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Relationship between C:N ratios of lake sediments, organic matter sources, and historical deforestation in Lake Pleasant, Massachusetts, USA

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Abstract

The C:N ratios of lake sediments may reflect proportions of terrestrial and algal carbon contributing to accumulation of sediment. This possibility was tested in Lake Pleasant, Massachussetts, USA which underwent watershed deforestation in about 1780 A.D. The C:N profile of a 70-cm sediment core clearly reflected deforestation through a rise in C:N ratio caused by an increase in watershed contributions to sedimentary carbon. Spatial variability of C:N in modern surficial sediments is small compared to the change caused by deforestation.

Introduction

Variations of C:N ratios within lake sediments have been used to determine historical changes in sources of organic matter for lakes. Algae have a C:N ratio between 4 and 10, whereas terrestrial organic matter has a C:N greater than 20 (Meyers, 1994). Increases in C:N ratio within sediment profiles have been interpreted to identify periods in a lake's history when sediments received a high proportion of terrestrial organic matter (Guilizzoni et al., 1996). Conversely, decreases in C:N ratios have been used to identify periods when lake sediments have received a high proportion of algal organic matter (Kanassanen & Jaakkola, 1985).

The validity of using C:N ratios to discern changes in organic matter sources has been questioned (Goosens et al., 1989; Thornton & McNamus, 1994) because the C:N of terrestrial organic matter decreases during diagenesis, while that of algae increases (Meyers, 1984). In addition, the C:N record of a particular coring site may not provide an accurate representation of changes in the entire lake. The purpose of our work was to assess the reliability of using sedimentary C:N to identify historical changes in sources of organic matter to Lake Pleasant, Massachusetts (USA) through the analysis of long core and surficial sediments.

Background setting

Our work was prompted by the finding that a 70-cm core taken from Lake Pleasant, Massachusetts (Figure 1) showed a rapid increase in C:N following deforestation of its watershed (Figure 2). Lake Pleasant, which serves as a back-up (or emergency) drinking water supply for Montague Township, Massachusetts, has a surface area of 20 ha. Although the watershed now is completely forested, historical sources show that intense deforestation of the watershed during European settlement began approximately 200 yrs ago. Evidence from pollen indicates deforestation of the watershed beginning at 38 cm within the core or 210 +/- 50 y.b.p. (extrapolated from ^{210}Pb dating) due to the presence of ragweed and decline in pollen from arboreal taxa (Figure 2). Bulk density increased and percent organic matter decreased about 200 y.b.p., as would be expected with increased erosion rates (Binford et al., 1987; Brenner & Binford, 1988). In our 70-cm core, C:N also increased from a pre-deforestation mean of 16.1 (s.d. = 2.19) to a mean value of 25.2 (s.d. = 5.94) after deforestation. C:N after land clearing was significantly higher than the pre-deforestation mean (Student's t, $p < 0.05$). All methods used for chemical and pollen analyses performed on the core are similar to those found in Brenner & Binford (1988).

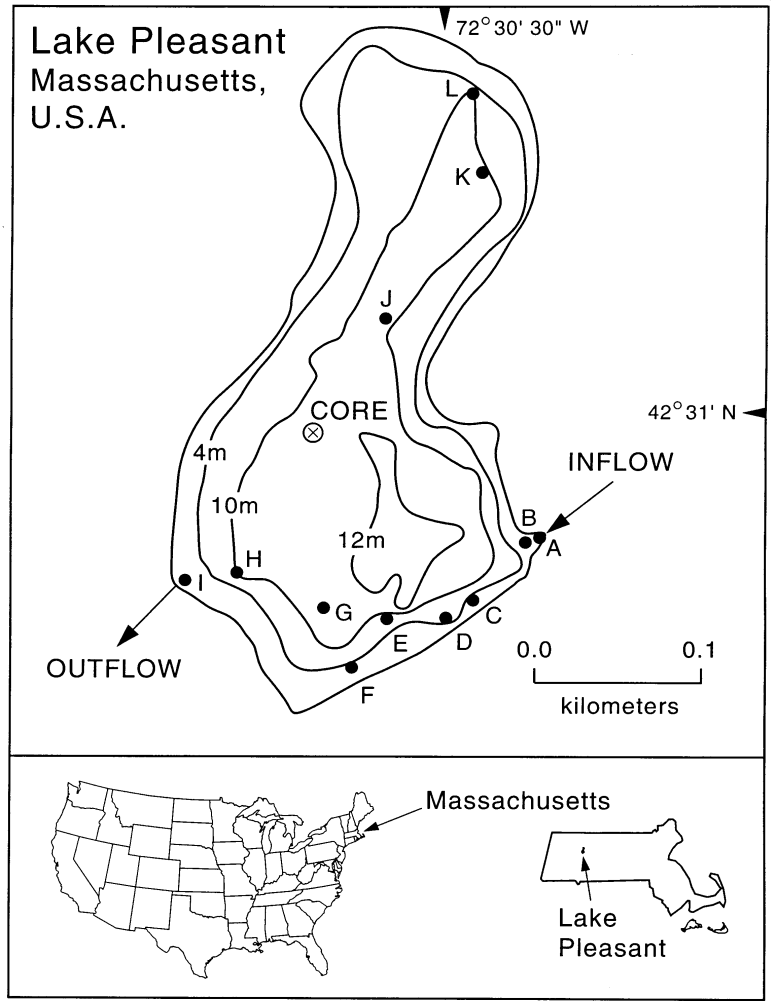

Figure 1. Bathymetric map of Lake Pleasant, Massachusetts (U.S.A.). The large dot with the cross indicates the site of the 70-cm sediment core, and black dots with letters indicate the sites where surficial sediments were taken.

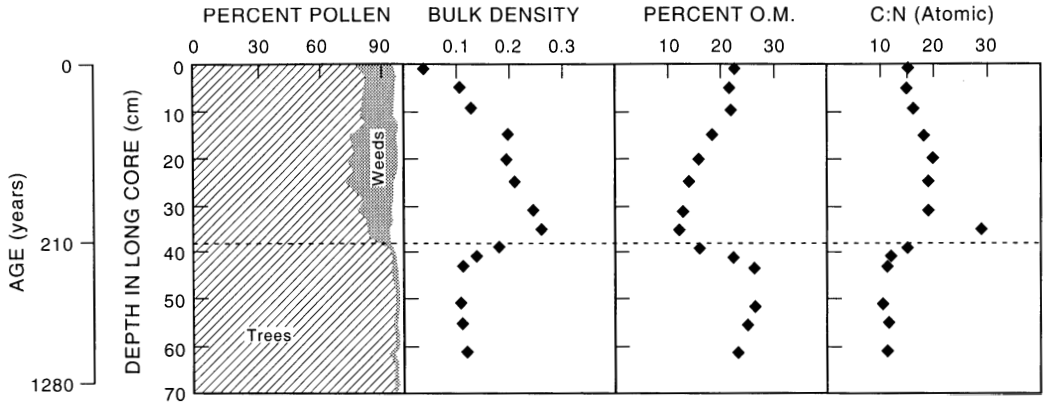

Figure 2. Pollen, bulk density, percent organic matter, and C:N (atomic) profiles for a 70-cm core taken from Lake Pleasant, Mass. Historical records and pollen analysis indicate that the L. Pleasant watershed was deforested approximately 200 y.b.p. The age at 38.5 cm is 210 (+/-50) y.b.p. according to ^{210}Pb dating and is represented by the dashed line.

Surficial sediment analysis

In order to test whether the observed increase in C:N after deforestation was actually significant compared with the natural variability of C:N in sediments within the lake basin, we sampled surficial sediments along two transects in Lake Pleasant (Figure 1) during July, 1996. Three samples were taken from each site, placed into plastic bags, and then stored at 2°C prior to analysis. Organic carbon content and atomic C:N of bulk sediment samples were determined by combustion of the refrigerated surface sediments in a CHN analyzer. The pH of Lake Pleasant water was well below 7, and conductance of lake water was very low (40 μS/cm), indicating that carbonates were negligible in Lake Pleasant water and suggesting that the sedimentary carbon would be organic.

Results and discussion

Surficial sediments for sites with water depths greater than 10 m showed less variability than sediments from shallower depths (Figure 3). Only the first four sites along the transect starting from the inflow had a C:N high enough (> 20) to be characteristic of terrestrial organic matter. This indicated that the inflowing stream was an important source of terrestrial organic matter up to ~150 m from its mouth.

Our results show that C:N ratios in lake sediments can be used reliably to identify historical sources of sedimentary organic matter, and indicate human disturbance of watersheds. Large diagenetic changes in C:N, which would have led to an overlap of terrestrial and algal C:N, were not evident in either the surface or core sediments. We also found that the natural variability of C:N for surficial sediments in the center of Lake Pleasant is very small compared to the change of C:N that we observed in response to deforestation. Therefore, the significant increase in C:N after deforestation (to values similar to surficial sediments near the inflow) was most likely caused by an increase in the proportion of terrestrial organic matter in the lake's central sediments following deforestation. The proportion of terrestrial organic matter could have risen because of increased particulate matter loads (Hedin, 1988) and discharges (Hornbeck et al., 1986) of streams directly following deforestation. As the Lake Pleasant watershed became reforested, the proportion of terrestrial organic matter incorporated into central sediments probably declined since stream discharges (Hornbeck et al., 1986) and sediment loads (Hedin, 1988) eventually decrease in an aggrading forest following disturbance. Consequently, the C:N of the lake sediments in our long core are also declining and now approaching the pre-deforestation values.

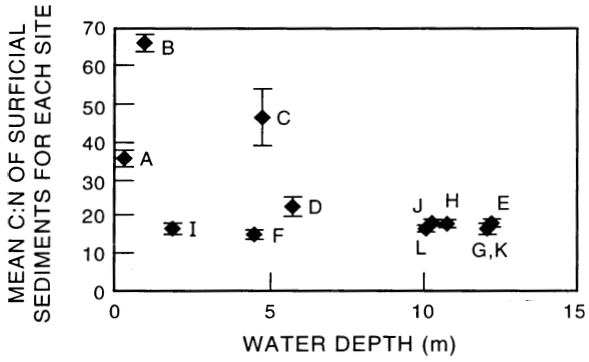

Figure 3. Mean C:N (atomic) of surficial sediments for each site plotted against water depth (bars denote s.d.).

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