INTERACTIONS BETWEEN URBAN LAKE HYDROLOGY AND SEDIMENTS; AN EXAMPLE FROM SUMMIT LAKE, AKRON, OHIO

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ABSTRACT

Summit Lake is an urban lake located in Akron, Ohio. Once used by industry, Summit Lake is currently being revitalized to provide urban recreation. It is important to study the lake's overall health through chemical and physical processes to make sure it is suitable for increased recreational use. Summit Lake is dimitic, meaning the water column gets mixed twice a year. From May to October the lake is thermally stratified and the hypolimnion becomes anoxic. The anoxia results in the release of orthophosphate as phosphorus from the lake sediment into the water column. Throughout the warm months, orthophosphate as phosphorus increases in the hypolimnion reaching an average value of 1100 μg/L by October. As Akron works to reduce the number of combined sewage overflows and nutrients entering surface waters, it is important to characterize the internal nutrient loading of orthophosphate as phosphorus into the anoxic hypolimnion. During the sunny spring/summer months, as algal productivity and water temperature both increase, there is a drawdown of CO_2 in the epilimnion. These conditions result in the precipitation of calcite grains referred to as a whiting. Sediment cores from Summit Lake show rhythmic layering of white and brown mud. XRD, SEM, and optical microscopy reveals the white layers to be composed of ellipsoidal to rhombohedral, calcite grains about 5 μm long. The white layers are interpreted as deposition from the spring and summer whiting, and the brown layers are interpreted as deposition of organic matter through the remainder of the year. Thus, a white and brown sediment couplet is a varve deposited in one year. Because the layering has not been bioturbated, the varves provide a high-resolution chronology of the sediment deposit. When recently collected, cores were correlated to year 2003 cores, there were 16 sediment couplets present in the 18 years between the two coring times thus supporting the varve interpretation. The varve chronology, resulting from the seasonal water cycle, allows sediment records of heavy metal pollution to be interpreted with great temporal resolution.

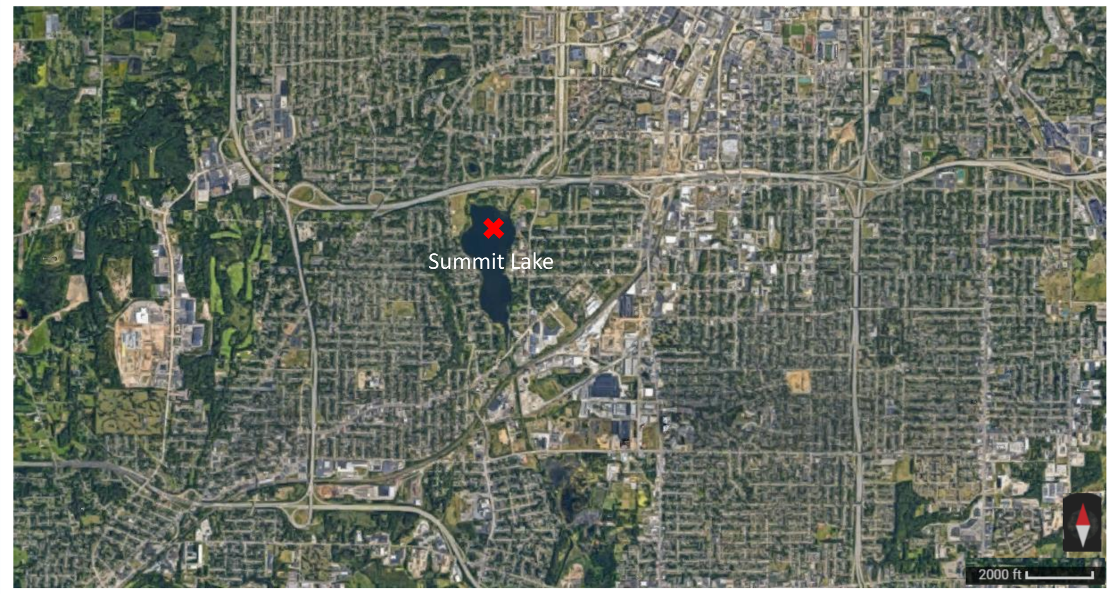


Figure 1. Photograph showing Summit Lake located in urban Akron, OH. The red X marks the sampling site location (Image from Google Earth).

RESEARCH QUESTION

- The rhythmically-laminated brown and white colored mud are varves produced by seasonal changes in water chemistry and sedimentation.

MATERIALS AND METHODS

- Water column measurements were performed seasonally
- Sediment cores were also extracted each season.
- Cores were split open lengthwise, allowed to oxidize, and photographed.
- Sediment measurements included: LOI, RGB, XRD, SEM, pore water chemistry, thin sections, smear slides, heavy metals, and magnetic susceptibility.
- A varve-based age model was produced once the sedimentation mechanism was determined.

RESULTS

Seasonal Water Column

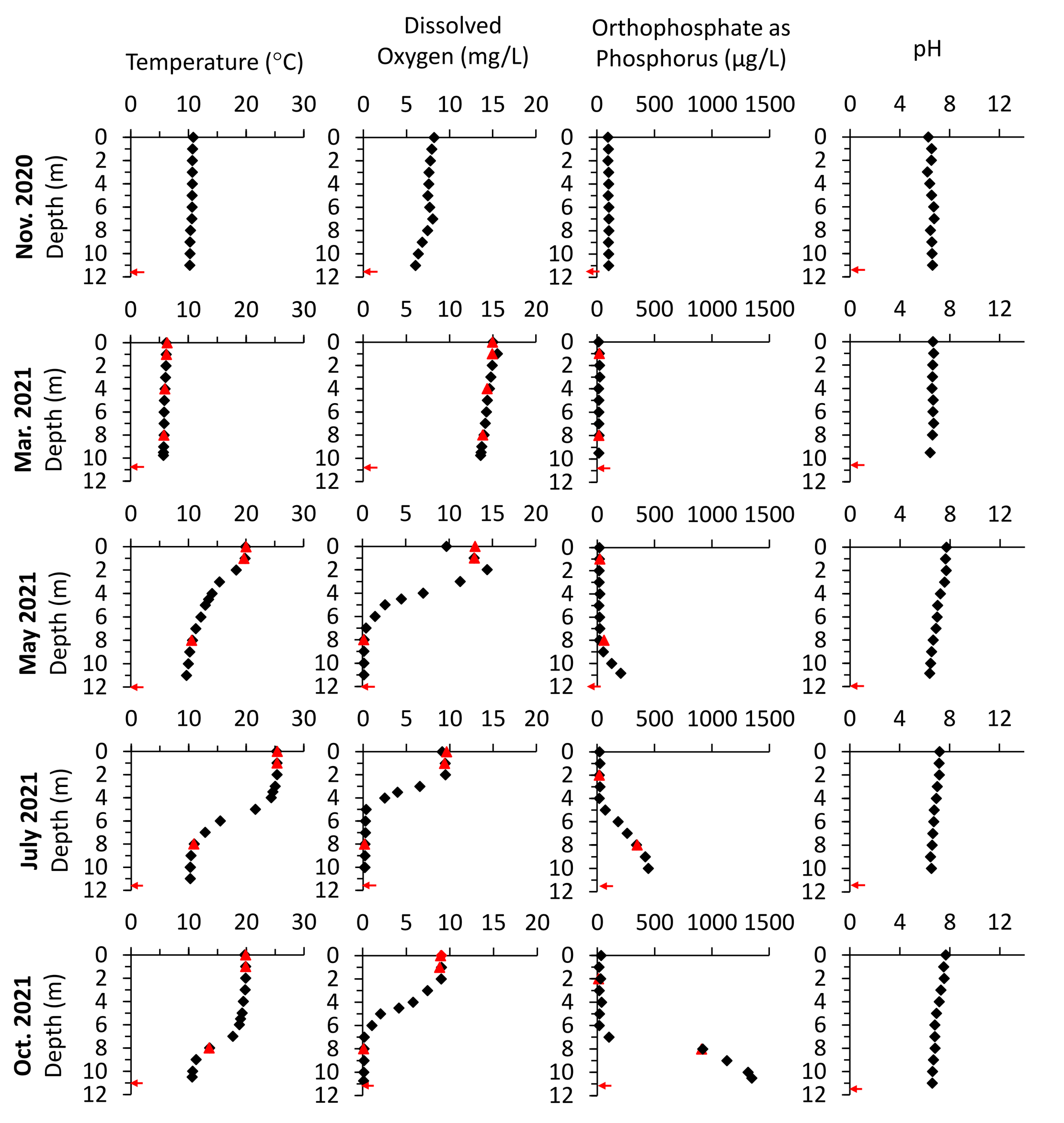
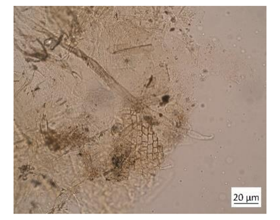


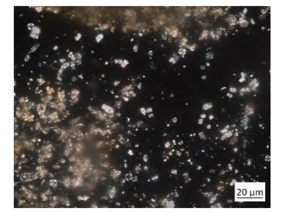
Figure 2. The lake is thermal stratified from May to October. From May to July, warmer temperatures and algal productivity draw down CO_2 in the epilimnion resulting in a more alkaline pH and calcite precipitation. At the same time, microbial respiration in the isolated hypolimnion produces anoxic conditions resulting in the release of P and Fe^{2+} from the sediments.

Suspended Sediment in November



Organic Matter

Suspended Sediment in May



Calcite Grains

Pore Water

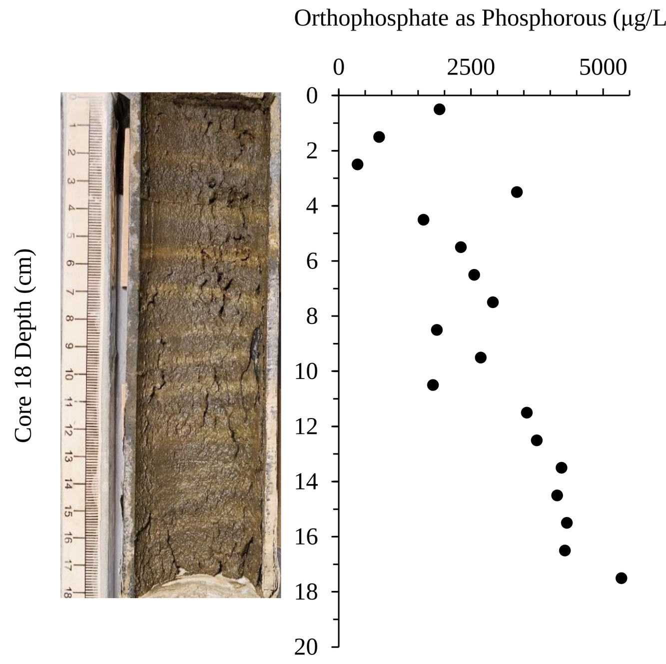


Figure 3. Sediment pore water concentration of orthophosphate-P is similar to and greater than the October hypolimnion concentrations. These data illustrate the important role lake water chemistry (anoxia) has on releasing nutrients (P) from the sediment into the overlying anoxic water. The city of Akron is investing considerable resources to reduce the number of CSOs in order to limit external loading of nutrients into waterways. However, this study shows water-sediment interactions can internally load legacy P into Summit Lake and potentially impact water quality.

Layer Composition

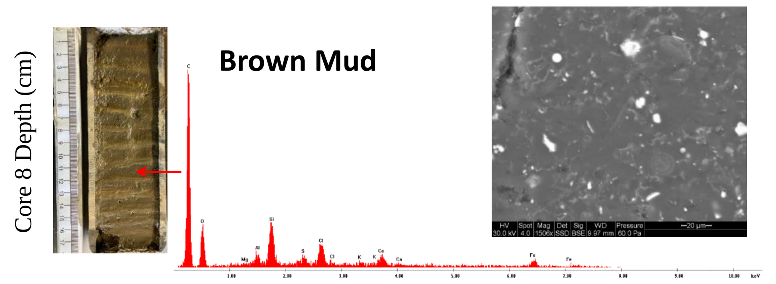


Figure 4. November and March plankton tows contain abundant organic matter as suspended sediment (left). Organic rich brown mud (above) contains abundant C, O, Si, and Fe, SEM-EDAX (above).

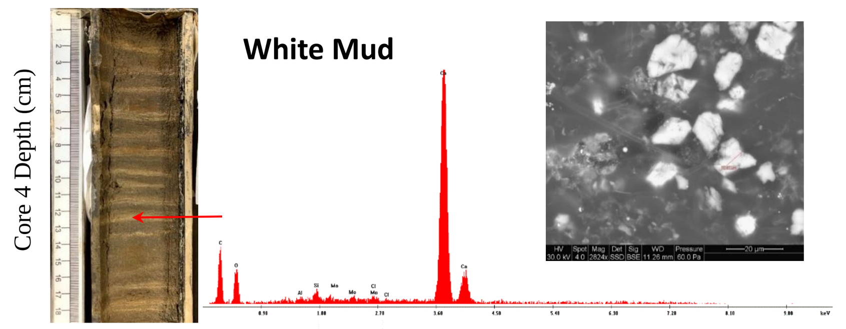
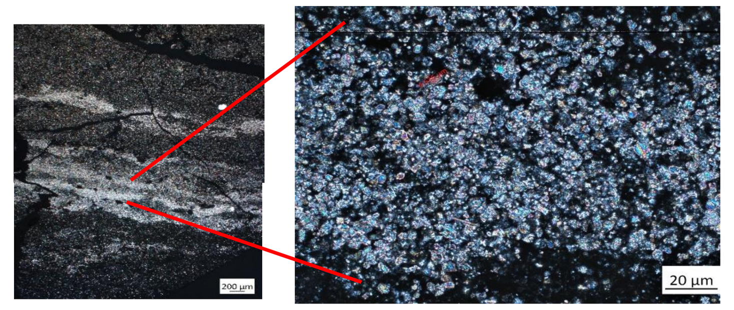


Figure 5. May plankton tows contain abundant calcite grains as suspended sediment (left). Calcite rich mud (above) contain abundant Ca, C, and O SEM-EDAX (above). Thin sections of white mud reveal abundant calcite grains (below).



Varve Mechanism

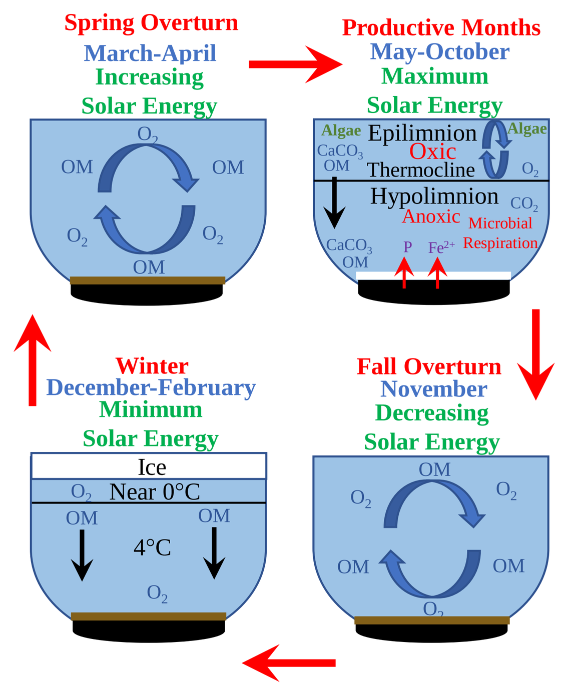


Figure 6. Conceptual model relating lake water physical, chemical, and biological processes to seasonal sedimentation in dimitic Summit Lake, OH. From May to October the warm epilimnion with algal productivity lowers the CO_2 and results in calcite precipitation and deposition of the white mud layer. During the rest of the year the lake is mixed and organic matter settles resulting in the deposition of the brown mud layer.

Long Core Profile

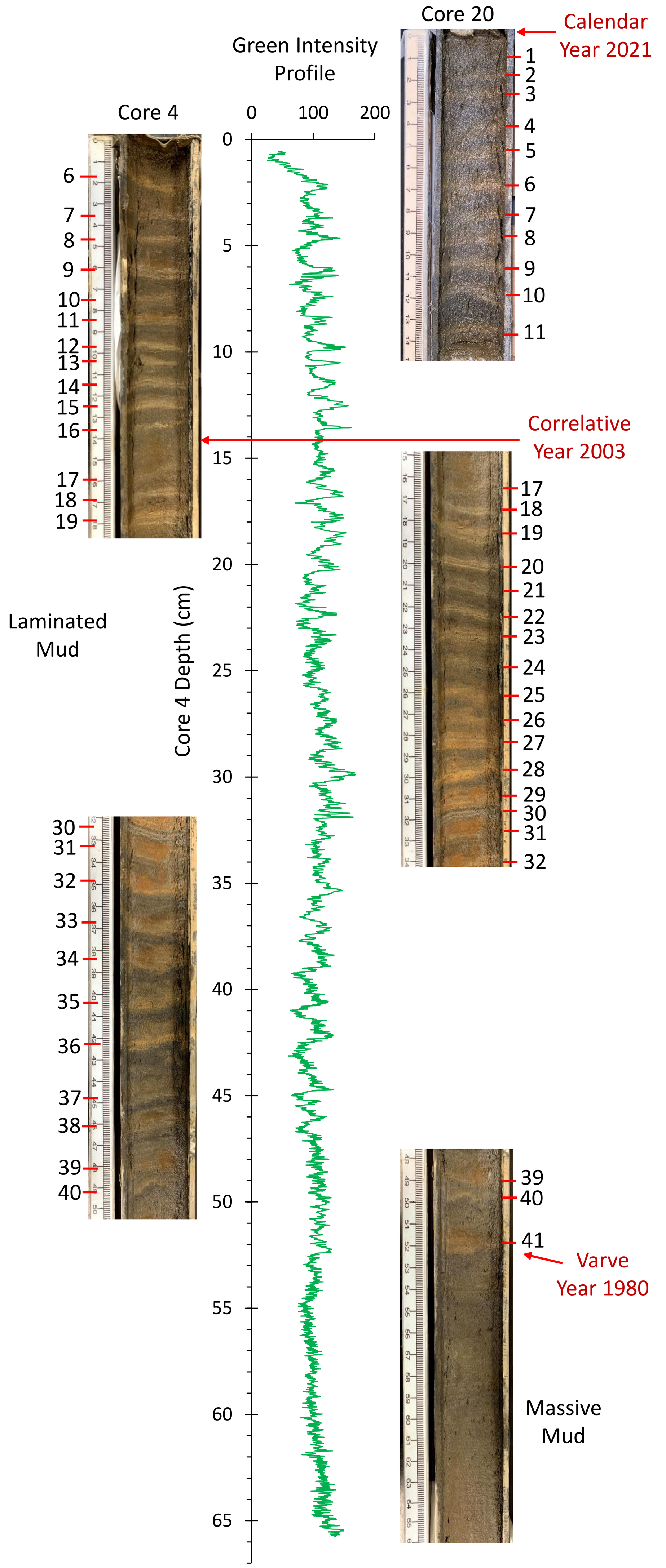


Figure 7. Green color intensity profile for core 4 (collected in Nov. 2019) and photographs of core 4 and core 20 (Oct. 2021). Higher green intensity corresponds to the white calcite layers interpreted as warm month sedimentation; thus, each white layer represents one year. Counting the white layers indicates the year 1980 may lie 52 cm deep in core 4. Prior to the year 1988, B. F. Goodrich (a tire company) had a water intake located in the north basin of Summit Lake. The withdrawal of water may have fundamentally changed the lake hydrology and prevented the precipitation of calcite thus explaining the lack of white calcite layers below 52 cm deep.

Correlation and Varve Age Model

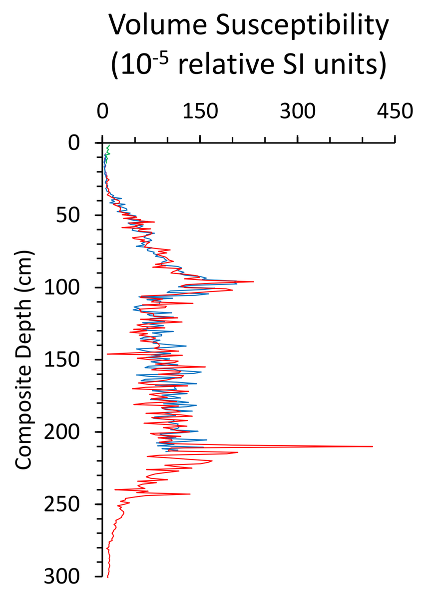


Figure 8. The magnetic susceptibility profiles for year 2021 cores (green, blue, and purple lines) are highly correlated to the year 2003 core from Haney (2004) (red line). This correlation shows that in the 18 years since 2003, 16 white layers were deposited and supports the varve interpretation of the calcite layers.

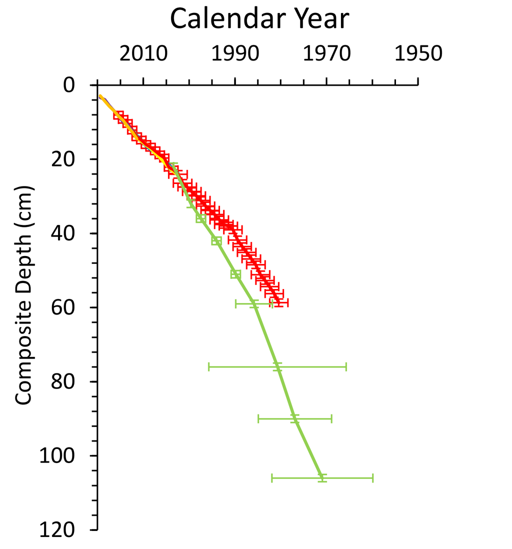


Figure 9. The varve age model for year 2021 cores (blue, yellow, red, and orange) and the ^{210}Pb age model (green) from Haney (2004). Within the error, these two different dating methods are similar further supporting the interpretation that the calcite layers are varves.

Past and Present Heavy Metal Concentrations

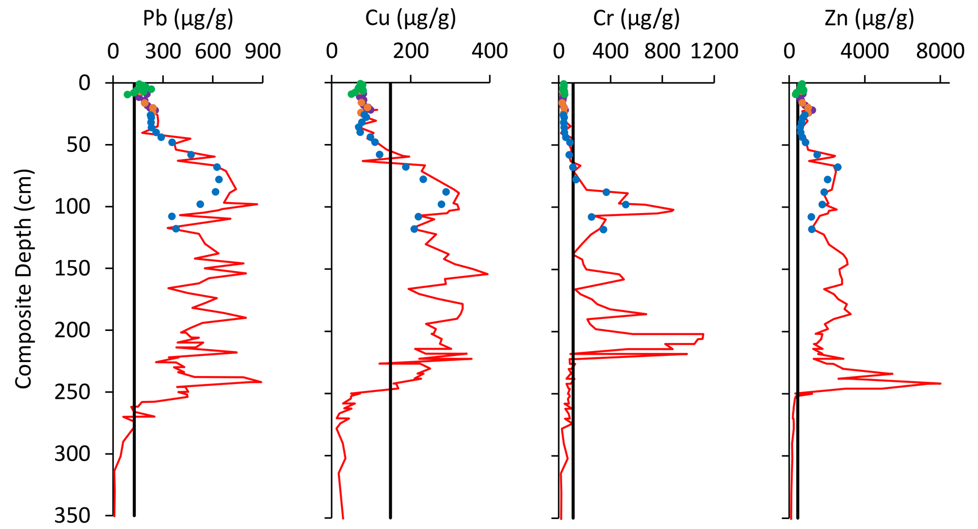


Figure 10. Correlated heavy metal profiles for year 2021 cores (green, purple, and blue) and year 2003 core from Haney (2004) (red line). Values above the probable effects concentration (PEC) (black line) indicate when adverse biological effects are likely to occur (MacDonald et al., 2000).

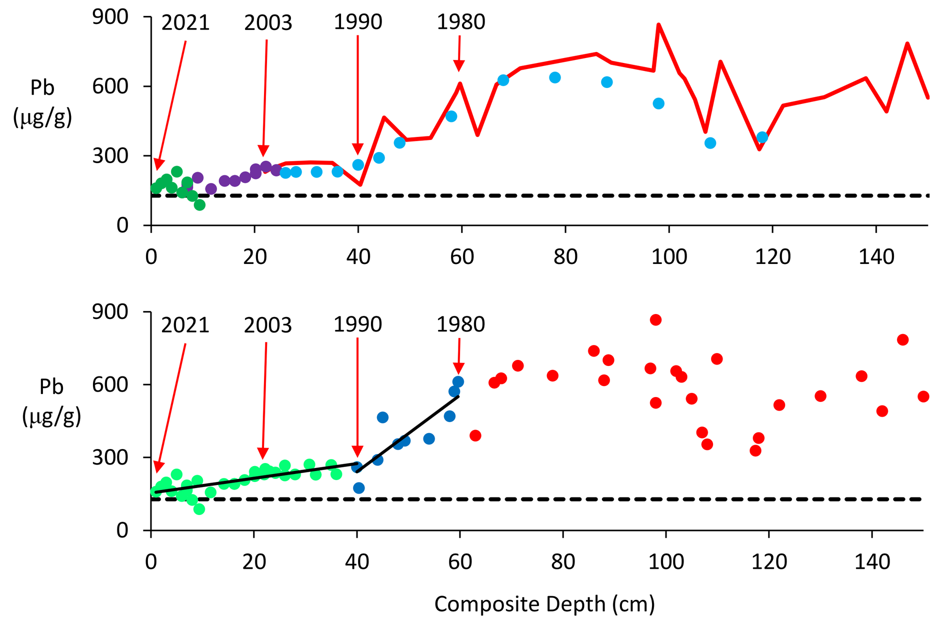


Figure 11. Correlated heavy metal profiles (top figure) dated using the varve age model, provide a time series of variations in heavy metal pollution (bottom figure). Before 1980, Pb concentrations are high (red dots). From 1980 to 1990, Pb concentrations decrease dramatically (blue dots) as a result of a sharp decline in industrial activity and the effectiveness of the Clean Air and Water Act. Since 1990, the rate of declining Pb values is greatly reduced (green dots) possibly reflecting urban watershed background heavy metal influx.

CONCLUSIONS

1. Seasonal changes in the lake water result in seasonal differences in sedimentation.
2. From May to October warm temperatures and algal drawdown of CO_2 result in calcite precipitation and deposition of white sediment layers.
3. For the remainder of the year the water column is mixed and organic matter settles depositing the brown sediment layers.
4. Correlation to a 2003 core and to ^{210}Pb ages supports the interpretation that the white/brown rhythmites are varves.
5. From 1980 to 1990, as industry shut down and environmental regulations went into affect there was a sharp decline in heavy metal concentrations. Since 1990 the decline in heavy metals is less pronounced, possibly reflecting urban watershed background influx.

IMPLICATIONS

The city of Akron is redeveloping Summit Lake for greater recreational opportunities. This study indicates:

- Given recent declining Pb concentrations, it is projected that Pb will attain the PEC in 2028.
- When the hypolimnion goes anoxic in the warm months phosphorus is internally loaded from the sediments into the water column, and potentially could lead to poor water quality and potentially HABs.

ACKNOWLEDGEMENTS

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REFERENCES

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MacDonald, D. D., Ingersoll, C. G., and Berger. T. A., 2000. *Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems.* Archives of Environmental Contamination and Toxicology. 39, 20-31.
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