

Railroad Fly Ash as A Relative Dating Tool in Lake Sediments

Marathon and Waushara Counties, Wisconsin, USA



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Introduction

The purpose of our research project is to determine whether fly ash from fossil fuel combustion is a viable relative dating tool for sediment cores. Railroad fly ash is the byproduct of high temperature combustion resulting from coal-fired train engines, it is released into the atmosphere and then settles and accumulates. The study includes lake core sediment samples from lakes in Marathon and Waushara counties, Wisconsin. Our original intentions involved using multiple methods to identify the presence or lack of fly ash in the layers of lake sediment who coincide with presence of ragweed pollen detected in the samples.

Land clearing for agriculture results in an increase of ragweed pollen and can be used as a temporal marker in sediment cores if the settlement date in an area is known. Due to unforeseen circumstances, we were limited to focusing on the magnetic susceptibility method of testing. We used previously existing ragweed pollen data and lake proximity historical railroad lines to determine which lakes to use for our testing. Given the absence of extenuating environmental conditions, a spike in fly ash at a certain layer depth should parallel the establishment date of nearby railways since at that time there were no other nearby uses of coal.

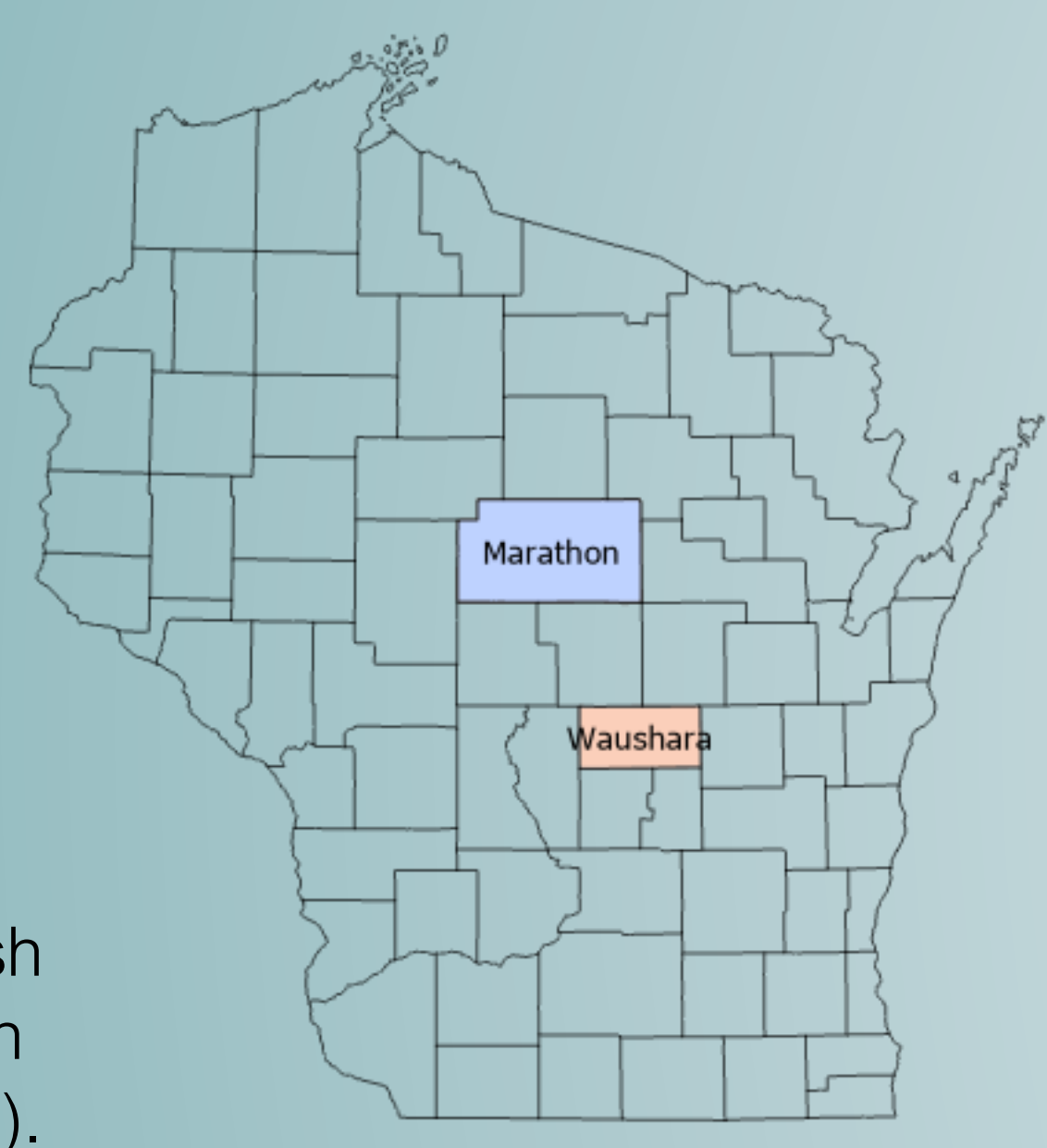
Study Site

Marathon Lakes:

- Big Bass (44.72350, 89.43348)
- Mayflower (44.91021, 89.43348)
- Mission (44.77910, 89.35352)

Waushara Lakes:

- Pleasant (43.98479, 89.55374)
- Wilson (44.17465, 89.17552)
- Long (44.21535, 89.12636)



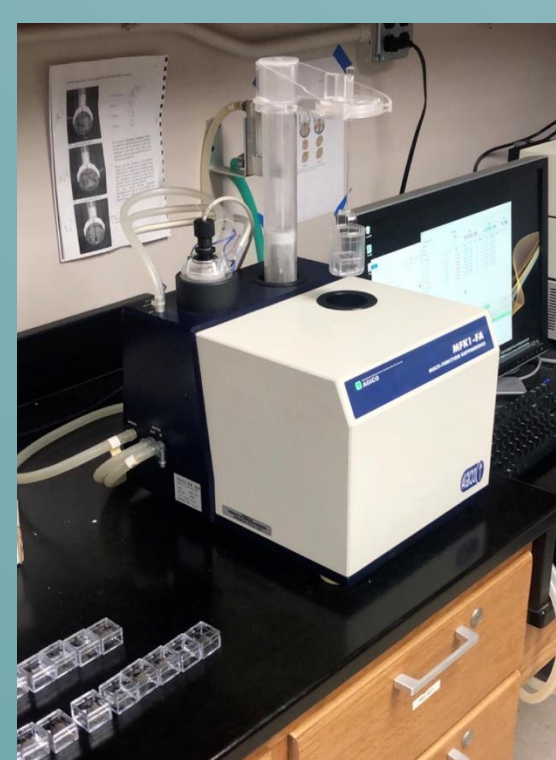
Central Wisconsin, fondly known as the "Central Sands", is a flat and sandy outwash plain from the Laurentide ice-sheet (Green Bay Lobe is most important for these lakes).

Methodology

For this project we began by examining previously analyzed pollen data (Bruening, 2015) from the lakes. In the original studies the researchers were examining the presence of ragweed pollen to use as a possible indicator of the initial appearance of modern agriculture and industry on the landscape of central Wisconsin. From these pollen counts we selected several lakes with robust data for further examination of magnetic susceptibility.

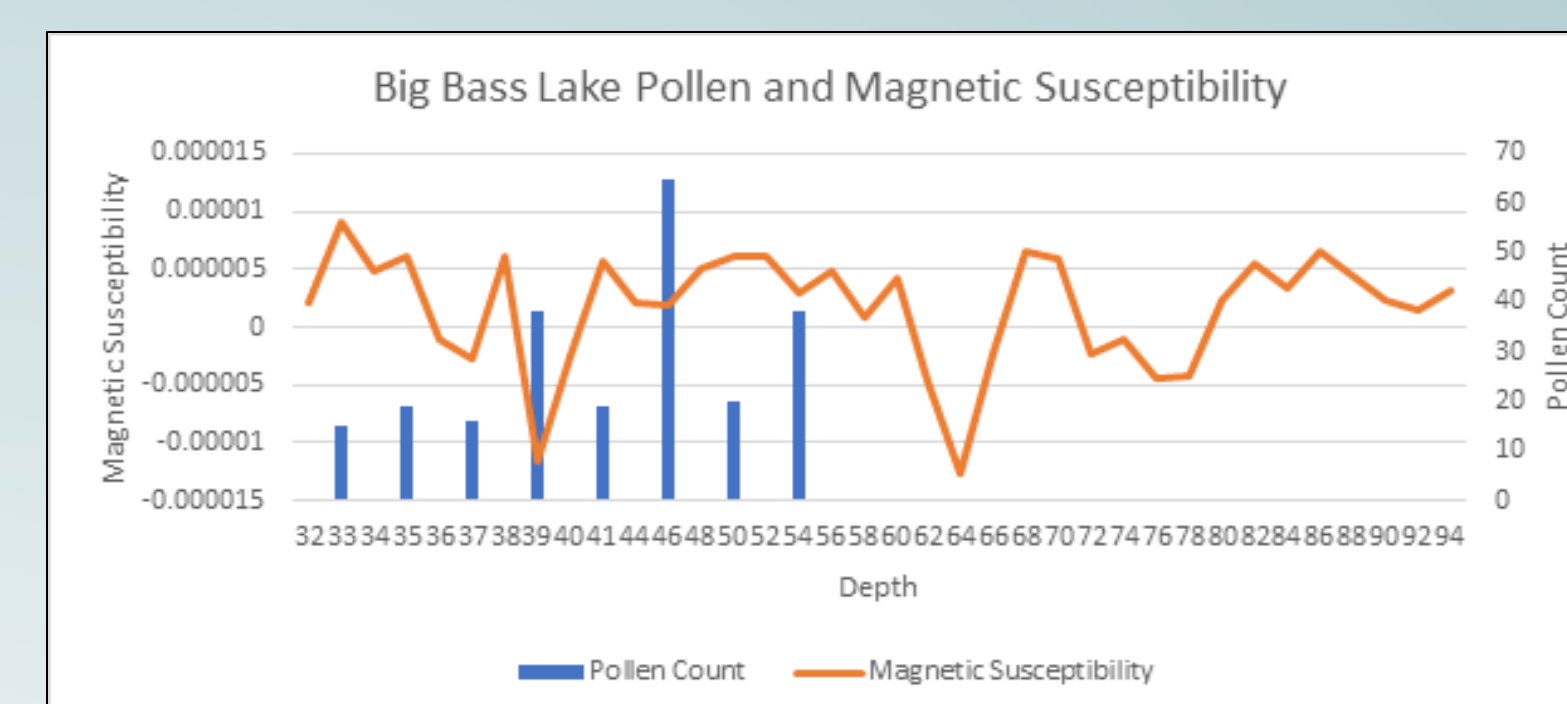
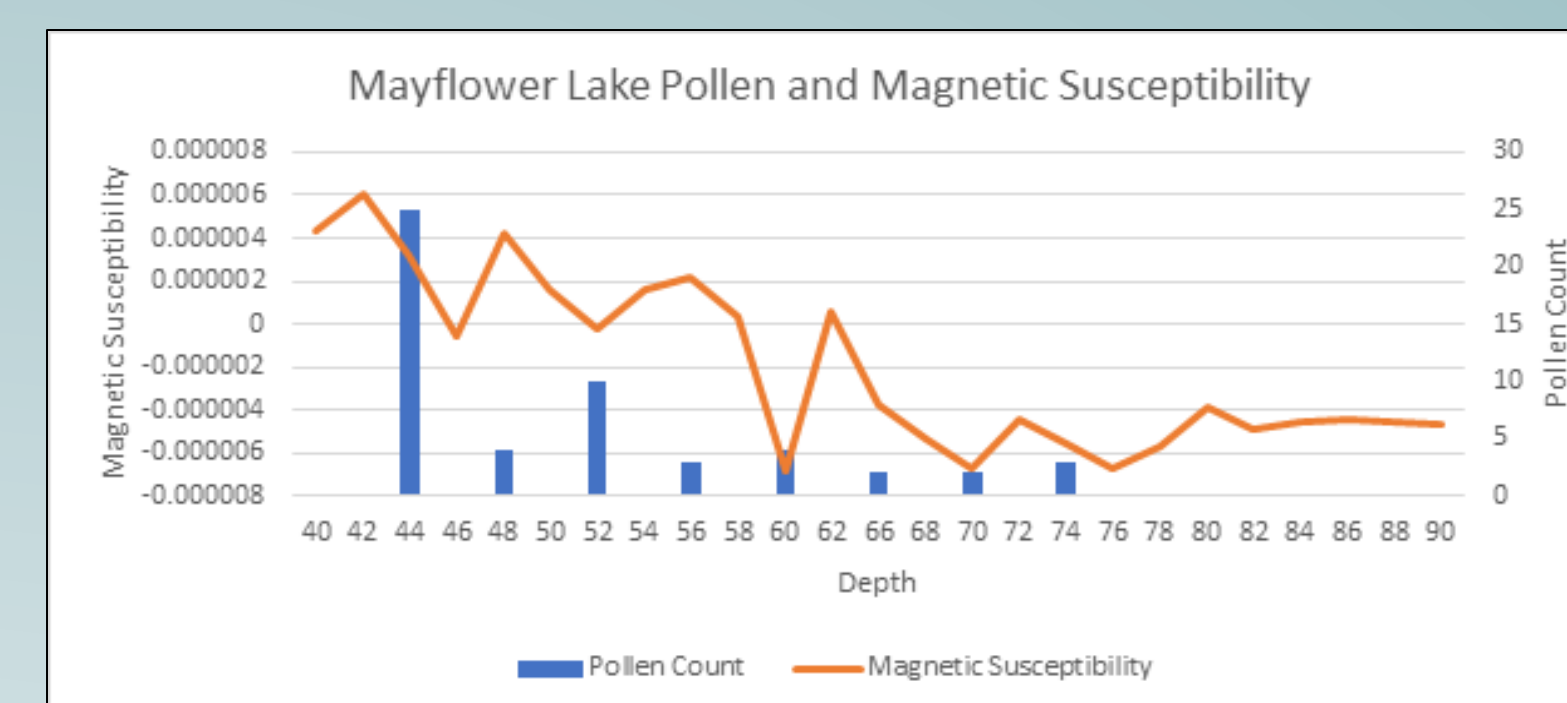
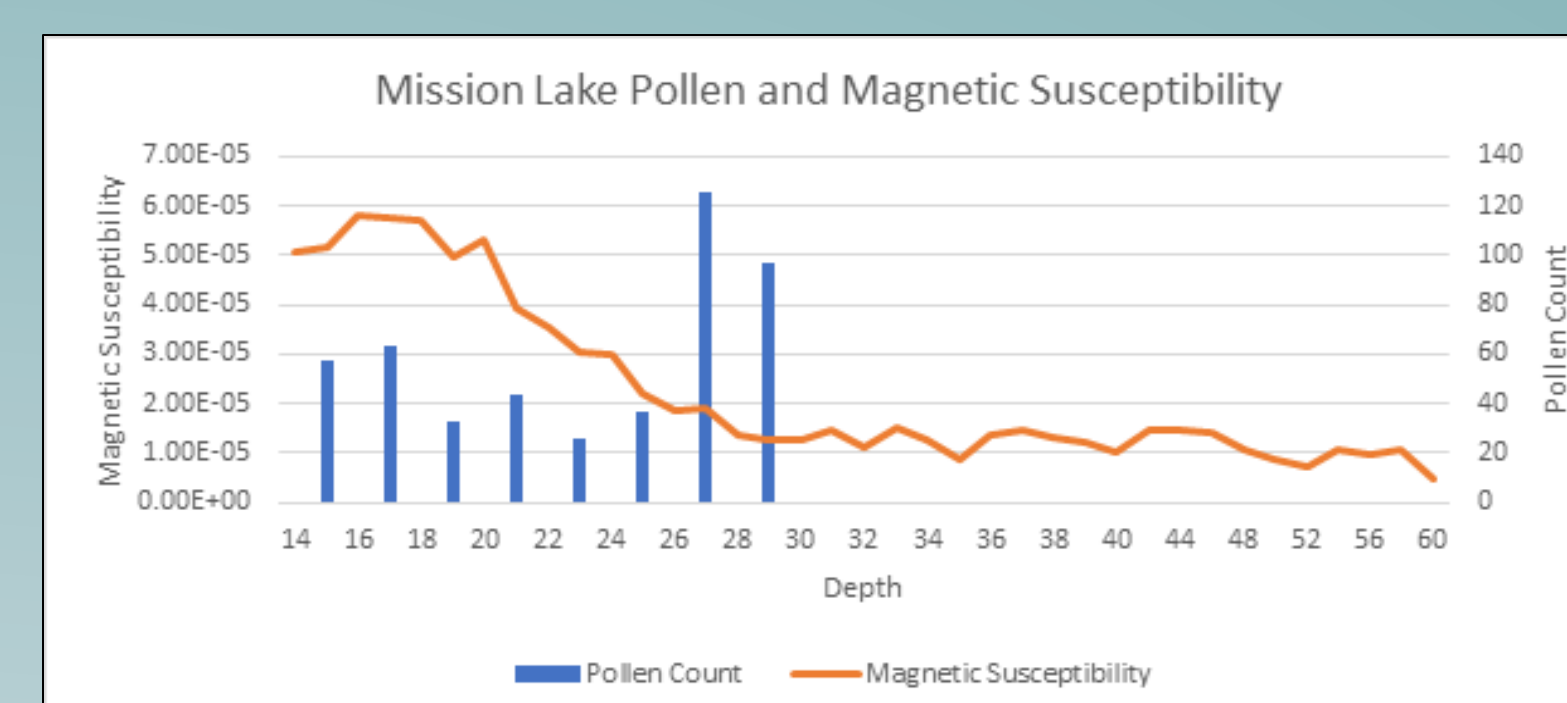
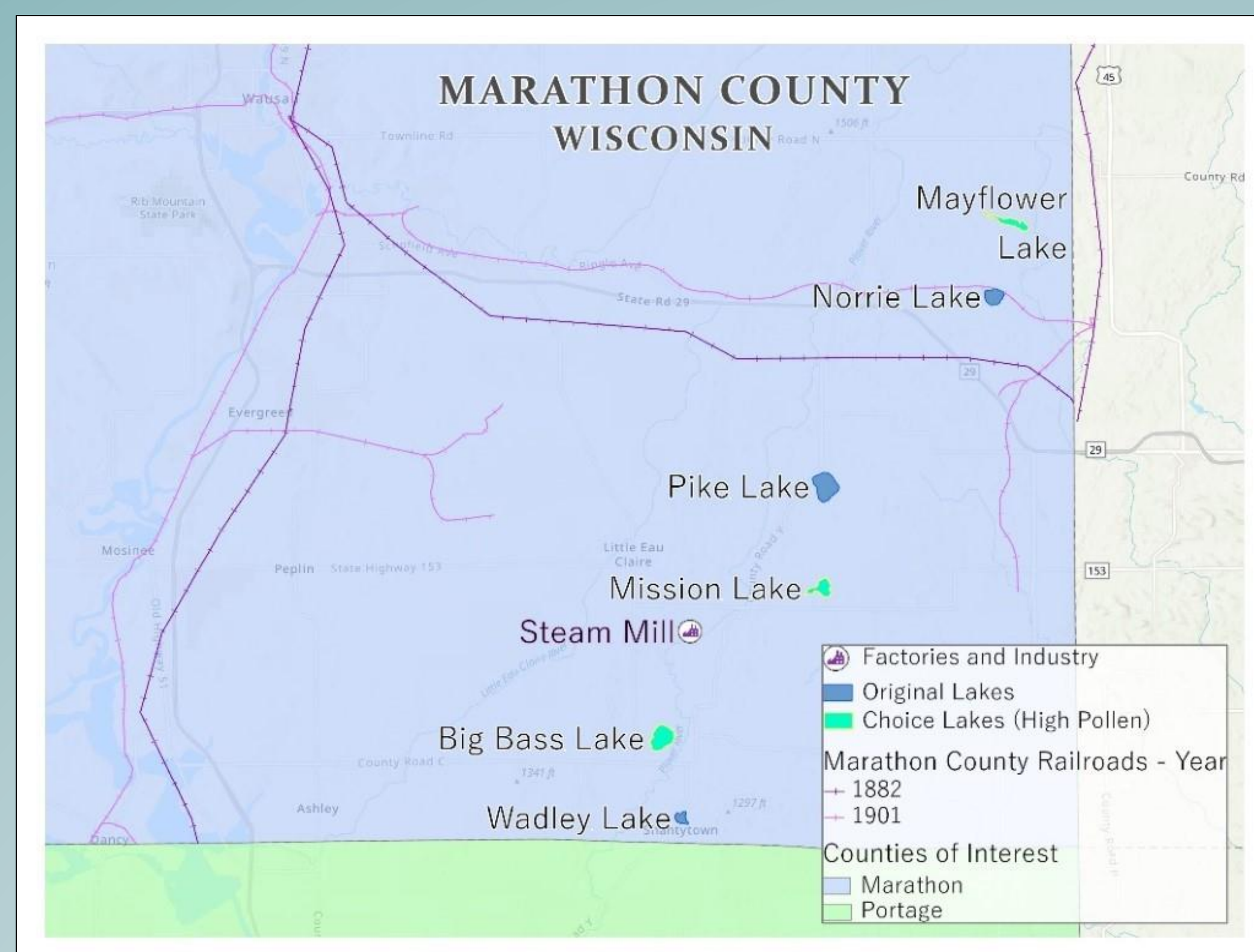
In our research, GIS is used in conjunction with the pollen data as a deciding factor for which lakes to select for further analysis. Lakes that are spatially close to the railroad data locations or industry or presented a large spike in pollen counts in the original study, were selected. Of the original 13 lakes in the study, we chose three from each county for our research. Using ArcGIS Pro (version 2.4.0), existing files were converted from ArcMap feature classes to ArcGIS Pro file feature classes. These classes include a Marathon County Steam Mill, Waushara lake locations, Marathon lake locations, county line boundaries, and previously digitized railroad locations. These items were chosen for GIS analysis because they are sources of coal fly ash within our study sites. After highlighting the selected lakes and adding the railroad layers, we were able to analyze how close in proximity our chosen lakes were to the 1878, 1882, and 1901 railroad positions.

We conducted magnetic susceptibility determinations at the University of Wisconsin-Milwaukee, using their Paleomagnetic Lab. Their lab provided access to a MFK1-FA Kappabridge AMS machine. This allowed us to measure the direct dependency of magnetic susceptibility (or AMS) of our samples, and bulk susceptibility. The Kappabridge machine operates by rotating a sample through three magnetic frequency levels and automatically recording the output via proprietary software. The lake cores were previously sub-sampled and 1 cc aliquots placed into in small acrylic boxes with no magnetic properties. We ran each sample twice and averaged the two resulting values.

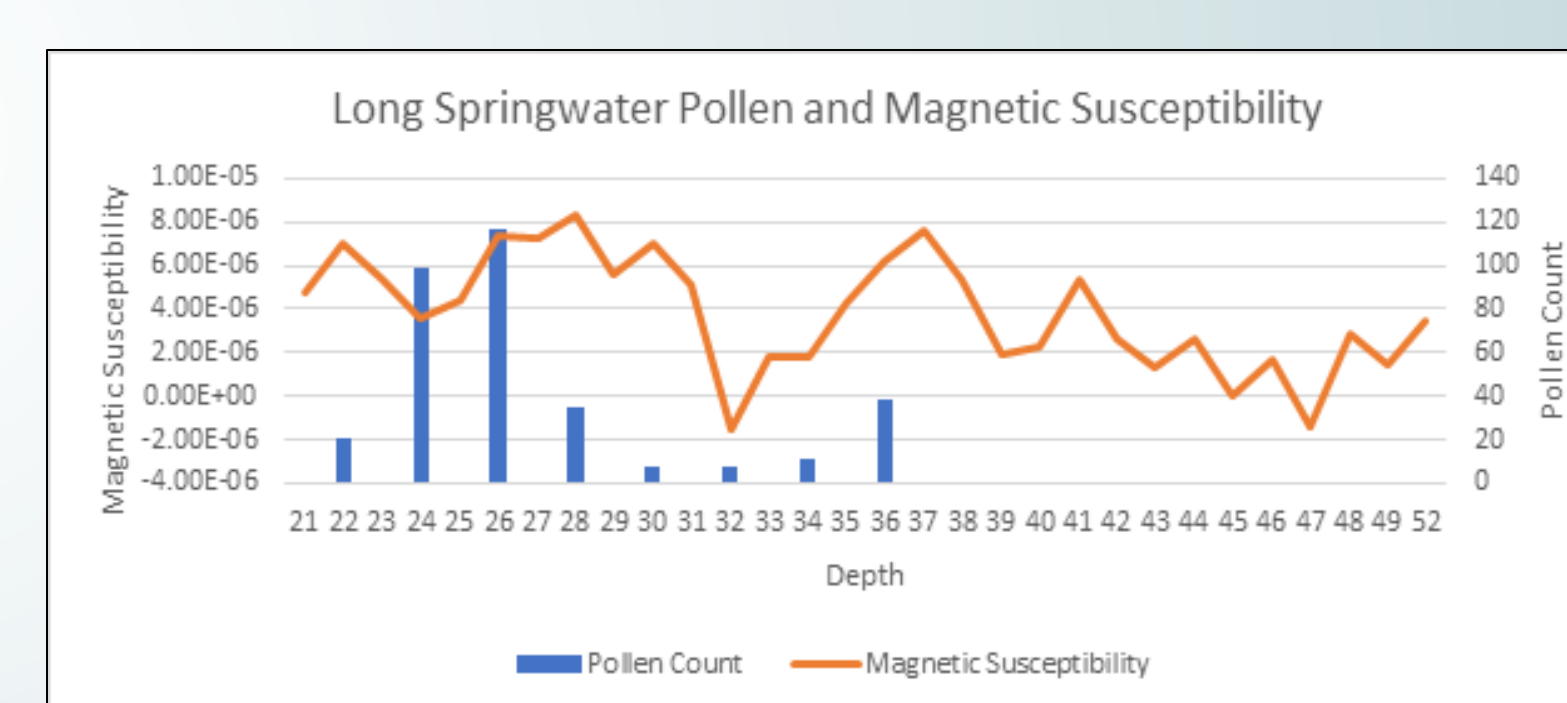
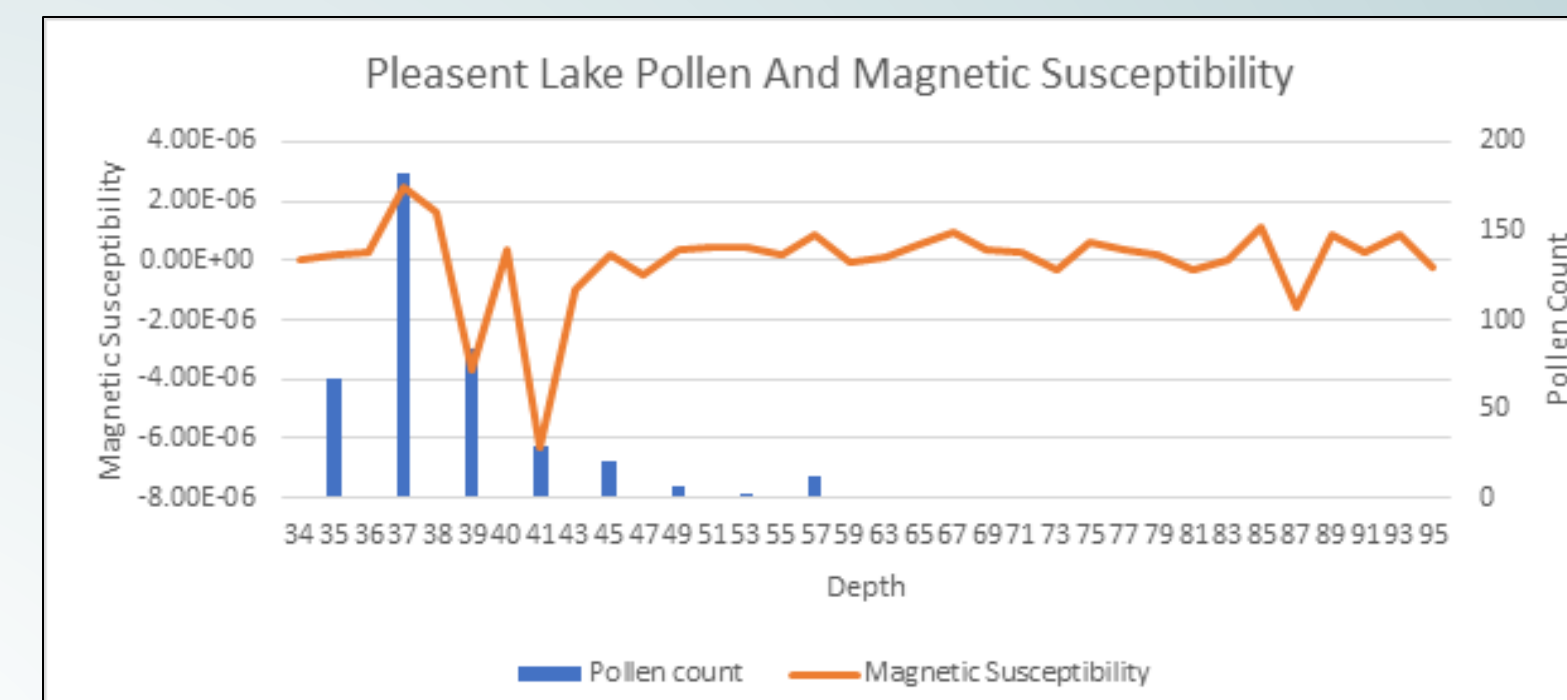


MFK1-FA Kappabridge AMS machine, UWM, 2020

Marathon County



Waushara County

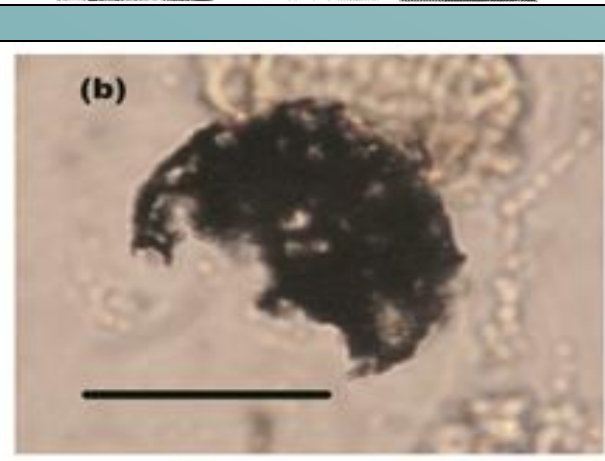
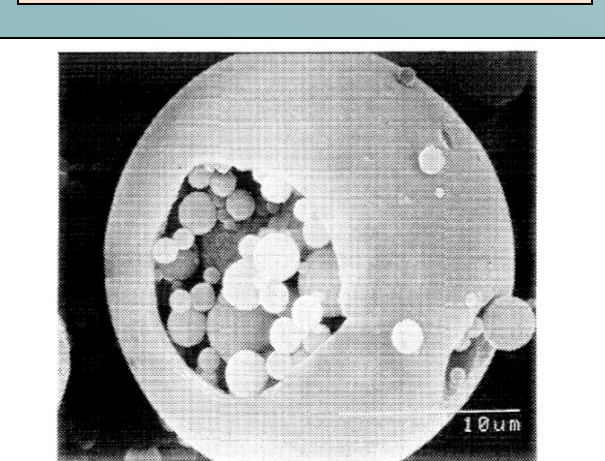


Results

In the lakes evaluated, ragweed pollen increases between depths of 20-50 cm in the core. It is assumed that this depth represents land clearing and European settlement in the late 1800's and first decade of the 1900's.

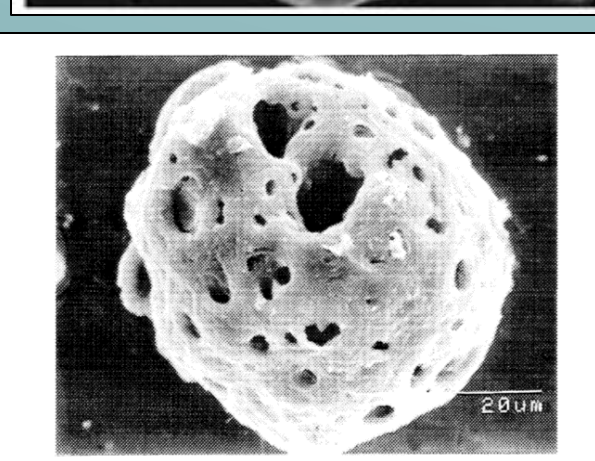
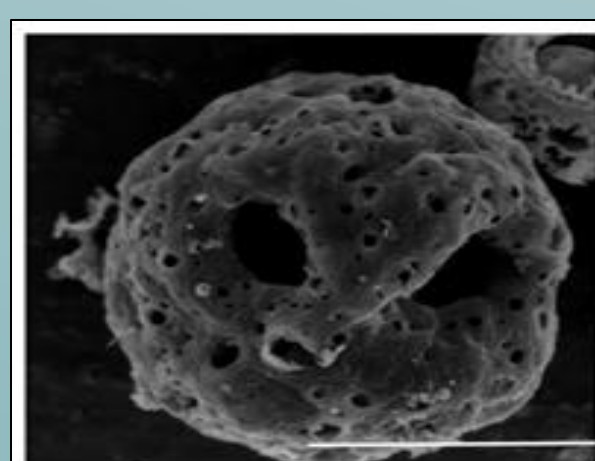
The pollen count and magnetic susceptibility of Mission Lake in Marathon County align closely from 14 to 26 centimeters. Between 27 and 29 centimeters there is a spike in the pollen count that the magnetic susceptibility does not emulate. After 29 centimeters there is no recorded pollen data, and magnetic susceptibility levels out. It's worth noting that all three lakes have an initial higher spike in magnetic susceptibility. Mayflower Lake shows relatively strong correlation throughout the core sample until a spike in magnetic susceptibility around 48 centimeters, where the pollen count remains lower, this occurs again around 56 centimeters. The last lake that shows an alignment between our data is Long Springwater Lake in Waushara County. There's a high spike in pollen count data around 24-26 centimeters, and then it quickly decreases. Mayflower lake has pollen data showing at the greatest depth of all the lakes looked at in this study, with a pollen count recorded at 74 centimeters. Of these three lakes, Mayflower also is located the nearest to established railways. There are two railways nearby, one dating from 1882 and the other from 1901. Mission Lake does not have any railways in proximity; however, the nearest railway is dated from 1901. The nearest railway, although not close, to Long Springwater Lake was established in 1878. The remaining two lakes from this study, Pleasant and Big Bass Lake do not show logical correlations. There are synchronous changes in the MS and pollen, but the magnetic susceptibility for both lakes is abnormal (variable and/or near zero).

Inorganic Ash Spheres (IAS)



Rose, 2008

Spheroidal Carbonaceous Particles (SCP)



Rose, 1994



Example of coal, Wikipedia



Example of 1850's steam locomotives; Wikipedia

Discussion

In Pleasant Lake, the MS becomes more variable at the same depth ragweed pollen increases, so both are likely responding to changes in the lake basin due to land clearing, but it is not clear why the MS is responding the way it is. One idea is that there is more algae blooming or sediment accumulating in response to disturbance in the lake that is diamagnetic, thereby diluting the signal. A consideration is how far IAS and SCP can disperse across the environment for its source. IAS have a diameter of less than 20 µm. Airborne particles, such as fly ash, with a diameter range of 1 – 20 µm have the potential to travel long distances in air streams, due to finite settling velocities, which are considered low with respect to normal wind speeds. Furthermore, as IAS are more numerous and generally smaller than SCP, there is additional potential to travel further in air streams. Another issue with the readings lies in the room that the Kappabridge magnetometer was housed in. The lab was an earth materials lab with a strong ventilation system and a large amount of loose sediments present on the ground, tables, and air. An additional source for error is that the magnetometer itself was on and running for around 7 hours non-stop.

The other primary source of error with the machine itself is that it is an extremely sensitive device that we were told could potentially detect any magnetic objects that we have would have on our persons if we stood too close to the device while it was running. Other sources of error with the magnetic susceptibility include potential differences in the MS of the bug boxes that the samples were stored in, potential contamination of the samples themselves, and the location of the computer next to the magnetometer. With 3 of the 5 lakes that that we were able to test the magnetic susceptibility for, 60 percent of the lake set, resulting in data that can be viewed as a correlation it is a bit difficult to determine if this method could be used for determining whether fly ash could be used as a relative dating tool. It stands to reason that the data is strongly related to the distance from the source of the fly ash with the lakes that are closer to a source, be it the railroads, or in the case of Mission lake, the steam mill in Marathon county. More testing, with lakes both near and far from sources to determine if the correlation is coincidental or if there is truly a relation present in the data. As Rose suggests, despite an increase in applications of IAS and SCP analysis, there is lack of international standardizing, such as standardizing analytical methodology, common nomenclature, reliable reference material, and experiment replication which would allow for beneficial quality control in SCP sediment analysis. Additionally, an international inter-calibration per sample, microscope slide exchange, and identification criteria for light microscopy would allow for a uniform standard internationally (Rose, 2008).

IAS and SCP analysis demonstrates the influence and environmental change that anthropogenic activity brought to the landscape. The establishment of railways, fossil fuel combustion, and intensified need for electricity marks the beginning of a substantial increase in particulate accumulation. This is documented globally.

Conclusion

Though we were unable to complete the liquid separation and magnetic extraction by magnetic stirring and light microscopy, our bulk magnetic susceptibility analysis can be considered an ideal precursor to narrow down sediment samples with promising fly ash concentrations. Our projects desired outcome is to develop a new and less laborious method of relative dating of sediments using the presence of railroad fly ash and ragweed pollen. The appearance of ragweed pollen suggests anthropogenic land clearing and should associate with the establishment of railways and therefor the byproduct fly ash. By detecting magnetic particles in lake sediment and comparing to recorded pollen data, the spikes should correlate. Our study did indicate that there is synchronicity between the data.

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