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MAGNETIC SUSCEPTIBILITY AS AN INDICATOR OF ANTHROPOGENIC ALTERATION TO THREE WISCONSIN LAKES

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ABSTRACT

In the middle of the 19th century, European settlers began occupying the United States Midwest. These settlers altered the landscapes they inhabited to create roadways and housing settlements. The purpose of this research is to analyze the extent of anthropogenic modification of three Wisconsin lakes. Analysis of the magnetic susceptibility of sediments has been previously used to show human interaction with landscapes in the form of roadside pollution. In this study, analysis of sediment cores taken from these lakes was conducted to correlate magnetic susceptibility peaks with European settlement and modern anthropogenic activity. This data was then compared with historical records to contextualize our findings. Results show that the lakes most heavily associated with human activity since European settlement show significant changes in percent carbonates and inorganic and organic materials, as well as levels of magnetic susceptibility. Sediment influx into the lakes likely corresponds to erosion due to the alteration of land to construct houses and neighborhoods, in addition to the clearing of land for agricultural purposes. Sedimentation rates were determined for each lake, using peaks in magnetic susceptibility as an indicator of European settlement, and then averaging the rate of sedimentation since the peaks occurred. Lake Monona is inferred to have a sedimentation rate of 2mm per year. The Sedimentation rate of Shadow Lake and Sparkling Lake is inferred to be approximately 1mm per year. Future work with Pb-210 dating will confirm our age model and will provide more quantitative data on the history of these three lakes.

INTRODUCTION

Conservation paleobiology is a relatively new scientific discipline that combines historical research with analysis of geologic and biologic processes to understand how ecosystems respond to changes in their environments (Dietl et al., 2015). These changes often have anthropogenic origins, and can be analyzed within a timeframe of the last 150 years. This timeframe corresponds European settlement in Wisconsin, our field area (Bortleson, 1975). Examination of anthropogenic modification to these lakes in the past can be used to discuss how humans are affecting the lakes currently.

Magnetic susceptibility of sediments is an important tool in environmental studies. It is a process used to determine the types of iron-bearing minerals in sediments, as well as the amount of these minerals (Bityukova et al., 1999). Examination of the levels of magnetic susceptibility within the sediment cores is an easy and efficient way to begin analysis of environmental pollution (Bityukova et al., 1999). Bityukova et al. (1999), discussed magnetic susceptibility as an indicator of pollution in lakes in Estonia, given that many anthropogenic materials produced, contain magnetic particles, which are reflected by spikes in the magnetic susceptibility of a sediment core (Bityukova et al., 1999). These spikes are useful as points of interest to be analyzed in greater detail. Sediments can be dated to discuss anthropogenic sources of contamination within a temporal context. For this research, the largest peaks of magnetic susceptibility are presumed to be associated with European Settlement.

A large portion of the history of these lakes, and their surrounding regions, is preserved in literature, documentation, and photography. Through analysis of information provided by various government databases, and literature from the last 150 years, connections can be made with human history and changes in the lakes. Population statistics, urban development creation, and water treatment history are all helpful tools in gathering the necessary information to discuss how anthropogenic changes can alter the lakes and their ecosystems. In addition, aerial photography provides a visual representation of the landscape changes through time and can show the influence of urbanization and industrialization.

METHODS

The lake cores were collected by boating out to the sample locations, based on the bathymetric profile of the lakes. Upon arrival at the desired locations, water depth at each site was measured, as well as the distance from the top of the water to the bottom of the deck. To collect cores from the lakes, a single piston modified Livingstone corer, with drive rods attached at the top, was used to drive the corer into the sediment. Once the corer was driven into the sediment, it was then brought back up onto the pontoon and capped. The cores were split using a surgical saw at the LacCore laboratory in Minnesota. One half of the core was set aside for archival purposes and the other for analysis.

The cores were scanned for magnetic susceptibility and high-resolution color imagery using geotek machinery. Values were recorded at half centimeter intervals and were plotted against the core depths. The high-resolution core surface images were then exported into Psicat and Corelyzer.

RESULTS

Estimated sedimentation rates for each lake were created by associating magnetic susceptibility peaks with the year 1850, and then dividing the amount of sedimentation from the peak to the top of the core. For Lake Monona, the estimated sedimentation rate is approximately 2mm per year. Using the same method for Shadow and Sparkling lakes, estimated sedimentation rates appear to be approximately 1mm per year. These findings appear to confirm original hypotheses of sedimentation rates of the sites.

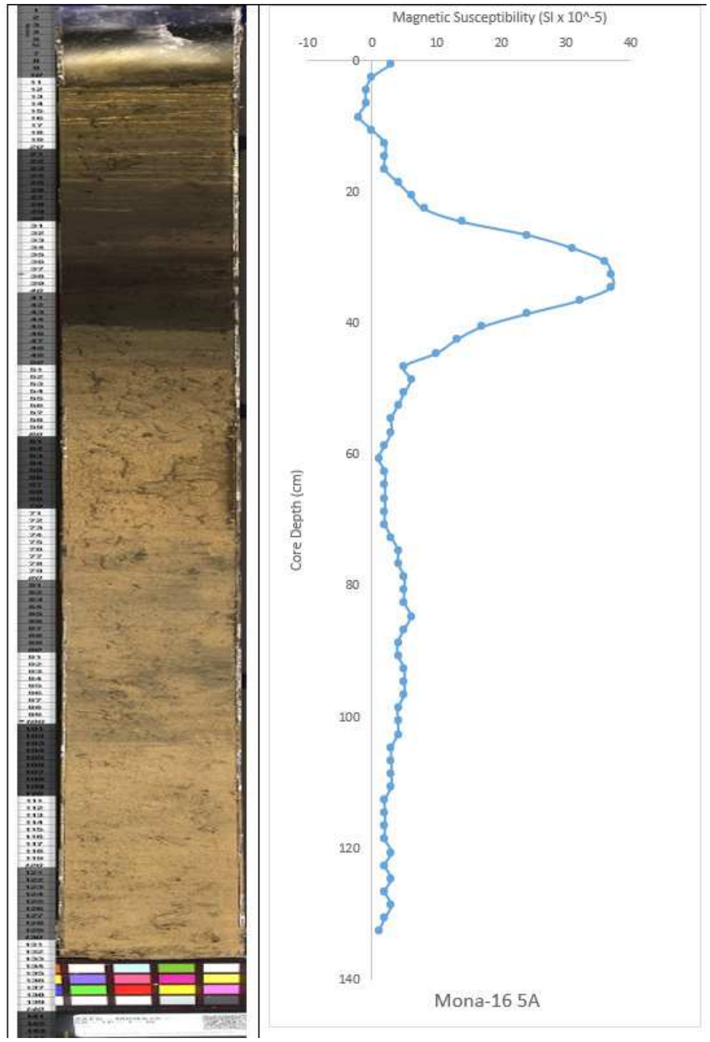

Figure 1.

The estimated sedimentation rates put the time of European Settlement at a depth of ~36cm in the Lake Monona core, which aligns with the interval of peak magnetic susceptibility (Figure 1). The Shadow Lake (Figure 2) and Sparkling Lake (Figure 3) cores peak in magnetic susceptibility at ~20cm. If the magnetic susceptibility peaks of the other cores also indicate European settlement, then the sedimentation rates of Shadow Lake and Sparkling Lake are lower than that of Lake Monona.

DISCUSSION

The core extracted from Lake Monona has a peak in magnetic susceptibility that is likely evidence

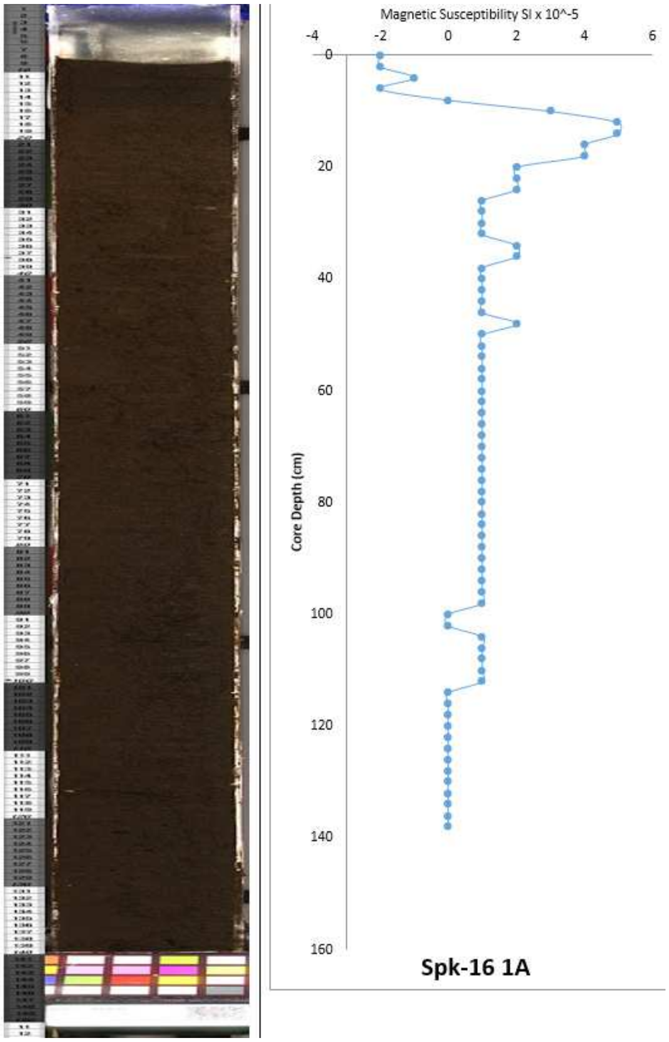

Figure 2.

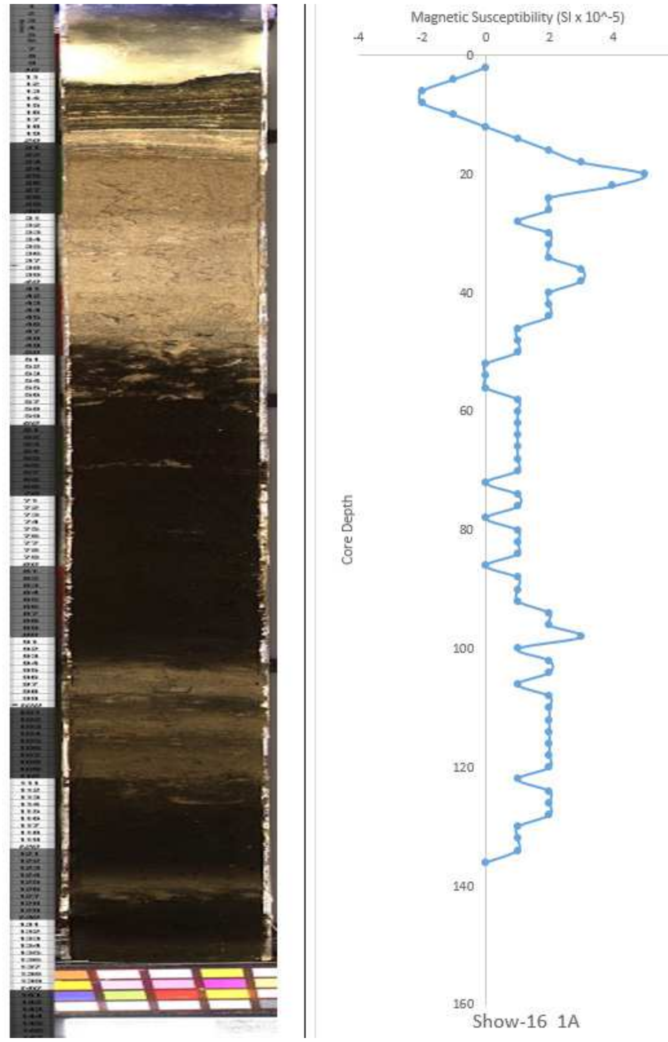

Figure 3.

of anthropogenic effects that are associated with European Settlement. The peak occurs over the interval ~20-40cm. This interval is believed to encompass the effects of the early settlement of Dane County, as well as the construction of major roadways that surround Lake Monona. The timeframe of this interval is believed to be ~1850CE to ~1940CE.

Initial settlement of Dane County began as early as 1850 by the French (Hawley, 2010). These small settlements and their populations began to grow around 1890. This sharp increase is associated with domestic drainage from both rural and urban areas (Bortleson and Lee, 1975). Raw sewage was dumped into Monona Lake during the end of the 19th century (Bortleson and Lee, 1975). Even into the 1930's, treated sewage was dumped into the lake. This process drastically increased algal levels in the lake for decades to follow and corresponds to high levels of phosphorus caused by the introduction of poorly treated sewage into the lake (Bortleson and Lee, 1975).

Lake Monona is surrounded by heavily trafficked roads, and Shadow lake is close to roads on nearly half of its banks. Increased levels of magnetism within the soils can be attributed to two anthropogenic sources: emissions from vehicles and from materials used to construct roads, such as asphalt and bitumen (Hoffman et al., 1999).

Construction of roadways, and the creation of largescale highways increased dramatically from 1900 to the 1930's (Wisconsin Department of Transportation, 2016). The beginning of the magnetic susceptibility peak, near the 36cm interval of the Lake Monona core (Figure 1), is hypothesized to be associated with the beginning of European settlement. The latter end of the magnetic susceptibility peak likely coincides with roadway construction within Dane County. The construction of major roadways occurred approximately 80-100 years after the arrival of European settlers, so the magnetic susceptibility shift from 20-40cm could encompass both events, and correlates with the estimated sedimentation rates of ~2mm per year.

Shadow Lake has been impacted by land alteration, but on a much smaller scale. This small peak in magnetic susceptibility occurs at the 10cm interval of the sediment core which implies a lower rate of sedimentation than that of Lake Monona. This is consistent, given that Lake Monona has experienced anthropogenic changes at a larger scale than Shadow Lake and less erosion is presumed to take place. Dumping of Aluminum Sulfate into the lake took place in the 1970's and is exhibited in the core at the ~5cm interval. This finding also implies that sedimentation rates at Shadow Lake are lower than that of Lake Monona. The magnetic susceptibility peak is of a smaller magnitude than the Lake Monona peak which also corresponds with the occurrence anthropogenic effects, but at a smaller scale. The peak could be associated with the construction of the small neighborhood, extending on numerous banks of the lake.

Sudden and distinct changes in levels of magnetic susceptibility are indicative of anthropogenic alteration. In the cores where less anthropogenic pollution is present, the magnetic susceptibility levels are stable. The cores with high levels of anthropogenic pollution are the lakes heavily affected by humans and have distinct peaks. The singular shift in magnetic susceptibility found in the 5a core from Lake Monona is hypothesized to indicate settlement from European settlers in the late 19th century.

Sparkling Lake had a small peak in magnetic susceptibility, but there are no significant shifts in sediment composition. Organic-rich material is present throughout the entire core. This confirms the hypothesis that Sparkling Lake is the lake closest to pristine, reflecting conditions before the time of human impact. The small magnetic susceptibility peak could be correlated to a small road that is relatively close to the boating dock of Sparkling Lake. There is one data point that shows a dramatic shift in composition, but is believed to be an outlier associated with a sample processing error. Sparking Lake is isolated from human impact, evidenced by the uniform composition and sedimentation and observed in the core. No major anthropogenic alterations occurred within Sparkling Lake.

CONCLUSIONS

In conclusion, the information gathered from this research project implies that human interaction with surrounding landscapes can be observed within sediment cores. The information from these cores can then be used to show the physical impact of anthropogenic activity. This information can show potential timeframes in which these changes occurred. Several specific conclusions can be drawn from this project:

1. Magnetic susceptibility peaks correlate to times of large scale anthropogenic activity, such as European settlement that correspond with changes in sediment color and composition.

2. Anthropogenic alteration to Lake Monona was the most substantial of our 3 field sites.

3. Shadow Lake was moderately affected by European Settlement in comparison to Lake Monona, and has been continually affected by humans, but to a lesser degree.

4. Sparkling Lake was not significantly affected by European settlement and appears to be relatively pristine.

5. The sedimentation rate for Lake Monona appears to be approximately 2mm per year. For Sparkling Lake and Shadow Lake, it appears to be 1mm per year. This correlates to the original estimated rates of sedimentation.

These sedimentation rates allow for the discussion of biological changes within a temporal context. Establishing a geochronology using historical analysis and magnetic susceptibility allows for a more holistic discussion of the extent of anthropogenic alteration, as it associates sediment intervals with specific timeframes.

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