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ORGANIC GEOCHEMICAL ANALYSIS OF LATE GLACIAL AND EARLY HOLOCENE ECOSYSTEM CHANGES: A CASE STUDY FROM NORTHERN NEW ENGLAND LAKES

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ABSTRACT

The lacustrine sedimentary archive of organic remains provides important evidence for the reconstruction of the environmental histories of lakes and their watersheds, recording the response of the Earth’s biota to changes on scales varying from the local to the global. The last Glacial-Interglacial transition presents an opportunity to investigate how, and at what rates, watershed and lake ecosystems were established on once glaciated, carbon and nutrient-poor landscapes. The small lakes of northern Vermont (USA) provide an appropriate setting in which to investigate such changes.

As part of a multidisciplinary study of three Vermont lake sediment cores, samples ranging in age from approximately 0 to 15 ka were subjected to molecular organic geochemical analysis by pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS). Diagnostic compounds in the pyrolyates (e.g., indole and guaiacol) permit discrimination between the principal organic matter sources (e.g., algal/bacterial and higher plant) and their shifting proportions over time as a function of environmental change. While the nature of this shift is similar, it does not occur at the same rate in all three lakes, indicating the profound influence of local conditions.

METHODS

Activation of sediment with a 122 °C pyrolysis unit (Pyrolyzer, Pye-Unicam Ltd., England) and a CDS 2000 gas chromatograph with a 25 m DB-5 column and a FID detector was used to determine pyrolysis products. The GC was operated under the following program: heating from 30 °C to 150 °C at 10 °C/min., followed by heating at 4 °C/min. to 300 °C and held at 300 °C for 1 min. A measured amount (~15 mg) of dry, powdered sample was pyrolyzed in a flow of helium for 20 min. in a platinum cell at 600 °C, as measured by a thermocouple in the sample holder. The GC oven was operated under the following program: heating from 30 °C to 150 °C at 10 °C/min, followed by heating at 4 °C/min. to 300 °C and held at 300 °C for 1 min. The MS was operated in 423 Scan (150 °C) and other parameters (see poster SS3.09.131) to the OM inputs and local environmental conditions.

Pyrolysis-Gas Chromatography/Mass Spectrometry

Total Ion Current Pyrogram

Sterling Pond

Lake Morey

Duck Pond

FCA

Livalestro et al. 2006

440 cm

423 cm

510 cm

445 cm

Pyrolysis Products of Biogenic Organic Matter

Examples of pyrolylates from the post-glacial transition at the base of the sediment sequences in two lakes. Note the relative increase in aliphatic hydrocarbons (\(~-\)1; \(~+)1) and lignin markers (G, S) across the transition, as well as the relative decrease in nitrogen compounds (Pd, BCN, AN). The relative sulfur enrichment seen in the pyrolylate of the Sterling Pond sample might be the result of early diagenetic (microbial) processes in the presence of sulfate-rich pore water, the source of which, however, is not known to the authors.

The first principal component deflects strongly at the base of the sedimentary sequence in the Lake Morey and Sterling Pond cores (above), reflecting significant organic matter changes at the last Glacial-Interglacial transition. (The details on the molecular level may be seen in the pyrograms on the left and in summary form in the depth plots on the right.) The transition at Duck Pond is chemically different, showing a strong deflection in the second principal component (see figure at right), corresponding to a change from an aliphatic OM to a predominance of lignin-derived material.

The timing of the transition also varies, being earliest at the more northerly, higher elevation Sterling Pond, and latest at the more southerly, lower elevation Lake Morey site. The bulk geochemical parameters (see poster SS3.09.131) organic carbon content, C/N and \(\delta^{13}C\) show a similar effect.

The eigenvectors (“EV”) for the first two principal component (PC 1 and PC 2) are plotted as a function of age (yr) for the three lakes. The data show a strong deflection in the first principal component at 440 cm for both Sterling Pond and Lake Morey, and at 423 cm for Lake Morey. The second principal component shows a strong deflection at 440 cm for both Sterling Pond and Lake Morey, and at 423 cm for Lake Morey. The bulk geochemical parameters (see poster SS3.09.131) organic carbon content, C/N and \(\delta^{13}C\) show a similar effect.

Most of the parameters plotted above (as a function of depth) show a strong deflection at the base of the sequence, corresponding to the post-glacial transition. The OM shifted from algal bacterial at the very base to terrestrial, with a different algal/bacterial assemblage tending to regain dominance in the younger sediments. This is shown clearly in the ratio of nitrogen compounds to lignin markers (Pd) and in the ratio of carbohydrate markers (FCA/LVGL). Although the cores show similar trends in OM inputs, these trends are found in different ways. The first principal component shows a strong deflection at the base of the sequence, corresponding to the post-glacial transition. The OM shifted from algal/bacterial at the very base to terrestrial, with a different algal/bacterial assemblage tending to regain dominance in the younger sediments. This is shown clearly in the ratio of nitrogen compounds to lignin markers (Pd) and in the ratio of carbohydrate markers (FCA/LVGL). Although the cores show similar trends in OM inputs, these trends are found in different ways.