

# INORGANIC AND ORGANIC CARBON ANALYSIS OF LACUSTRINE SEDIMENTS, CANANDAIGUA LAKE, NY

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## INTRODUCTION

During the upper Pleistocene (~13,320 BP), Canandaigua Lake was 2-3 °C warmer than present temperature (Ellis, Mullins, Patterson, 2004). This study analyzes Holocene levels of carbonate and organic matter in Canandaigua Lake in order to predict future climate trends. By analyzing  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  in lake carbonates, it is possible to find the surface water temperature at the time of carbonate formation if  $\delta^{18}\text{O}$  and constants A and B are known in the formula

$$10^3 \ln \alpha_{xy} = B10^6 T^2 + A$$

where  $\alpha$  is the isotopic fractionation factor, A and B are experimentally determined or calculated constants, and T is temperature (Ito, 2001)

## CANANDAIGUA LAKE

The underlying rock units of the Finger Lakes region consist of the Catskill Delta deposits from the Acadian Orogeny. The major units found beneath Canandaigua Lake are the Devonian Genesee and Hamilton Groups, both of which consist of shale and limestone. As a result of the Laurentide Ice Sheet retreat, meltwater carried an influx of sediment over the glacially-carved Finger Lake region. A majority of the unlithified sediments beneath Canandaigua Lake were deposited rapidly between 14.4 and 13.6 +/- 0.2 ka (Mullins et al., 1996). Canandaigua Lake is elongate

and narrow with a maximum depth of 84 m in its center. Sediment thickness ranges from 50 to 202 m (Mullins et al., 1996) and the sedimentation rate ranges from 0.27-2.44 m/1000 yr. (Wellner and Dwyer, 1996). Possible causes for the fluctuations in rate of sedimentation are lake productivity change, climate variations that would affect river input, and, more recently, the deforestation around the lake that led to an increase in runoff (Wellner and Dwyer, 1996).

## METHODS

The site of the core was determined by examination of seismic reflection profiles in order to find an area with a continuous record of environmental change. After the 4.7 m long core was taken using a gravity corer, measurements were made of the bulk magnetic susceptibility using a Barington MS-2 meter with a loop. The core was then split, described, and photographed before TOC and TIC of samples were determined for every other centimeter of the core using LOI (methods from Dean, 1974). Finally, carbonate-rich samples will be chosen to be run through a mass spectrometer in order to determine  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values of the TIC.

## RESULTS

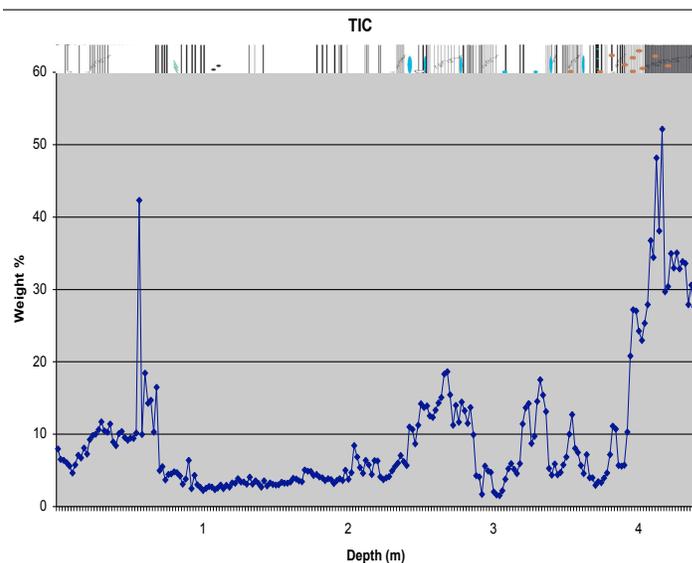
The core is both increasingly laminated (ranging from 0.5 cm to less than 1.0 mm in thickness) and mottled with depth. Aside from intact

organic matter (i.e. twigs and leaves) and charcoal, there are ostracodes, which have shells of low-Mg calcite, found at 266 cm during a stable period of moderate carbonate content and high occurrence of vivianite. Iron oxide and the iron phosphate Vivianite ( $\text{Fe}^{2+}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$ ) occur throughout the core but increase in appearance with depth. The core bottoms out in pink proglacial mud at 470 cm and manages to penetrate the entire Holocene record. At about 250 cm, there is a marked increase in laminations, vivianite, ostracodes, and mottles.

Magnetic susceptibility of the core from about 170 to 270 cm consists of cycles of end-on-end crescent-shape fluctuations between  $30 \times 10^{-6}$  and  $45 \times 10^{-6}$  SI units. Below 270 cm is a steady gentle sloping decrease in charge. This could be due to a decrease in hematite or ilmenite that was the result of a lack of  $\text{O}_2$  found in the eutrophic nature of such a productive deep lake. The iron oxides did not oxidize until they were exposed to air after the core was split, which means that it was deposited in an oxygen poor environment.

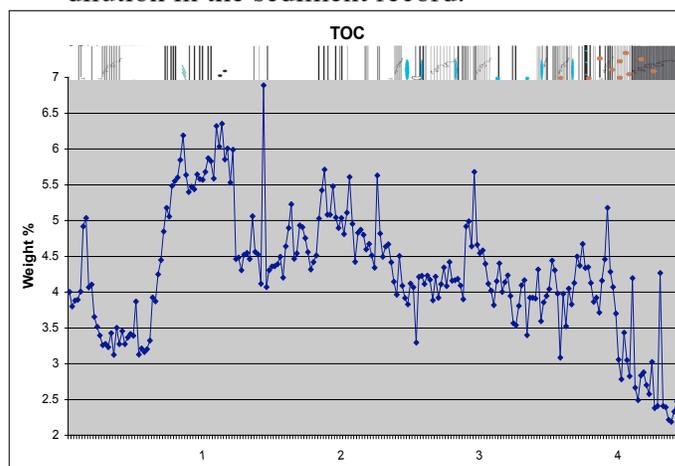
From 100 to 240 cm, TIC was very low and magnetic susceptibility was cyclically high (Figure 1). It's possible that the low productivity allowed for more oxygen to reach the bottom of the lake and oxidize iron and titanium, making hematite and ilmenite. The opposite is true for the last 70 cm of core. High TIC and low magnetic susceptibility values are the result of high productivity and low oxygen. Increased primary productivity explains high TIC because phytoplankton secrete calcite (Ellis, Mullins, and Patterson, 2004). Since it is known that this time period was 2-3 °C warmer and photosynthesis consumes  $\text{CO}_2$  in water, increased pH must have played a role in the calcite precipitation (Ellis, Mullins, Patterson, 2004). This increased productivity would have led to an anoxic lake bottom due to the consumption of  $\text{O}_2$  via decomposition of the sinking organic matter. The lack of  $\text{O}_2$  on

the lake bottom would have prevented iron and titanium from oxidizing and forming magnetic hematite and ilmenite.



**Figure 1. TIC with stratigraphic column.**

When comparing TIC to TOC (Figure 2), it is evident that TIC increases and TOC decreases with depth. At times of low TIC, calcite producing plankton were not necessarily less productive but were likely eaten more by plankton consuming organisms. The opposite is also true: fewer predators allowed plankton to populate and create more calcite. The low TIC could also be a result of climate, nutrient input, controls on calcite saturation, and the effects of dilution in the sediment record.



**Figure 2. TOC with stratigraphic column.**

## DISCUSSION

### Carbonate Precipitation

The cause of carbonate precipitation in Canandaigua Lake is multifaceted, which has led to the fluctuations that are evident in the record. The most influential factor is the calcite saturation of surface waters, which is controlled by  $\text{Ca}^{2+}$  and  $\text{HCO}_3^-$  concentrations in addition to the solubility of calcite (Ellis, Mullins, and Patterson, 2004). Sources of calcite include detrital (i.e. erosion), allochthonous (i.e. calcite whitening events), and authigenic (i.e. forms between pores). The leading control on solubility of calcite in lakes is temperature, meaning that at times of lower water temperature more calcite could be held in solution. Another major contributor is primary productivity, namely phytoplankton. Phytoplankton can act as both a nucleation site for calcite and, through photosynthesis, pH controller. In photosynthesis,  $\text{CO}_2$  is removed and pH is increased, which can allow for the precipitation of calcite.

During the early to mid- Holocene, calcite whitening events were both significant and widespread throughout the Finger Lakes (Anderson et al, 1997; Mullins, 1998). During that time period, mean annual temperature is thought to have been 2-3°C warmer than present. By ~5.5 ka and ~3.5 ka, calcite whitening events ceased in Seneca and Cayuga Lakes, respectively. Calcite production in seven out of the eleven Finger Lakes did not occur again until the late 1880s to mid-1900s (Lajewski et al., 2003). Sediment in Canandaigua Lake has shown the presence of calcite from 1821 A.D. until present and waters from the lake have been supersaturated with calcite at least from 1972 to 1999 A.D..

### Climate Change

During the upper Pleistocene (~13,320 BP),

there was significant regional postglacial warming during the Bolling and Allerod warming period (Ellis, Mullins, and Patterson, 2004). These warming events lead to an increase in primary productivity and a resultant spike in TIC. Since that time period was 2-3 °C warmer and the mean global surface temperature is expected to increase by 1.4-5.8 °C by the end of the 21<sup>st</sup> century, it is expected that TIC will return to previously high levels of the lower Holocene. Using the C-14 date from the bottom of the core, ~13,320 BP, a rough sedimentation rate can be calculated to be 0.35 mm/yr, which is close to the rate of 0.3 mm/yr from Wellner and Dwyer, 1996. Thus a new carbonate-rich interval should be seen in the next 3 cm of deposition.

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