Quantification of charcoal content in historic lake sediments

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Abstract

Quantification of charcoal content in lake sediments allows identification and interpretation of paleo-fire events. LOI, visual logging, and % elemental carbon analysis were used to measure changes in organic and inorganic carbon. Short core sediment samples from Ogontz Lake, New Hampshire, recorded % carbon values between 1-2%, comparable with results reported by Brown (2000). Good correlation between LOI and %carbon data suggests that fires are not a controlling factor in lake sedimentation at this location, and that the inorganic layer observed is likely a storm layer.

Introduction

The presence of organic charcoal in lake sediments has been widely used as an indicator of paleo-fire events on both a local and regional scale (Birks, 1997; Pitkanen 2000). Identification of charcoal peaks is also important for paleoclimatic reconstructions, as one must distinguish between increased sedimentation rates caused by wildfire-related devegetation from increased sedimentation rates due to large paleostorm events. This distinction is complicated in historic sediments by the presence of anthropogenic charcoal & soot produced by fossil fuel combustion and other human activities following European settlement of North America (Schmidt and Noack, 1999).

Several methods exist for charcoal content analysis. Anthropogenic soot and organic charcoal can be physically distinguished under an optical microscope, though this method is tedious and time-consuming (Schmidt and Noack, 1999). Nitric acid digestion eliminates sulfides, carbonates, and organic carbon, leaving only inorganic sediment and elemental carbon (charcoal) that can be measured by loss-on-ignition (LOI) analysis (Winkler, 1984). Difficulties in detecting low charcoal contents using the LOI technique led Brown (2000) to suggest the use of an elemental analyzer for charcoal content analysis.

This study uses elemental analysis, LOI, and visual logging to quantify historic charcoal contents in New England lake sediments. These data can be used to identify significant historic anthropogenic and natural events affecting lake sedimentation.

Methods

Five short (30-40 cm) cores were taken from Ogontz Lake (Fig. 1a) and Sandy Pond (Fig. 1b) in New Hampshire using a gravity corer. Coring locations were decided by measuring a rough bathymetric profile along the major axis of the delta and choosing sites at distal locations where the slope appeared to level off. Cores were extruded in the field and bottled in 1cm portions for analysis (see Fig. 1c for core depths and lengths).

One core, OGa, was chosen for analysis and dried using a freeze dryer. A visual log was recorded by examining each centimeter of the core and noting characteristics such as color, grain size, and organic debris (Fig. 2b). A set amount of each sample was weighed for LOI analysis and placed in an oven overnight at 80°. The remaining post-combustion sample was reweighed and % carbon loss calculated (Fig. 2a). Adapting methods used by Brown (2000) (Appendix A), approximately 2g from each 1cm portion were removed from the total sample and weighed. To remove all organic material these samples were mixed with 15mL of concentrated nitric acid and allowed to sit in a hot bath for three hours. The samples were washed by adding DI water, centrifuging, and decanting. This process was repeated seven times, after which the samples were dried for three days at 80° and weighed again. Inorganic (charcoal) content of the samples (Fig. 2c) was determined using a CE Instruments NA2500 elemental analyzer with peach leaf standards.

Results

LOI analysis revealed two major peaks centered at 15 and 28 cm, and a large drop between 17-28 cm (Fig. 2a). Several smaller drops were observed at the 5 and 8 cm level. Occurrence of organic debris (Fig. 2b) such as wood chips seems to correlate well with drops in LOI, especially within the 17-28 cm range. The visual log also recorded a significant darkening of color in sediments lower than 17 cm.

Elemental %N in this core ranged from .01 to .12 (Appendix B) while Brown (2000) recorded values between .03 and .29. Elemental %C ranged from 1.04 to 2.07, higher than but comparable to Brown's (2000) values between 0 and 2.

Consistent %N values over the length of the core suggest that washing was complete and no residual nitric acid remained. Average %C was 1.41, and most values clustered around this number. Significant departures were found in the large peaks centered at 15 and 28 cm, and the large drop between 17-28 cm (Fig. 2c). These results seem to correlate well with similar trends observed in the LOI data. C/N ratios of 15-20 are considered normal for these sediments.

Discussion

The %carbon analysis data correlate very well with the LOI data, with minor variations. If fire were affecting sedimentation in this watershed, we would expect to see an increase in %carbon during large decreases in LOI (representing rapidly deposited inorganic layers). That our results are the opposite of those expected suggests that fires were not a significant factor in sedimentation.

A possible explanation for the observed correlation is that elemental analysis measured residual (undigested) organic carbon rather than charcoal. An experiment was planned to determine the time needed to sufficiently digest organic material in these samples, but could not be completed due to time constraints.

Another possibility is that elemental analysis did measure charcoal contents, and the variations represent natural variations in sedimentation rate. Higher LOI values generally represent periods of slower deposition, giving organic material time to accumulate, while low LOI values represent periods of rapid deposition. If the regional background rate of charcoal deposition remained the same, unaffected by fires or anthropogenic factors, the amount of charcoal deposition in the lake should correspond to sedimentation rates in the lake, as observed.

Conclusions

The correlation between LOI and %carbon data indicates that fires were not a major factor in Ogontz Lake sedimentation. While this correlation may represent incomplete digestion, we conclude that the large drop in LOI and %carbon between 17-28 cm likely represents a storm layer. This interpretation is supported by a noticeable color change and frequent occurrence of woody debris over this section.

References

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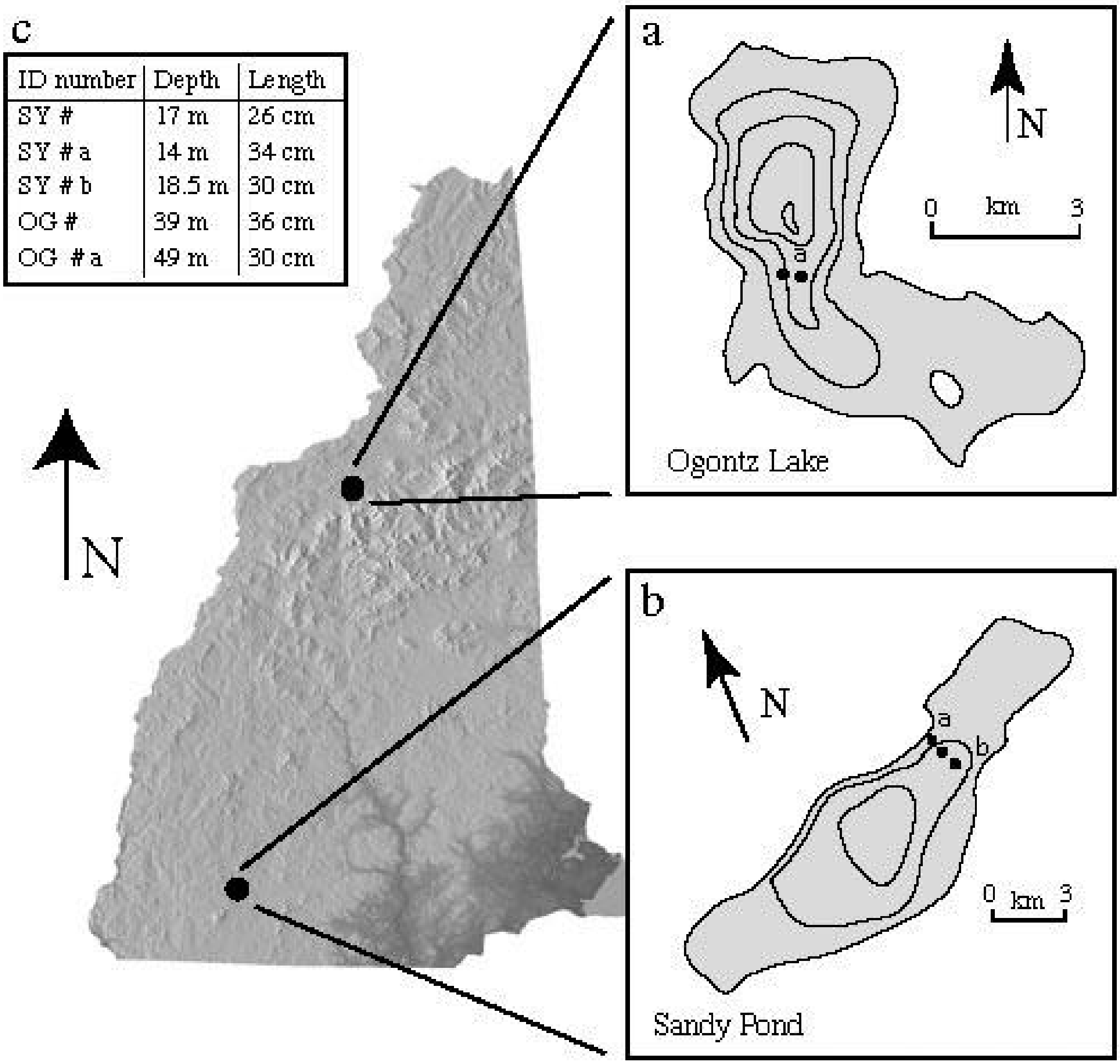

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ID number	Depth	Length
SY #	17 m	26 cm
SY # a	14 m	34 cm
SY # b	18.5 m	30 cm
OG #	39 m	36 cm
OG # a	49 m	30 cm

Figure 1. Sample locations of study. Core locations are shown on bathymetric maps with contour intervals of 20'. Note: Water depths measured at coring locations in Sandy Pond do not agree with bathymetric map. (c) shows core depths and lengths.

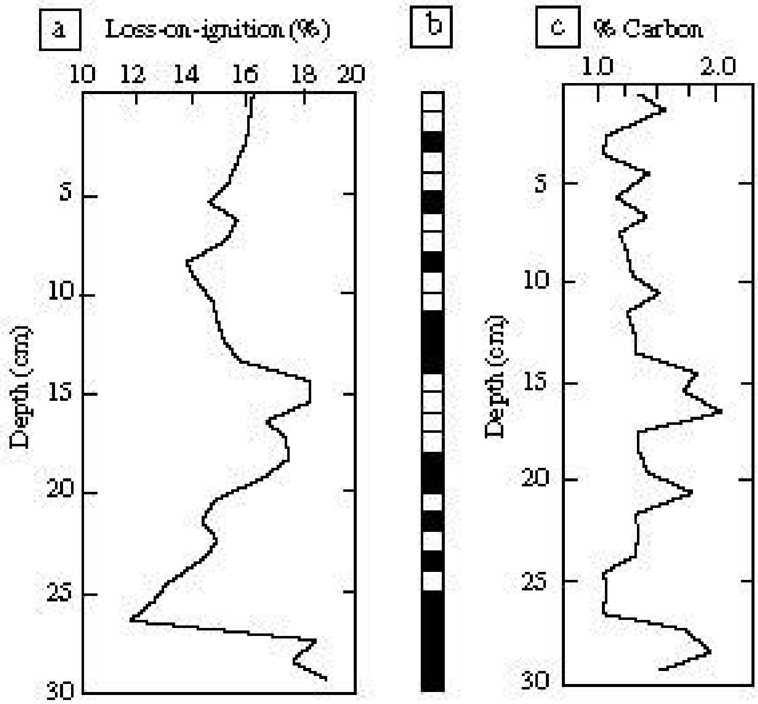

Fig. 2. Results of LOI (a) , visual log (b), and elemental analyzer (c) data. Black boxes in (b) indicate locations of identified organic debris such as pine needles or wood chips.

Appendix A. Methods used by Brown (2000)

TOTAL CARBON AND NITROGEN

Materials

Elemental Analyzer
silver capsules, spatulas and tweezers
microbalance
drying oven, crucibles, mortar and pestle
1N HCl, pipet

Procedure

1. Dry samples in crucibles at <80°C. Grind and homogenize sample with mortar and pestle.
2. Using microbalance, weigh 3-40 mg into a silver capsule, recording weight in computer spreadsheet. For organic samples use <10 mg; for sands use 30-40 mg.
3. Place open capsule in culture tray.
4. Add three drops of HCl with a plastic pipet to remove secondary carbonate
5. Allow to sit for 2 hours. Dry overnight at 60°C.
6. Close sample capsule with tweezers and load into carousel.
7. Begin run with a blank and two standards (peach leaves, 5 mg). Run two standards every 20 samples.

Appendix B. Elemental analysis data, OGa

Sample number	%N	%C	C/N
0-1	0.10	1.37	13.70
1-2	0.08	1.59	19.88
2-3	0.06	1.05	17.50
3-4	0.05	1.07	21.40
4-5	0.07	1.45	20.71
5-6	0.06	1.18	19.67
6-7	0.05	1.44	28.80
7-8	0.06	1.22	20.33
8-9	0.06	1.24	20.67
9-10	0.06	1.30	21.67
10-11	0.08	1.52	19.00
11-12	0.07	1.28	18.29
12-13	0.07	1.31	18.71
13-14	0.06	1.31	21.83
14-15	0.11	1.84	16.73
15-16	0.09	1.76	19.56
16-17	0.16	2.07	12.94
17-18	0.07	1.33	19.00
18-19	0.01	1.37	137.00
19-20	0.07	1.44	20.57
20-21	0.08	1.82	22.75
21-22	0.07	1.33	19.00
22-23	0.07	1.33	19.00
23-24	0.06	1.34	22.33
24-25	0.06	1.07	17.83
25-26	0.05	1.09	21.80
26-27	0.06	1.04	17.33
27-28	0.10	1.77	17.70
28-29	0.12	1.95	16.25
29-30	0.09	1.52	16.89