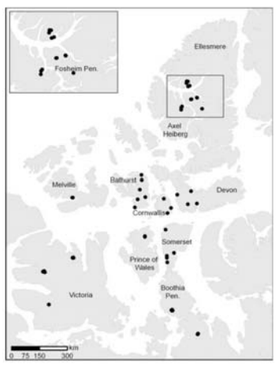


Pollen data are the most widely used proxy for paleoclimate reconstructions (Gajewski et al 1995; Gajewski 2006). Pollen calibration data from lakes (Ritchie et al 1987; Gajewski 1995, 2002; Gajewski et al 1995) as well as snow and ice samples (Bourgeois et al 2001) have shown that it is possible to separate low from high Arctic regions.

BSi & LOI

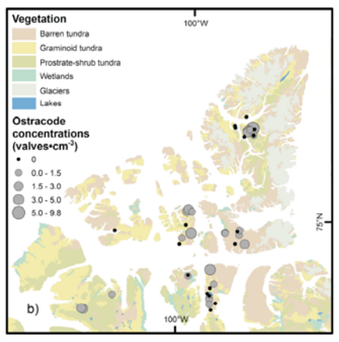
Fortin & Gajewski (2009) presented a regression equation to reconstruct pH using %carbonate & %BSi in a core. We found that bedrock is a major influence on sediment LOI and BSi content, and lake water temperature is a secondary influence.



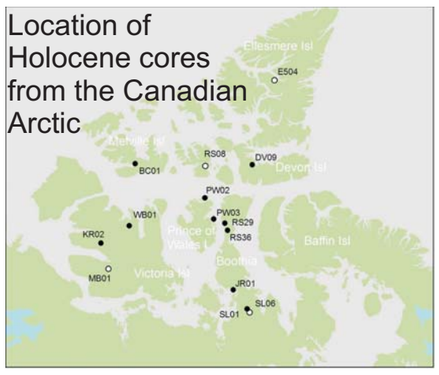


Ostracods

Ostracod diversity is low in the Arctic, with only 7 species identified in 43 sites (Bunbury & Gajewski, 2009). Some taxa are cosmopolitan in the area, whereas others are limited by ion concentrations.

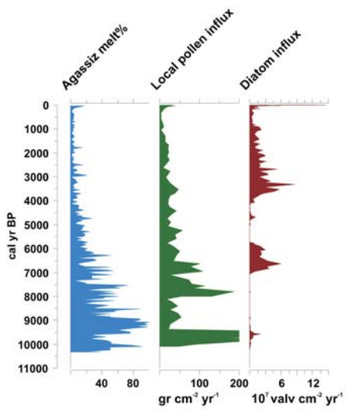


Location of Holocene cores from the Canadian Arctic



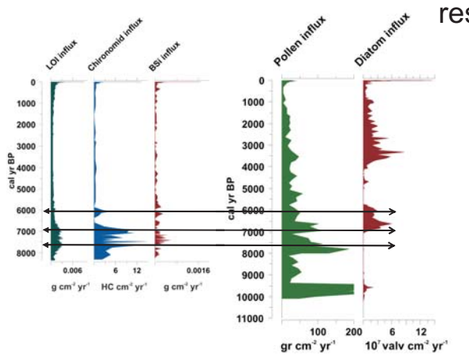
Results: Holocene cores from the Canadian Arctic

New lake sediment cores, with sequences spanning the Holocene, have been obtained from several areas of the Canadian Arctic. Multi-proxy analyses, including pollen, diatoms, chironomids, ostracods and sediment parameters have shown both differences and similarities in interpretation. Maximum temperatures were found in most areas immediately after deglaciation and the neoglacial cooling is seen in most proxies. Higher-frequency variability is also identified in records sampled at high enough resolution; transitions are coherent with those seen in ice cores and other regions.

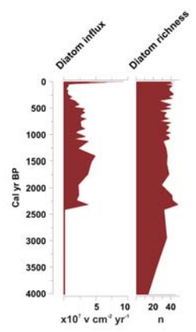


Pollen (Peros & Gajewski, 2008) and diatom (Podritskie & Gajewski 2007) influx, indicative of primary production) from western Victoria Island (KR02) compared to the Agassiz ice core melt% data.

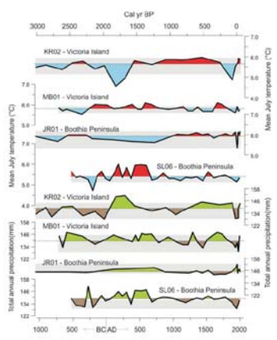
Chironomid records from northern Victoria Island (WB01;Fortin & Gajewski 2009) also show early Holocene maxima in production, and high frequency variability in production records show close coherence with a site from western Victoria Island.

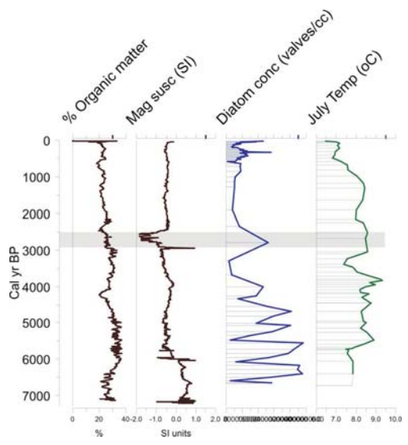


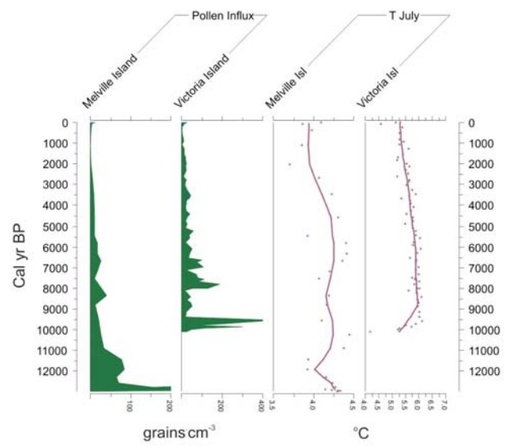
Diatom (LeBlanc et al 2004) and pollen (Zabenskie & Gajewski 2007) records from a core in the middle Arctic (JR01) show coherent changes. When sampled at high enough resolution, high frequency variability, such as the Little Ice Age and Medieval Warm Period can be clearly identified.



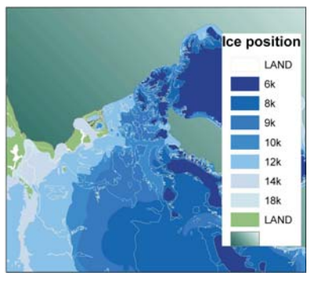
Both n-s and e-w differences are seen in these high resolution pollen records of the past 3000 years (Peros & Gajewski 2009).







Pollen records from several regions, including the central Arctic (Gajewski 1995; Gajewski & Frappier 2001; Zabenskie & Gajewski 2007) and western Arctic (Gajewski et al 2000), including these two records from the northwestern Arctic (Peros & Gajewski 2008; Peros et al subm) show long-term decreases in temperature and pollen production.



Diatom records have proven difficult to interpret, with large changes in production and diversity in the early-, mid- and late Holocene (e.g. Finkelstein & Gajewski 2007, 2008)

Deglaciation of Northern Canada (Dyke et al 2003).

Acknowledgements

This research was supported by grants from NSERC and CFCAS, and logistic support was provided PCSP. We acknowledge the people working on this project, including J Bunbury, S Finkelstein, P Hamilton, M LeBlanc, C Courtney-Mustaphi, T Paull, M Peros, B Podritskie, S Zabenskie and many student assistants.

References

Atkinson, D and K Gajewski. 2002. High-resolution estimation of surface air temperature in the Canadian Arctic Archipelago. Journal of Climate 15: 3601-3614.
Atkinson, D, B Alt and K Gajewski. 2000. A new database of high arctic climate data from the Polar Continental Shelf Project archives. Bull Amer Met Soc 81: 2621-2629.
Barley, E, I Walker, J Kurek, L Cwynar, R Mathewes, K Gajewski and B Finney. 2006. A northwest North American training set: distribution of freshwater midges in relation to air temperature and lake depth. J Paleolim. 36: 295-314.
Bouchard, G, K Gajewski and P Hamilton. 2004. Freshwater diatom biogeography in the Canadian Arctic Archipelago. J Biogeogr 31:1955-1973.
Bourgeois, J, K Gajewski and R Koerner. 2001. Spatial patterns of pollen deposition in arctic snow. J Geophys Res – Atmos 106(D6): 5255-5266.
Bunbury, J and K Gajewski. 2009. Biogeography of freshwater ostracodes in the Canadian Arctic. Arctic.
Dyke, A, A Moore y L Robertson. 2003. Deglaciation of North America. Geological Survey of Canada Open File 1574
Finkelstein, S and K Gajewski. 2008. Responses of Fragilarioid-dominated diatom assemblages in a small Arctic lake to Holocene climatic changes, Russell Island, Nunavut, Canada. J Paleolim 40: 1079-1095
Finkelstein, S and K Gajewski. 2007. A paleolimnological record of diatom-community dynamics and late-Holocene climatic changes from Prescott Island, Nunavut, central Canadian Arctic. Holocene 17: 803-812
Fortin, M-C and K Gajewski. 2009. Holocene climate change and its effect on lake ecosystem production in northern Victoria Island, Canadian Arctic. J Paleolim doi: 10.1007/s10933-009-9326-7
Fortin, M-C and K Gajewski. 2009. Assessing sediment production indices in Arctic lakes. Polar Biol. doi: 10.1007/s00300-009-0598-1
Gajewski, K. 2008. Comment on "Abrupt environmental change in Canada's northernmost lake inferred from fossil diatom and pigment stratigraphy" by Dermott Antoniades et al. Geophys Res Lett 35, L08701
Gajewski, K. 2006. Is Arctic palynology a "blunt instrument"? Géogr phys Quat 60: 95-102.
Gajewski, K. 2002. Modern pollen assemblages in lake sediments from the Canadian Arctic. Arct, Antarct Alp Res 34:26-32.
Gajewski, K. 1995. Modern and Holocene pollen accumulation in some small arctic lakes from Somerset Island, N.W.T., Canada. Quat Res 44:228-236.
Gajewski, K and D Atkinson. 2003. Climatic change in northern Canada. Environ Rev 11: 69-102.
Gajewski, K, G Bouchard, S Wilson, J Kurek and L Cwynar. 2005. Distribution of Chironomidae (Insecta: Diptera) head capsules in recent sediments of Canadian Arctic lakes. Hydrobiologia 549: 131-143.
Gajewski, K and M Frappier. 2001. A Holocene lacustrine record of environmental change in northeastern Prince of Wales Island, Nunavut, Canada. Boreas 30: 485-489.
Gajewski, K, M Garneau and JC Bourgeois. 1995. Paleoenvironments of the Canadian High Arctic derived from pollen and plant macrofossils: problems and potentials. Quat Sci Rev 14:609-629
Gajewski, K, RJ Mott, JC Ritchie and K. Hadden. 2000. Holocene vegetation history of Banks Island, Northwest Territories, Canada. Can J Bot 78:430-436.
Hamilton, P, K Gajewski, D Atkinson and D Lean. 2001. Physical and chemical limnology of 204 lakes from the Canadian Arctic Archipelago. Hydrobiologia 457:133-148.
Leblanc, M, K Gajewski and P Hamilton. 2004. A diatom-based Holocene paleoenvironmental record from a mid-Arctic lake on the Boothia Peninsula, Nunavut, Canada. Holocene 14: 423-431.
Paull, T, P Hamilton, K Gajewski and M LeBlanc. 2008. Numerical analysis of small Arctic diatoms (Bacillariophyceae) representing the Staurosira and Staurosirella species complexes. Phycologia 47: 213-224.
Peros, M and K Gajewski. 2009. Pollen-based reconstructions of late Holocene climate from the central and western Canadian Arctic. J Paleolim 41: 161-175.
Peros, M and K Gajewski. 2008. Holocene climate and vegetation change on Victoria Island, western Canadian Arctic. Quat Sci Rev 27: 235-249.
Podritske, B and K Gajewski. 2007. Diatom community response to multiple scales of Holocene climate variability in a small lake on Victoria Island, NWT, Canada. Quat Sci Rev 26: 3179-3196.
Ritchie, JC, K Hadden and K Gajewski. 1987. Modern pollen assemblages from the high arctic of western Canada. Can J Bot 68: 1605-1613.