GETTING TO THE BOTTOM OF IT: HOLOCENE CLIMATE CHANGE IN KEUKA LAKE, NY

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INTRODUCTION

Lakes often respond to variations in temperature and precipitation by changing their hydrologic balance. Previous studies suggest the timing of lake highstands and lowstands in the Midwest does not correlate with those in the eastern United States. The mid-Holocene Hypsithermal (~9 - ~5 ka) is recorded as a period of warm, dry climate in western and central North America (COHMAP 1988; Dean et al. 1996), but as a warm, wet interval in the eastern Great Lakes region (Dwyer at al. 1996; Silliman et al. 1996). In the White Mountains, NH, pollen records indicate a moister climate than present between 10,000 and 8,000 yr BP and a warmer period (2°C warmer than present) occurred at ~9,000 yr BP (Shuman et al., 2002; Davis et al., 1980). Paleoclimatic studies based on sediment and seismic reflection data from three Finger Lakes (NY) indicate higher lake levels during the Hypsithermal and lower lake levels during the Neoglacial, most likely as the result of changes in precipitation and temperature (Dwyer et al. 1996; Mullins 1998; Wellner and Dwyer, 1996). These lake level changes may reflect changes in jet stream position.

The objective of this study was to develop a high-resolution record of Holocene environmental and climatic change from Keuka Lake interpreted from the analysis of a 4 meter sediment core for magnetic susceptibility, grain size, loss-on-ignition, and charcoal abundance.

Site Description

Keuka Lake is the third largest of the 11 Finger Lakes by surface area (47 km^2) and fifth by volume (1.4 km^3) (Mullins et al., 1996) (Fig1 *Not available*). The lake has two unique characteristics compared to the other Finger Lakes. It has a Y-shape and it drains eastward into another Finger Lake, Seneca Lake. Its present morphology results from the deepening of pre-existing stream valleys during the Wisconsin glaciation, which explains why the Keuka Lake is narrow (3.3 km max. width) and long (32 km). The narrow, deep basin (up to 57 m) allows for the collection of undisturbed sediment that preserve suitable records of environmental changes since the retreat of the Laurentide ice sheet from this region ~14 ka (Mullins et al., 1996).

METHODS

Field

A core site was selected to recover the thickest and most undisturbed Holocene section based on a preliminary high-resolution seismic survey. The site also avoided ice meltout structures, and was positioned offshore from a major tributary to investigate the variability in fluvial sedimentation in the lake (Fig 2). A 4-meter piston core (ETH Design) was recovered from the southern arm of Keuka 50 meters of water from the *JB Snow*, Hobart and William Smith's 25-ft pontoon boat.

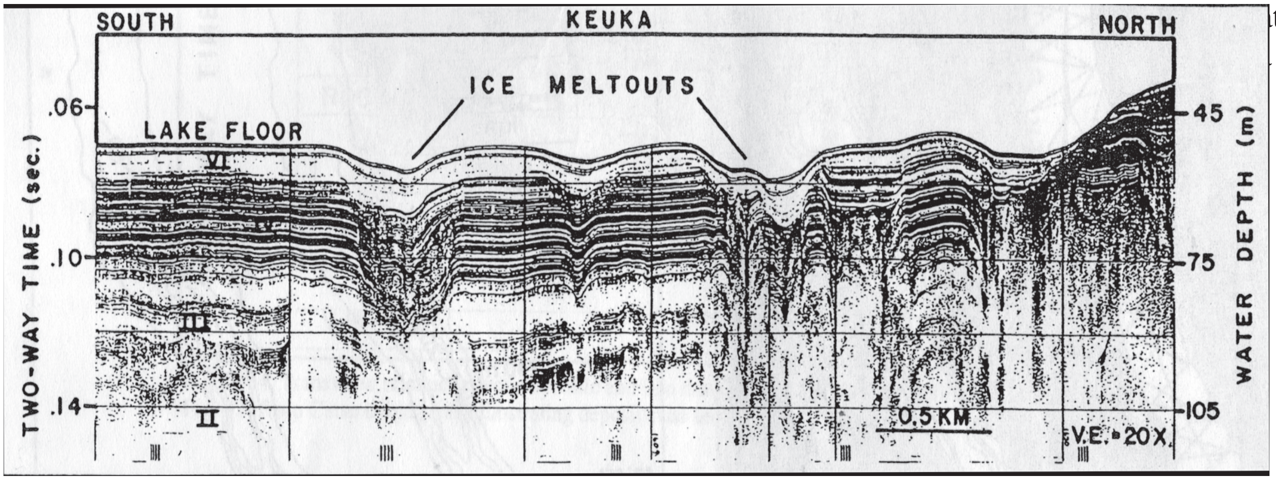


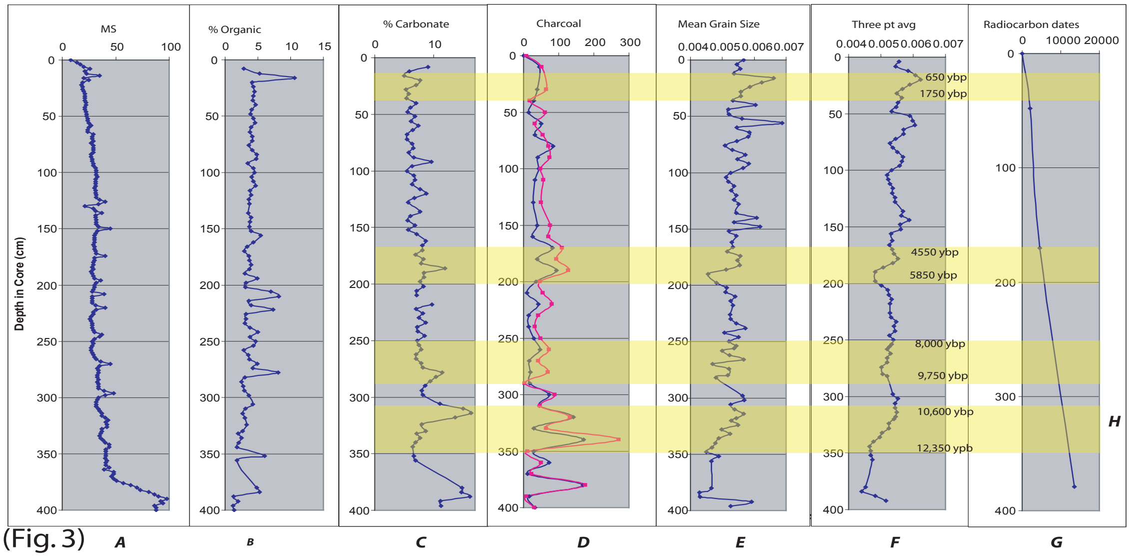
Figure 2. Meltout structures are noted in the diagram above. Meltout structures arise from glacial ice that becomes buried by or is driven into sediment, once there it can take much longer to melt. Sediment is deposited on top of the ice as it melts causing unconformities in the sediment. Keuka is known for having more meltout structures than the other lakes (Mullins et al., 1996).

Laboratory

Magnetic susceptibility (MS) was measured with a Bartington MS-2 meter and coil at a 2-cm interval along the entire length of the core. The core was then split, digitally photographed, described, and 1-cm thick subsamples were collected at a 4-cm interval along the entire core. The subsamples were freeze-dried to determine the water content (wt.%). Loss-on-ignition (LOI) techniques determine the relative weight percent organic (500°C) matter (%TOM) and carbonate (1000°C) content (%TC) (Dean, 1974). Because the LOI method overestimates the carbonate content by ~4%, any sample with a value of 4% is considered to have no carbonate (Dean, 1974). Grain size was measured on organic and carbonate-free samples for particle size distribution between 0.04-2000 μm using a Coulter LS 230. The mean, standard deviation (sorting), and skewness of each sample were calculated using the method of moments (Boggs, 2001). Charcoal abundance was determined from 1 cm^3 samples in two sieved size fractions, 125 and 149 μm, to evaluate the record of fire intensity (Whitlock et al. 2001). Three plant macrofossil samples were collected from 47 cm, 170 cm and 379

RESULTS

The core consists of massive (0 to 336 cm) olive gray and (from 337 to 374 cm) underlying laminated olive-gray and black silty clay (Fig. 3). The MS decreases from the bottom to the top of the core (from 88 to 8cm). The %TOM increases from the bottom of the core at 2.6% to the top of the core at 4.2%. There are also several spikes in %TOM (up to 10.6 %) that correlate to the spikes in MS. Average %TC decreases upcore from 8% to 5%. There are four intervals of above average %TC, between 344-314 cm, 294-278 cm, 206-186 cm, and 36-20 cm that do not correlate with the MS and %TOM spikes. The percent content of sand, silt and clay yielded a correlation between increases in MS and increases in percent content of sand at 16cm, 66cm and 246. Silt also seems to be the controlling factor in increasing mean grain size. Percent content of silt increases upward through the core, starting at an average of 57% and increasing to an average of 63% (Fig 4). Mean grain size gradually coarsens from the bottom to the top of the core mostly in the range of silt sized particles (Fig. 3). Superimposed on the coarsening upward trend are four intervals of larger mean grain size: 346-300 cm, 274-250 cm, 200-178 cm, and 50-20 cm. Charcoal



(Fig. 3)

A Magnetic susceptibilty (MS) showed little correlation with other data sets, MS decreases gradually from the bottom of the core to the top

B Percent organic content also correlates poorly with other data sets, however there are six distinct increases in organic content possibly from terretrial sources

C Percent carbonate content displayed four periods of increased production with a gradual decrease in percent content from the bottom of the core to the top

D Charcoal frequency data shows four or possibly five periods of increased fire activity, the grain sizes 125 to 149 microns and >149 microns correlated well

E Mean grain size data displays four locations of increased mean grain size, grain size increased slighly from the bottom to the top of the core

F The three point running average demonstrates the broader trends of mean grain size and the four periods of increased grain size

G Carbon-14 dating quantified three dates along the core

H The yellow shaded areas represent the periods where the carbonate LOI, mean grain size and charcoal data correlate, the ages of the four climatic events based on C- 14 dating are:
12,350 ybp - 10,600 ybp: 350-310cm,
9,750 ybp - 8,000 ybp: 290-250cm,
5,850 ybp – 4,550 ybp: 200-170cm,
1,750 ybp – 652 ybp: 40-15cm

abundance in the >149 μm and the 149 to 125 μm fractions covary, except at 50 cm. Five intervals reveal higher charcoal abundance at concentrations above 50 particles/cm^3: 390-380 cm, 350-300 cm, 280 cm-260 cm, 200-170 cm, and 40-20 cm. Three AMS ^{14}C ages are 2030 at 48 cm, 4530 at 170 cm, and 13580 at 379 cm. Average sediment accumulation rates were 0.23 mm/year in the upper part of the core and 0.49 mm/year in the bottom half of the core.

DISCUSSION

We found convergent data for %TC mean grain size, and charcoal frequency. Based on our analysis, we find four to five significant climatic events recorded by the sediment. Mean grain size, %TC, and charcoal frequency all show a positive correlation.

Four periods of higher mean grain size are likely due to an increase in precipitation or storm intensity. Increases in storm intensity and precipitation can be caused by increases in temperature. Higher temperatures lead to faster evaporation rates, which transfers moisture into the atmosphere. Mean grain size changes in Keuka Lake are more likely attributed to changes in precipitation than to lake level due to its steep valley walls and flat lake bottom. Changes in the %TC, like grain size, indicate four climatic events during the early to mid-Holocene. The highest %TC occurs between 12,350 and 5,000 yrs BP. We infer higher %TC to result from an increase in erosion of carbonate-rich sediment in the watershed, warmer temperatures, increased biotic activity in the lake.

Percent content of silt, sand and clay possibly indicate storm events though brief increases in percent content of sand. In three out of four periods of increased mean grain size there are at least one to two events that cause an increase

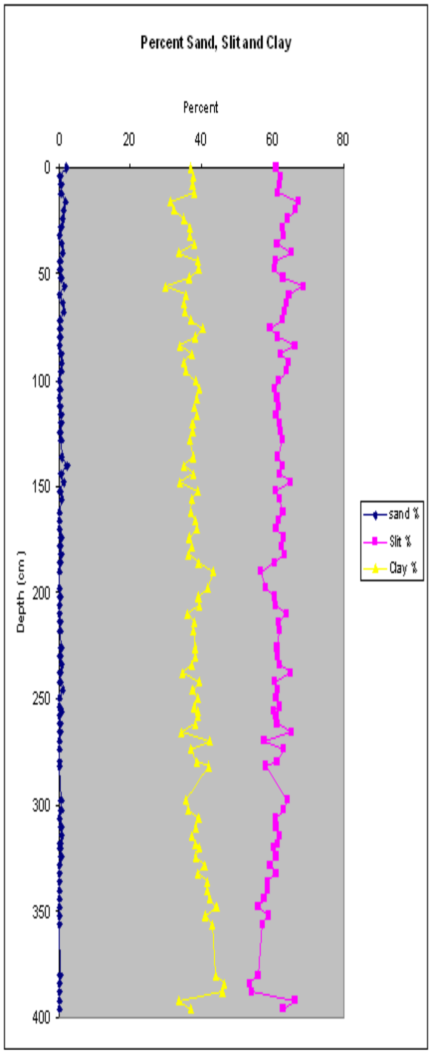


Figure 4. Relative changes in percent content of clay, silt and sand. Notice the percent content of silt trends upwards from the bottom of the top of the core.

in percent sand content. This is possibly an indication that these events periods of increased storminess.

Charcoal frequency data also indicates four or possibly five significant periods of aridity. Higher temperatures may lead to more frequent natural forest fires. Fires were frequent between 12,400 and 8,000 years BP. Based on the decrease in the number of fire events after 8000 yrs BP, we infer the onset of humid conditions during the mid-Holocene. The fire event record shows a variable fire period between 5800-4530 years BP and 1739-652 yrs BP. A decrease in fire frequency could correspond to a cool, humid climate. Vegetation changes observed in a drill core collected south of Canandaigua Lake record an overall drying and warming trend during the Holocene with warmest temperatures and reduced evapotranspiration (and precipitation) during the mid-to late Holocene (Wellner and Dwyer, 1996). The charcoal data are at odds with the inferred climate using pollen abundance. However, charcoal data correlates with the Shuman et al. (2002) study that used pollen found a warmer period at about 9,000 yrs BP. This correlates well with my data, interfering from the %TC an increase around 9,000 yrs BP.

While charcoal, grain size and percent carbonate correlated well, not all the data collected tended to display such a robust correlation. The %TOM and MS seemed to correlate little with the other datasets. The MS may not correlate to grain size if the dominant signature in the sediment is related more to fine grain hematite in the clay. In this case we would see less correlation with mean grain size. The %TOM may be related more with terrestrial inputs and may not be related to primary production.

The data from the Keuka Lake core exhibits at least four climatic events. The positive correlation of each data set represents convergent data. The other two datasets proved not to correlate with the other data. The four climatic most likely resulted in an increase in temperature and precipitation or storm intensity.

CONCLUSION

The results of this study indicate a positive correlation of mean grain size, charcoal frequency, carbonate content and percent content of sand. The positive correlation of these four data sets indicates the possibility of four or five periods climatic change (12,356ybp - 10,616ybp: 350-310cm) (9,747ybp - 8,008ybp: 290-250cm) (5834ybp - 4530ybp: 200-170cm) (1739ybp – 652ybp: 40-15cm). During these periods, temperature rose and precipitation increased in either amount or intensity. These changes lead to increased carbonate production, an increase in mean grain size and an increase in forest fire frequency.

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