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HOLOCENE AND “ANTHROPOCENE” CLIMATE AND ENVIRONMENTAL CHANGE IN THE FINGER LAKES, NY

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INTRODUCTION

Lakes are excellent archives of environmental and climate change because they respond quickly to perturbations and preserve annual- to century-scale resolution records. The sedimentary deposits in New York’s Finger Lakes preserve a complete record of post-glacial climate history and environmental change (Fig. 1) (Mullins et al., 1996). Our goal is to reconstruct detailed paleoclimate records in three of the Finger Lakes, Seneca, Keuka, and Canandaigua, over the past ~14,500 years using a variety of stratigraphic, sedimentological, and geochemical tools.

Decimeter-scale, high-resolution (2-12 kHz) seismic reflection profile data from two Finger Lakes, Owasco, and Seneca, define a middle Holocene erosional surface at water depths up to 50-60 m (Halfman and Herrick 1998; Mullins and Halfman, 2001). Two hypotheses were proposed to explain the origin of the erosional surfaces: 1) subaerial erosion during a lowstand and 2) subaqueous erosion during enhanced internal seiche activity (Halfman and Herrick, 1998; Mullins and Halfman, 2001). Sedimentologic evidence exists for a ≤~5 m lake level drop at ~4.6 ka in Owasco, Cayuga, and Fayetteville Green Lakes, located in central New York (Dwyer et al., 1996; Hilfiger and Mullins, 1997; Mullins, 1998). Lowstands have been documented in many other lakes in the northeastern United States during the Holocene (Harrison, 1989). However, at ~4.6 ka, circulation in the lakes may have increased as atmospheric cold fronts with strong southwesterly winds initiated surface currents and internal seiche activity in Owasco and Seneca Lakes (Halfman and Herrick, 1998; Mullins and Halfman 2001). In this project, we use a multi-proxy approach to test these two hypotheses in Seneca, Keuka, and Canandaigua Lakes.

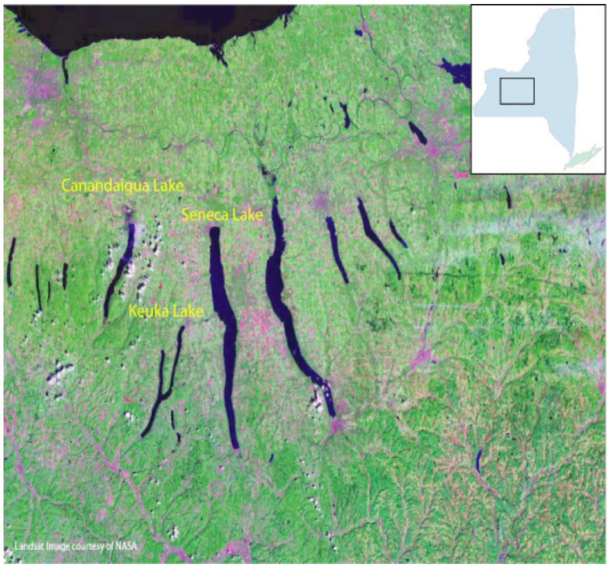

Figure 1. Location of the three Finger Lakes examined for this project: Canandaigua, Keuka, and Seneca. The insert shows the location of the Finger Lakes region in New York.

GEOLOGIC HISTORY OF THE FINGER LAKES REGION

The eleven Finger Lakes occupy deep, narrow, elongate, glacially scoured basins (Fig. 1) (Mullins et al., 1996). The Middle to Upper

Devonian Hamilton, Genesee, Sonyea and West Falls Groups are exposed in the Seneca and Canandaigua Lake watersheds whereas only the Genesee, Sonyea and West Falls Groups crop out in the Keuka Lake watershed. The Hamilton Group (shale, siltstone, limestone) represents deposition in a shallow marine environment (Woodrow and Isley, 1983). The overlying Tully Limestone pinches out between Seneca and Keuka Lakes. Deposition of the Genesee, Sonyea, and West Falls Groups (shale, siltstone, sandstone) reflect an abrupt change to deeper water marine environments (Woodrow and Isley, 1983).

The lake basins are oriented roughly north-south and follow preglacial stream valleys that were subsequently enlarged by glacial ice and pressurized subglacial meltwater during the Pleistocene (Mullins et al., 1996). As a result of glaciation, the Finger Lake basins have steep-sloped sides and flat basin floors (Bloomfield, 1978). Up to 275 m of glacial drift, proglacial rhythmites, and post-glacial mud accumulated in the basins as delineated by high-resolution seismic reflection profiles and cores (Mullins et al., 1996). The post-glacial sediment (<14,500 ^{14}C yrs BP) is weakly to well laminated (Mullins et al., 1996) and is the focus of this study. Seneca, Keuka, and Canandaigua Lakes vary in their maximum depths, lengths, and mixing characteristics (monomictic to dimictic) but have the same trophic state, oligotrophic (Table 1).

Table 1. Statistics of Finger Lakes examined in this study (Data from Bloomfield, 1978; Mullins et al., 1996).

Lake	Length (km)	Max. Width (km)	Max. Water Depth (m)		Max. Sedimentary Thickness (m)	Trophic State	Over-turn
Canandaigua	25	2.4	84	407	202	oligotrophic	dimictic
Keuka	32	3.3	57	405	146	oligo-mesotrophic	monomictic
Seneca	57	5.2	186	1181	270	oligo-mesotrophic	monomictic

METHODS

Field Methods

Students worked in teams to collect high-resolution seismic reflection profiles, dredge samples, and piston cores from the *R/V William Scandling* and *J.B. Snow*. Each team identified the locations to collect sediment cores that would recover the highest resolution record of environmental and climate change based on analysis of seismic profiles. One core was collected from both Seneca and Canandaigua Lakes and two from Keuka Lake. The dredged sediment was described and subsampled in the field.

Laboratory Analyses

Students worked individually to develop high-resolution records of environmental change based on seismic data and paleoclimate indicators. Seismic data was processed using ArcGIS. Prior to describing, photographing, and splitting the piston cores, the magnetic susceptibility was measured. Subsamples of the cores and dredge samples were collected for loss-on-ignition (LOI), charcoal, and grain size analysis. LOI was used to determine the weight % water, organic matter and carbonate content (Dean, 1974). Samples for charcoal analysis were wet-sieved through 125 and

250 μm meshes (Whitlock and Larsen, 2001). Grain size distributions were determined on organic- and carbonate-free sediment using a laser particle size analyzer (Coulter LS 230) (Jackson, 1969). Oriented paleomagnetic cubes were used to sample sediment from Seneca Lake and analyze the anisotropy of magnetic susceptibility using a KappaBridge.

Chronology for the paleoclimate indicators and discrete events is based on linear interpolation between accelerator mass spectrometer (AMS) radiocarbon dates of terrestrial plant macrofossils preserved in the cores (Table 2). AMS dates were calibrated to calendar years using CALIB v. 4.

Table 2. Radiocarbon ages.

Lake	Core #	Depth in Core (cm)	Material	Laboratory Number	Cal Age in Yrs BP
Canandaigua	1	118	plant deb.	Beta-214910	830
Canandaigua	1	248	plant deb.	Beta-213732	3325
Keuka	1	16	plant deb.	Beta-214911	1245
Keuka	1	157	plant deb.	Beta-213344	4110
Keuka	1	224	plant deb.	Beta-214912	5185
Keuka	2	48	plant deb.	Beta-213346	1995
Keuka	2	170	plant deb.	Beta-213347	5175
Keuka	2	379	plant deb.	Beta-213348	16335

Summary of Student Projects

The students used a range of techniques to interpret paleoclimate record preserved in the sediment of Seneca, Keuka, and Canandaigua Lakes, ranging from high-resolution seismic reflection profiles to physical and geochemical properties of cores. Specifically, the Finger Lakes group is producing isopach maps that delineate sedimentation patterns in Keuka and Canandaigua Lakes as well as a relatively continuous, high-resolution (centennial to decadal) record of changes in atmospheric and hydrographic conditions since the last deglaciation. Below is a brief description of each student's project.

Seneca Lake

Megan Crocker determined the bulk mineralogy, grain size distribution, and anisotropy of magnetic susceptibility of laminated lacustrine sediments to infer changes in paleocirculation patterns over the past ~14,000 years.

Keuka Lake

Robert Aspinwall used a combination of high-resolution seismic reflection profiles and sedimentological analyses to describe the two youngest seismostratigraphic units and provide insight into the sedimentation processes responsible for the subsurface stratigraphy. **Benjamin Petrick** determined the weight percent organic matter and carbonate content in a core collected from the NW branch of the lake. He also inferred the timing of past storms using the thickness of coarser-grained beds and % sand content of his radiocarbon dated core. **Davin Lyons** determined the weight percent water, organic matter, and carbonate content of a well-dated core collected from the S branch of the lake. He also examined the charcoal abundance and grain size distribution to infer the timing of past storm events.

Canandaigua Lake

Hannah Woodson examined high-resolution seismic reflection profiles in order to reconstruct the thicknesses of the two Holocene units, investigate changes in sedimentation patterns, and identify erosional surfaces.
Wesley Darden used LOI to determine weight percent water, organic matter, and carbonate content. He will also analyze the $d^{13}C$ and $d^{18}O$ of authigenic carbonate of select samples.
Clare Morgan conducted grain size analyses of a radiometrically-dated core as well as analyzed for charcoal abundance to infer the relative timing of major storm events in the watershed.

SEISMO- AND LITHO-STRATIGRAPHY OF KEUKA AND CANANDAIGUA LAKES

A recent seismostratigraphic study of Seneca (Halfman and Herrick, 1998) and Owasco Lakes (Mullins and Halfman, 2001) reveals two depositional sequences: Sequence VIA and VIB. Both units are recognized in Keuka and Canandaigua Lakes (Fig. 2) (Aspinwall, 2006; Woodson, 2006). Sequence VIA is characterized by parallel, laterally continuous, weak reflectors whereas the overlying sequence VIB is acoustically transparent. Visual analysis of the sediment cores that penetrate sequence VIB reveals olive-gray mud. Sequence VIA is olive-gray with more distinct, thin black laminae. Within sequence VIA, reflectors generally correlate with intervals of increased magnetic susceptibility and % sand content (Aspinwall, 2006).

Based on AMS dates, the boundary between sequence VIA and VIB in Keuka and Canandaigua Lakes occurs at ~4800 cal yrs BP, similar to what is inferred for Owasco and Seneca Lakes. The VIA/VIB boundary could have formed during flood events in the watersheds. Storm events could form a zone of coarser-grained sediment (reflectors) that extends father into the lake. In support, sequences VIA and VIB are thicker near major streams that drain into the lake. Dark reflectors that occur along basin edges pinch out towards the basin centers and initiate along modern deltas and streams. As the thickest of these reflectors coincides with the boundary of sequence VIA and VIB, Aspinwall (2006) and Woodson (2006) infer that the boundary reflects a significant change in sedimentation style and circulation in the lake.

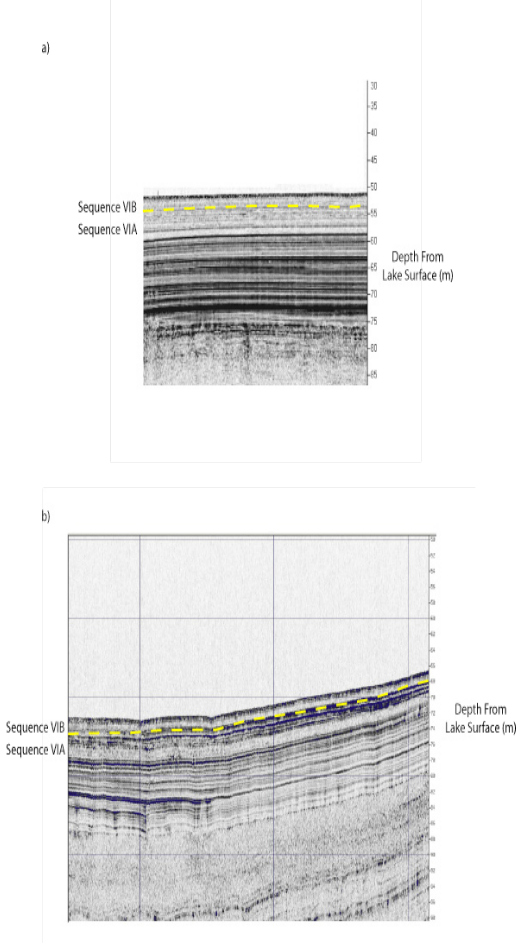

Figure 2. Comparison of Sequences VIA and IVB in a) Keuka and b) Canandaigua Lakes. A dashed yellow line denotes the boundary between the two sequences. Sequence VIA is characterized by parallel, laterally continuous low-amplitude internal reflectors that onlap older units. Sequence VIB is acoustically transparent and thinner than Sequence VIA.

MAJOR LAKE LEVEL FLUCTUATIONS OR STORM EVENTS DURING THE LAST 14,500 YEARS?

Because the cores were recovered from the deepest regions of Seneca, Keuka, and Canandaigua Lakes, they provide a relatively continuous record of sedimentation. The cores are punctuated by sandier intervals up to ~10 cm thick. Three conditions could account for an increase in siliciclastic supply to the deepest regions of the lakes: 1) lake lowstands, 2) hydrologic events or 3) removal of vegetation by fire. Near the base of two cores, one from Keuka Lake (Lyons, 2006) and the other from Canandaigua Lake (Morgan, 2006), there is an increase in charcoal abundance and well-defined laminae. The charcoal abundance is greatest prior to ~5500 cal yrs BP, suggesting that fires could have played an important role in hillslope erosion. In the Seneca and Canandaigua Lake cores, carbonate abundance is highest during this interval, suggesting warmer conditions (Crocker, 2006; Darden, 2006). The carbonate and charcoal abundance data suggest that prior to 5.5 ka, the climate was warm and relatively dry.

The deposition of coarser-grained layers is more frequent after ~5500 cal yrs BP (Fig. 3) (Crocker, 2006; Lyons, 2006; Morgan, 2006; Petrick, 2006). Deposition of coarser-grained material during this interval may be controlled by either a drop in lake level or large flood events (Crocker, 2006; Lyons, 2006; Morgan, 2006). If lake level dropped, then more coarse-grained material could accumulate in deepwater cores. Alternatively, siliciclastic material could be washed from the watershed into the lake and transported towards the basin center during large storm events. Fewer laminae observed in the uppermost section of the cores point to more vigorous lakewide circulation. Thus, the sediment characteristics define a major boundary at ~5,500 cal yrs BP that the group infers to reflect a significant change in sedimentation style and circulation in the lakes.

CONCLUSIONS

High-resolution seismic data coupled with evidence from sediment core analyses show that the Finger Lakes have undergone significant environmental change since the last deglaciation. Two distinct Holocene units are recognized in high-resolution seismic reflection profiles, Sequence VIA and VIB, which indicate

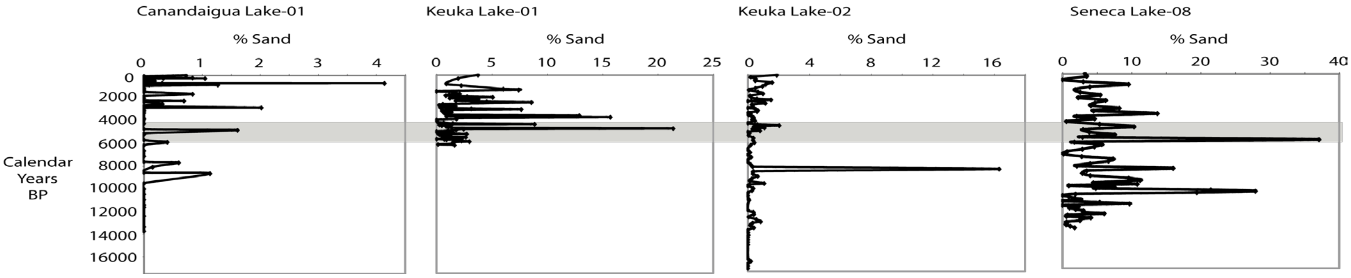

Figure 3. Correlation of grain size data (% sand) among Canandaigua, Keuka, and Seneca Lakes. The light gray bar highlights the ~5,500 cal yrs BP regional event. After ~5,500 cal yrs BP, the % sand content is generally higher than pre- 5,500 cal yrs BP.

a change style and type of deposition between the Early and Late Holocene.

Lacustrine sediments from Seneca, Keuka, and Canandaigua Lakes indicate that the frequency of sandier intervals increased at ~5.5 ka and preservation of authigenic carbonate and laminae decreased. A major change in sedimentation occurred at the mid-Holocene boundary.

REFERENCES CITED

Aspinwall, R., 2006. Seismic stratigraphy and depositional architecture of Holocene sediment in Keuka Lake, NY, this volume.

Bloomfield, J.A., 1978, Lakes of New York State, Vol. 1. Ecology of the Finger Lakes: NY, Academic Press, 465 p.

Crocker, M., 2006, Going with the flow: Evidence for changes in circulation in Seneca Lake, NY during the Holocene, this volume.

Darden, W. 2006, Carbonate and stable isotopic analysis of lacustrine sediments, Canandaigua Lake, NY, this volume.

Dean, W.E., 1974, Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss-on-ignition: comparison with other methods, J. Sed. Petrol., v. 44, p. 242-248.

Dwyer, T.R., Mullins, H.T., and Good, S.C., 1996, Paleoclimatic implications of Holocene lake-level fluctuations, Owasco Lake, NY, Geology, v. 24, p. 519-522.

Halfman, J.D., and Herrick, D.T., 1998, Mass-movement and reworking of late glacial and postglacial sediments in northern Seneca Lake, NY. Northeastern Geology and Environmental Sciences, v. 20, p. 227-241.

Harrison, S.P., 1989, Lake levels and climate change in eastern North America, Climate Dynamics, v. 3, p.157-167.

Hilfiger, M.F. and Mullins, H.T., 1997, Geology, limnology and paleoclimatology of Green Lakes State Park NY, In Field Trip Guide for the 69th Annual Meeting of the New York State Geological Association, (TW Rayne, DG Bailey, and BJ Tweksbury Eds.) pp. 127-158.

Jackson, M.L., 1969, Soil Chemical Analysis, M.L. Jackson, Madison, WI. 895 p.

Lyons. D., 2006, Getting to the bottom of it: Holocene climate change in Keuka Lake, NY, this volume.

Morgan, C.M., 2006, Reflections on mud: Holocene climate variability recorded by laminated sediments in Canandaigua Lake, NY, this volume.

Mullins, H.T., 1998, Holocene lake-level and climate change inferred from marl stratigraphy of the Cayuga Lake basin, NY, J. Sed. Res., v. 68, p 569-578.

Mullins, H.T., Hinchey, E.J., Wellner, R.W., Stephens, D.B., Anderson, W.T. Jr., Dwyer, T.R. and Hine, A.C., 1996, Seismic stratigraphy of the Finger Lakes: A continental record of Heinrich event H-1 and Laurentide ice sheet instability. GSA, Special Paper 311, p 1-36.

Mullins, H. T. and Halfman, J. D., 2001, High-resolution seismic reflection evidence for Middle Holocene environmental change, Owasco Lake, NY. Quat. Res., v. 55, p. 322-311.

Petrick, B., 2006, Sedimentation and indicators of Holocene climate change in Keuka Lake, NY, this volume.

Whitlock, C. and Larsen, C., 2001, Charcoal as a fire proxy *in* Tracking Environmental Change Using Lake Sediments, v. 2, Biological Techniques and Indicators (eds.) J.P. Smol, H.J.B. Burks, and W.M. Last. Dordrecht, Netherlands: Kluwer Academic Publishers, pp. 75-97.

Woodrow, D.L. and Isley, A.M., 1983, Facies, topography, and sedimentary processes in the Catskill Sea (Devonian), New York, Pennsylvania, GSA Bulletin, v.94, 459-470.

Woodson, H., 2006, High resolution mapping of Holocene sediments, Canandaigua Lake, New York, this volume.