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Fossils from Lake Sediments in Northern Québec and Labrador: A Window into Past Climate Changes

by Marie-Andrée Fallu

INTRODUCTION

I have always been fascinated by landscapes, and especially their origins. I ask myself: How was it before? How fast did it evolve? What are the processes involved in these changes, and what are their consequences for terrestrial and aquatic ecosystems? All these questions naturally brought me to study geography, or more precisely, biogeography.

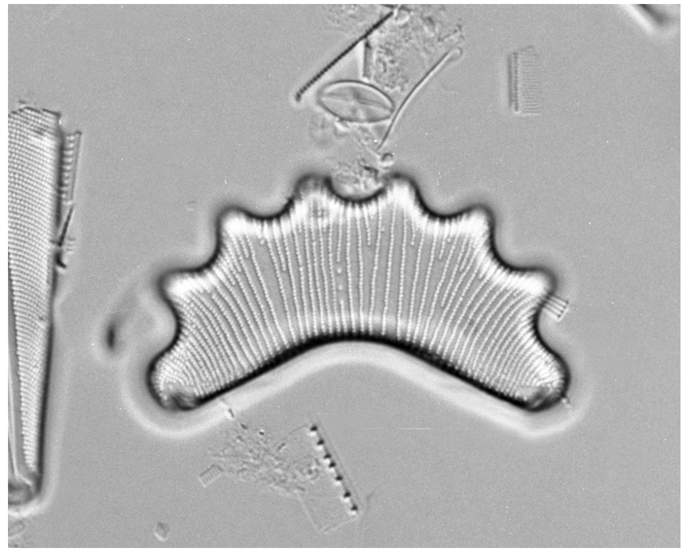
Biogeography is the scientific study of the spatial and temporal distribution of species. In northern regions, climate is the principal factor influencing the establishment and development of ecosystems. An important climate warming or cooling in these regions could have a serious impact on the distribution of species. Furthermore, human activity has recently complicated climatic cycles by degrading the ozone layer and by adding greenhouse gases to the atmosphere. Since these natural and anthropogenic changes have the potential for a large impact on aquatic communities, there is a need to determine the magnitude and nature of aquatic responses to such climate changes. The study of natural fluctuations that have occurred in the past is an important tool for understanding the evolution of ecosystems and their response to environmental changes. Although this approach is being widely used in climate change research, few such studies exist for the northern Québec-Labrador region.

Little is known about the evolution of aquatic ecosystems in this area of Canada. Deglaciation of the northern Québec-Labrador region occurred approximately 9000 to 6000 years ago. This major event shaped the landscape, creating thousands of lakes. Examination of past aquatic communities provides not only a spatial and temporal profile of their evolution in these lakes, but also information on the environment in which the lakes developed. To obtain this information, sediment cores can be extracted from the bottom of a lake and examined to see what fossils are present. These cores can be subsectioned at fine intervals and radiocarbon-dated to provide a chronological record of past climatic changes. Fossilized microorganisms that were once sensitive to environmental changes and have accumulated in great numbers in the lakes' sediments are good biological indicators. For my research, I decided to use two useful indicators: diatoms and chironomids.

Dr. Reinhard Pienitz, Dr. Ian Walker, and Marie-Andrée Fallu coring Oksana lake near Schefferville, north-central Québec.

Diatoms are microscopic, unicellular algae found in great abundance in northern lakes. Their cell is well protected by a silica wall that resists decomposition when deposited on the lake sediment. Species are identified using the ornaments present on this silica wall. Some

Example of a chironomid head capsule (K2 lake site).



Example of a diatom (Oksana lake site).

recent studies in the northern Québec-Labrador region have sought to understand diatom distribution by examining lakes from different biomes (Fallu et al., 2000). In this region, diatom assemblages are good indicators of past water alkalinity, colour, and concentration of dissolved organic matter (DOM) produced from plant and animal decomposition.

Chironomids, also called non-biting midges, are the second indicator. The life cycle of these flies (Diptera) includes an aquatic larval phase comprising four instars. During this larval phase, the chironomid's head is protected by a chitinous head capsule, which is shed at the end of each instar. This head capsule resists decomposition, and variations in its structure allow different species groups to be identified from their fossil remains. In the northern Québec-Labrador region, different species groups are associated with lakes in different climatic belts. Chironomids are good indicators of summer water temperature (Walker et al., 1991).

Other indicators can be found within the sediments. Pollen analysis gives information on vegetation dynamics. Analyses of fossil pollen can determine the time when various plant species first arrived in a lake catchment and how the vegetation later changed. Organic matter in the ancient sediments can also be analyzed to help identify the load of organic matter reaching the lake and variation in that load.

The overall objectives of my study are 1) to establish a high-resolution temporal reconstruction of environmental and climatic impacts on aquatic conditions at three sites, each at a different latitude and in a different ecoclimatic zone; 2) to develop a spatial-temporal image of postglacial environmental changes in the Québec-Labrador region through the use of radiocarbon dating; and 3) to compare the synchronicity of several indicators (diatoms, chironomids, and pollen) in order to assess differences between the responses of aquatic and terrestrial organisms to climate change. I am conducting my Ph.D. research at Laval University, in the Geography Department and at the Centre d'études nordiques (CEN). I work under the supervision of Reinhard Pienitz (Paleoecology-Paleolimnology Laboratory of CEN, Laval University) and Ian Walker (Okanagan University College).

METHODS

Sediment cores covering the complete postglacial sedimentary sequence were collected from three lakes located along the Québec-Labrador border. The first lake, K2 (informal name), is located at 58˚44′ N, 65˚56′ W, 6 km northeast of the town of Kangiqsualujjuaq and about 11 km southwest of Ungava Bay. The second lake, Oksana (informal name), is located at 54˚49′ N, 66˚50′ W, near Schefferville. The third lake, Lac au Sable at 51˚24′ N, 66˚13′W, was sampled by researchers George A. King and Herb E. Wright (Limnological Research Center, University of Minnesota) and is located about 130 km north of Sept-Îles. The sediment cores from each lake were subsampled at 1 cm intervals, each representing a period of approximately 10–50 years.

A portion of each subsample was used for diatom analyses. Sediment was digested with strong acids, leaving only the silica intact. A slurry of the resulting solution was mounted on a microscope slide, allowing the identification and counting of diatoms at a magnification of 1000×. A second portion (0.5 to 1 cc) of the subsamples was used for the extraction of chironomid head capsules. Sediments were sieved and processed with acids and bases to deflocculate the sediment and eliminate silica and other mineral matter. All the head capsules found were handsorted and mounted on slides for identification and counting at a magnification of 40×. The remaining sediment was used (by collaborators) to analyze pollen and macrofossils and to measure sediment organic content by loss-on-ignition (LOI).

The qualitative analyses enabled the identification of significant changes in the assemblages of diatoms and chironomids through time, i.e., between the subsamples taken from various depths in the cores. In addition to qualitative assessment, statistical methods were used to reconstruct paleoenvironments quantitatively. Mathematical models based on diatoms and chironomids are now widely used in reconstructions of past environments. For this study region, models exist to infer water temperature from chironomids and to reconstruct DOM concentrations, water alkalinity, and colour from diatoms. Additionally, pollen analysis and sediment organic matter (OM) analysis were performed. Furthermore, radiocarbon dating enabled the establishment of a good chronology for each core. AMS (Accelerator Mass Spectrometry) ^{14}C dating was used to establish precise timing for the sequence of events evident in the fossil records.

PRELIMINARY AND EXPECTED RESULTS

When vegetation (determined through pollen analysis) first invaded each lake's catchment, the diatom and chironomid assemblages changed. The first establishment of vegetation is usually a sign of warming climate. This warming is evident in the chironomid-based temperature reconstruction. Establishment of vegetation also leads to higher inputs of DOM to the lake. This DOM commonly imparts a strong brown colour to the water. It also acts as a sunscreen to protect aquatic organisms from UV radiation and to determine what wavelengths (colours) of light are available to aquatic organisms for both photosynthesis and vision. The diatom remains record this increase in DOM during the lakes' early development. My results also indicate a tendency towards climate cooling over the last ~3500 years and the acceleration of this trend in recent time. This cooling is evident from water temperature reconstructions based on chironomids and from DOM reconstructions based on diatoms. Although it seems contradictory to the global warming scenario, Chapman and Walsh (1993) have also shown that the Québec-Labrador region is presently undergoing a cooling trend.

Pollen analysis and analysis of sediment organic matter content will provide the paleobotanical information needed to compare the evolution of the terrestrial and aquatic environments, making it possible to verify the timing of the response of past ecosystems to climatic changes. We anticipate finding that the autochthonous aquatic organisms of the lakes responded more quickly and more directly to climate changes. Chironomids were most likely the first organisms influenced by temperature changes because water temperature is the variable that seems to best explain the distribution of chironomids in this area. We expect to perceive qualitative changes in diatom assemblages at the time of temperature change because certain species of diatoms are also influenced by water temperature. On the other hand, changes in the diatom assemblages will probably not be as marked as those of the chironomids, because the variables that seem to influence diatoms in this area the most are DOM and alkalinity. Thus, the diatom reconstruction models will be used to indicate the appearance or changes in density of vegetation in the catchment area of the lakes. Pollen and macrofossil assemblage changes will probably show a slight delay as compared to those of chironomids, but could be synchronous with those of diatoms.

AMS ^{14}C dating shows interesting results. Lac au Sable is approximately 7000 years old and was the first lake to be free of ice, followed closely by the northernmost site K2 (more than 6100 years old). Oksana lake, more than 5600 years old, is the youngest lake because of its position in north-central Québec: it is located in the vicinity of a residual ice sheet that persisted until about 6000 years ago. This implies that it is located in an area where we can find some of the youngest lakes in Canada. All the dating results have not yet been received, but they will soon add further precision to our chronologies.

CONCLUSION

This study is ongoing, and more interesting results are continually being revealed. Such research is important because our northern regions offer very sensitive ecosystems that can be affected by very slight climate changes. Since these systems are highly sensitive, some biological communities become powerful tools for reconstructing past lacustrine environments. So far, diatoms and chironomids have been underexploited as biological indicators of change in northern Québec-Labrador, and they will be increasingly used in future research.

Information about past climate changes has been made available by extracting sediments from these lakes and examining the fossils that are present. This type of historical information is essential in many ways: it adds knowledge about the response of aquatic and terrestrial ecosystems to climate change in the past; it advances our understanding of how climate directly and indirectly affects these ecosystems; and it helps us predict the future impacts of climate change on the global environment and on the people living in northern regions.

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