# THE MARL LAKE SEDIMENTS OF NEWELL LAKE BASIN, BELLEFONTAINE, OHIO: A RECORD OF HOLOCENE ENVIRONMENTAL CHANGE

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## INTRODUCTION

Marl deposits typically form in lakes with short hydrologic residence times, making them likely to preserve a record of paleoclimate (Drummond et al, 1995). A marl deposit is found in the Newell Lake basin, in Bellefontaine, Ohio. Sediments at the bottom of this basin were estimated by Zimmerman (1960) to be late Wisconsin in age and may record the retreat of the Laurentide Ice Sheet and succession into lake formation. Deposition of lake clays was followed by peat and marl, which Zimmerman (1960) attributed to a lowered lake level. Marl formation continued throughout the Holocene in this basin.

Marl lake deposits are rich in calcium carbonate that precipitates as carbon dioxide is released during the photosynthetic processes of aquatic plants, such as *Chara*. High-density mollusk populations are also common. Water levels and geochemistry of these lakes are subject and sensitive to local environmental changes; for example, increased deposition of marl generally occurs in warmer water temperatures when rates of photosynthesis are highest (Edwards and Fritz, 1988). These changes are inherently reflected in the depositional histories of marl lakes.

Bulk carbonate, *Chara* encrustations, and mollusk shells that comprise marl deposits share isotopic geochemistry with the lake water in which they are deposited, and consequently they are also in equilibrium with the hydrologic source.

The intent of this research is to better understand local climatic change from the sediments of the Newell Lake basin, concentrating on variations within the Holocene marl deposits.

### Study Site

The Newell Lake basin, site 0102 (Figure 1 in Wiles *et al*, this volume) is located approximately 6 miles southwest of Bellefontaine, and 3 miles northwest of West Liberty, Ohio, in Logan County. This lake basin is one of several marl lakes in the Midwest region that formed in a kettle imposed on glacial drift (Drummond *et al*, 1995). Groundwater and lime-rich surface drainage recharge the basin, which has been excavated commercially for marl deposits. The geomorphic setting of Newell Lake is complex, as it is located amid a buried kame field overlain by a thin layer of till that has been reworked by glacial meltwater (Markley, 2001). Tunnel valleys and moraines also surround the study site.

### Methods

#### *Field Coring*

Two overlapping cores, 2” in diameter and nearly five meters in length, were extracted using a manual piston corer. The sediment cores were visually inspected, photographed, and briefly described to note significant unit contacts and macrofossils. Before leaving the field site each core was wrapped in plastic wrap and placed in PVC piping.

### *Initial Laboratory Methods*

Cores were described in detail to note grain size, color, and contacts between major sedimentary units, and were digitally photographed. Sedimentary structures and organics were also noted, and the two overlapping cores were correlated using distinct sediment beds. Magnetic susceptibility readings were taken at 4-cm intervals on both cores. The first and most complete core was used for preliminary loss-on-ignition (LOI) and grain size analyses, both performed at 4-cm intervals. Grain size analysis was conducted using a Spectrex Laser Particle Counter Model PC—2000 to determine the mean grain size at each interval.

### *High-resolution Analyses*

Following preliminary sediment analyses, high-resolution loss-on-ignition analyses were performed on 1-$cm^3$ samples at a 1-centimeter interval to determine fine-scale trends in organic and carbonate ratios as a function of depth. Magnetic susceptibility readings were performed using a Bartington Instruments magnetic susceptibility meter, Model MS2. Readings were taken at three positions on the circumference of the core at 2-cm intervals of depth and recorded in c.g.s. units to measure a relative difference in the abundance of ferrimagnetic minerals.

### *AMS Radiocarbon dating*

Two fragments of wood were selected from different levels for AMS radiocarbon dating. Sample AA45068 came from near the bottom of the core and was pretreated at the Limnological Research Center at the University of Minnesota and then submitted to the accelerator at the University of Arizona. The second fragment, sample Beta-158292, was removed from just below the base of the marl sequence and was sent to Beta-Analytic.

Stable Isotope Analysis

Core sediment was sampled to obtain shells of the mollusk species *Valvata tricarinata* for use in stable oxygen isotope analyses. Species identifications were made using La Rocque's Pleistocene Mollusca of Ohio (1967). Forty samples were taken from marl beds at different levels to represent the most complete Holocene record. Analyses are currently underway at the Environmental Isotope Lab at the University of Waterloo. Results of these analyses will be reported in values of _$^{18}$O. Based on the assumption that the shells of this species precipitated in equilibrium with the lake water, these values can be used as a paleothermometer by converting _$^{18}$O values to changes in temperature (Edwards and Fritz, 1988).

## RESULTS

Between the two cores, approximately 480 centimeters of sediment were recovered, beginning at a depth of 250 cm. LOI results, magnetic susceptibility readings, and core descriptions reveal three primary units of varying depositional history (see Figure 1).

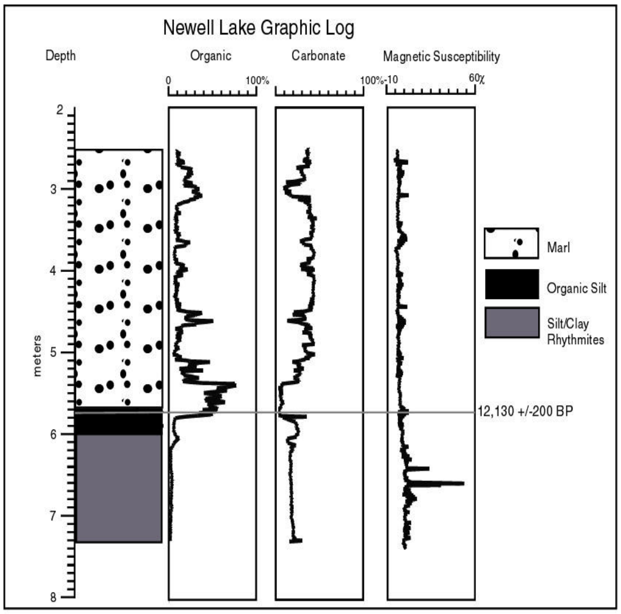
The basal unit, 732-600 cm, is a gray, lightly banded, clay-rich diamicton that grades into thinly laminated silt with 0-10% organics and 10-30% carbonate. Magnetic susceptibility (_) ranges from 2-13. Results of radiocarbon dating performed on sample AA45068 determined the age of this unit to be 35,120 +/- 820 BP (33, 168+/-820 BC). This unit is referred to as unit one.

Unit two is massive silt, 5-15% organic and 5-25% carbonate in composition that extends from 600-568 cm. These sediments are green to gray in color, with _ between –1.5 and 3. Sample Beta-158292 was extracted near the upper boundary of this unit and AMS results date it at 12,130 +/- 200 BP (10, 178+/-200 BC).

Unit three is comprised of the Holocene deposit, a sequence of marl and peat beds that begin at 568 cm and continue to the top of the core. LOI and magnetic susceptibility readings show frequent fluctuations that range from 10-80% organic content, 0-40% carbonate content, and _ between -3 and 7.

# DISCUSSION

The result of AMS radiocarbon dating on the




Figue 1. Laboratory results and graphic log of Newell Lake basin (site 0102) sediments.

lower sample is near 35,000 years, however, this date remains unexplained, and for this reason only one age constraint is used in this study. Radiocarbon dating of sample Beta-158292 yielded an age of 12, 130 +/- 200 BP (10,178+/-200 BC), for the silt in Unit 2, indicating that Unit 3 is younger than this and is representative of Holocene deposition.

The results of the laboratory analyses, in conjunction with the preferential habitat of extant native molluscan species were used to infer environmental change in Newell Lake, specifically water levels and variations in productivity. *Valvata tricarinata* is the most common gastropod found in this basin and can withstand significant environmental change, typically inhabiting water from the shoreline to depths of up to 9 meters. In general, most mollusk species found in Newell Lake can survive among weeds, though they flourish in waters slightly deeper than the shoreline. High organic content, therefore, may indicate periods of low lake levels and shoreline shifting, whereas high carbonate content indicates higher mollusk populations and carbonate production rates (Zimmerman, 1960). Shifts in these values can be found in the LOI results.

Earlier paleoclimate studies using lacustrine sediments reveal the following relationships (e.g., Zimmerman, 1960; Leonard, 1986; Lozano-Garcia and Ortega-Guerrero, 1998; Yu and Wright, 2001):

High organic content →Low lake level, shoreline shifting.

High carbonate content → Deeper water, larger mollusk populations.

Low organic, moderate-high carbonate content, moderate _ → Cool period with sufficient moisture resulting in low lake productivity, increased terriginous input, and decreased vegetal cover.

High LOI, low _ → Warmer conditions with increased lake productivity and decreased external input.

Low LOI and _ → Decreased external input and organic productivity due to cooling and deficient moisture.

Moderate-high LOI and _ → Significant terriginous input and vegetal cover.

Application of these general interpretations to the sediments of Newell Lake led to the following paleoclimate reconstruction. An abrupt shift in magnetic susceptibility and LOI suggest warming after the deposition of Unit 1, as evidenced by increased lake productivity and decreased terriginous input in Unit 2. This warming trend continues through Unit 2 and the transition into Unit 3.

A more detailed interpretation of Unit 3, in which there is a repeating series of marl beds that begin and end with a massive organic unit, provides clues to the climatic regime of this area during the Holocene. The lithological variation from massive organics to laminated marl has been interpreted as a record of increasing lake level as a function of increased precipitation, ultimately driven by climate change (e.g., Yu *et al*, 1997). The Newell Lake cores indicate at least four of these cycles within approximately 3 meters of sediment, which is reflected not only in the physical stratigraphy, but also in the LOI and magnetic susceptibility results.

Laminated marls are interpreted as deposits from periods of highest lake level (Yu *et al*, 1997). The laminae represent mm-scale changes within individual marl beds that vary in color from light to dark. These high-frequency changes could be the product of seasonal variation, with darker sediments deposited during warmer months of higher organic productivity (Drummond *et al*, 1995; Yu and Wright, 2000; Kirby *et al*, 2001).

# CONCLUSION & FURTHER INVESTIGATION

The sediments of the Newell Lake basin exhibit a series of dynamic climate cycles. The high-resolution LOI and magnetic susceptibility results indicate seasonal variation within a repeating cycle of lake level change during the warm period following deglaciation. When available, these results will be combined with the stable isotope analyses, converted to paleotemperatures, and plotted as a function of depth.

The results of this investigation can ultimately be pooled with the data from the other cores extracted during the summer of 2001 to reconstruct the retreat of the Laurentide Ice Sheet and to document regional environmental change. In addition, this data can be compared to other North American paleo-climate records, such as Twin Marl Lake and Fayetteville Green Lake, as studied by Z. Yu and Wright, and Kirby *et al*, respectively, in an attempt to better understand the timing and forcing of global climatic change (Yu and Wright, 2001; Kirby *et al*, 2001).

# REFERENCES CITED

Drummond, C.N., Patterson, W.P., and Walker, J.C.G., 1995, Climatic Forcing of carbon-oxygen isotopic covariance in temperate region marl lakes: Geology, v. 23, p. 1031-1034.

Edwards, T.W.D., and Fritz, P., 1988, Stable-Isotope paleoclimate records for Southern, Canada: comparison of results from marl and wood: Canadian Journal of Earth Sciences, v. 25, p. 1397-1406.

Kirby, M.E., Mullins, H.T., Patterson, W.P., and Burnett, A.W., 2001. Lacustrine isotopic evidence for multidecadal natural climate related to the circumpolar vortex over the northeast United States during the past millennium: Geology, v. 29, p. 807-810.

La Rocque, A., 1967, Pleistocene Mollusca of Ohio. Ohio Division of Geological Survey Bulletin 62.

Leonard, E.M., 1986, Use of Lacustrine Sedimentary Sequences as Indicators of Holocene Glacial History, Banff, National Park, Alberta, Canada: Quaternary Research, v.26, p. 218-231.

Lozano-Garcia, M.S., and Ortega-Guerrero, B., 1998. Late Quaternary environmental changes if the central part of the Basin of Mexico; correlation between Texcoco and Chalco basins: Review of Palaeobotany and Palynology, v. 99, p. 77-93.

Markley, B.K., 2001. Conceptual Modeling of Shallow Subsurface Sediment Distribution As Related to Geomorphic Interpretations: Bellefontaine and Southwestern Clark County, Ohio. [Master's Thesis]: Cincinnati, University of Cincinnati, 223 p.

Yu, Z., McAndrews, J.H., and Eicher, U., 1997, Middle Holocene dry climate caused by change in atmospheric circulation patterns: Evidence from lake levels and stable isotopes: Geology, v. 25, p. 251-254.

Yu, Z., and Wright, H.E., Jr., 2001, Response of interior North America to abrupt climate oscillations in the North Atlantic region during the last deglaciation: Earth-Science Reviews, v. 52, p. 333-369.

Zimmerman, J.A., 1960, Pleistocene Molluscan faunas of the Newell Lake deposit, Logan County, Ohio: The Ohio Journal of Science, v. 60, p. 13-39.