Reconstructing the Eutrophication of Gass Lake near Manitowoc, WI Since European Settlement Using Lake Sediment Chemistry

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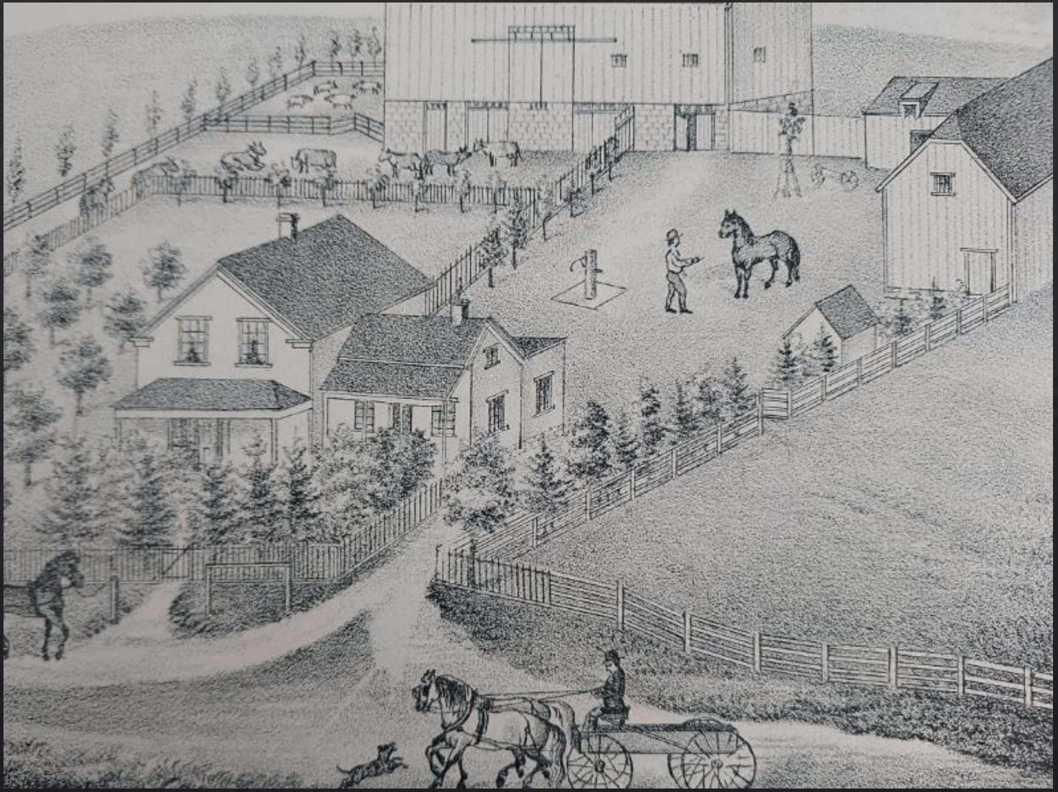
Modern Watershed Assessment and Management

- Today across Wisconsin, many lakes have modern water quality data used to assess productivity in the recent past (Secchi depth, TP) thanks to the DNR and lake management organizations

Photo of Gass Lake in Newton, WI.

What Was Aquatic Productivity Like in the Past?

- Water quality data is not present for the past ~200 years, making it difficult to determine what productivity was like before and during European settlement



Drawing of a residence in Newton, WI 1878 CE.

Past Watershed Assessment: Paleolimnology

- Sediment cores and chemistry can help us understand:

1. How sediment sources change over time alongside human activities in the watershed.

2. What aquatic productivity and organic matter content was like in the past before water quality measurements became common.

3. What “natural” levels of productivity and organic matter are like for a site before European settlement and industrialization.

Lake Sediment Chronology

- By establishing the age of the sediments with depth, we can begin to reconstruct the timing of human impacts on lakes in the past

10 years ago? 100 years ago? 1,000 years ago?

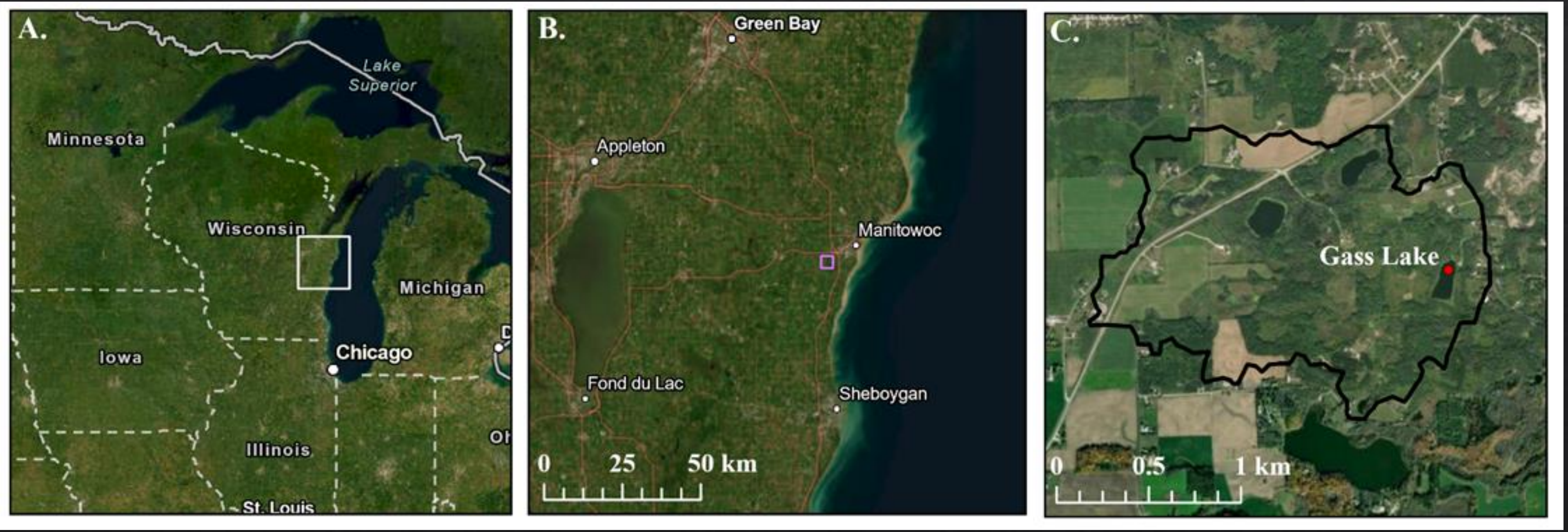
Study Goals

1. Identify the sources of sediments entering Gass Lake in Newton, WI and how they relate to European settlement.

2. Determine how and why the aquatic productivity of Gass Lake changed over the past ~200 years.

Gass Lake: Location

- Newton, WI
- Water Depth: Max = ~7 m, Avg = 3.7 m



Why Gass Lake? Past Research and History of European Settlement

- Gass Lake has previously been cored to develop a pollen record and showed a rise in regional ragweed pollen associated with European settlement around 1835 CE (Webb 1987)

- Historical records show that the Manitowoc County area was settled and began to be cleared by Europeans between 1840-1850 CE, with logging being more common than agriculture until ~1865 CE (Rappel et al. 1948)

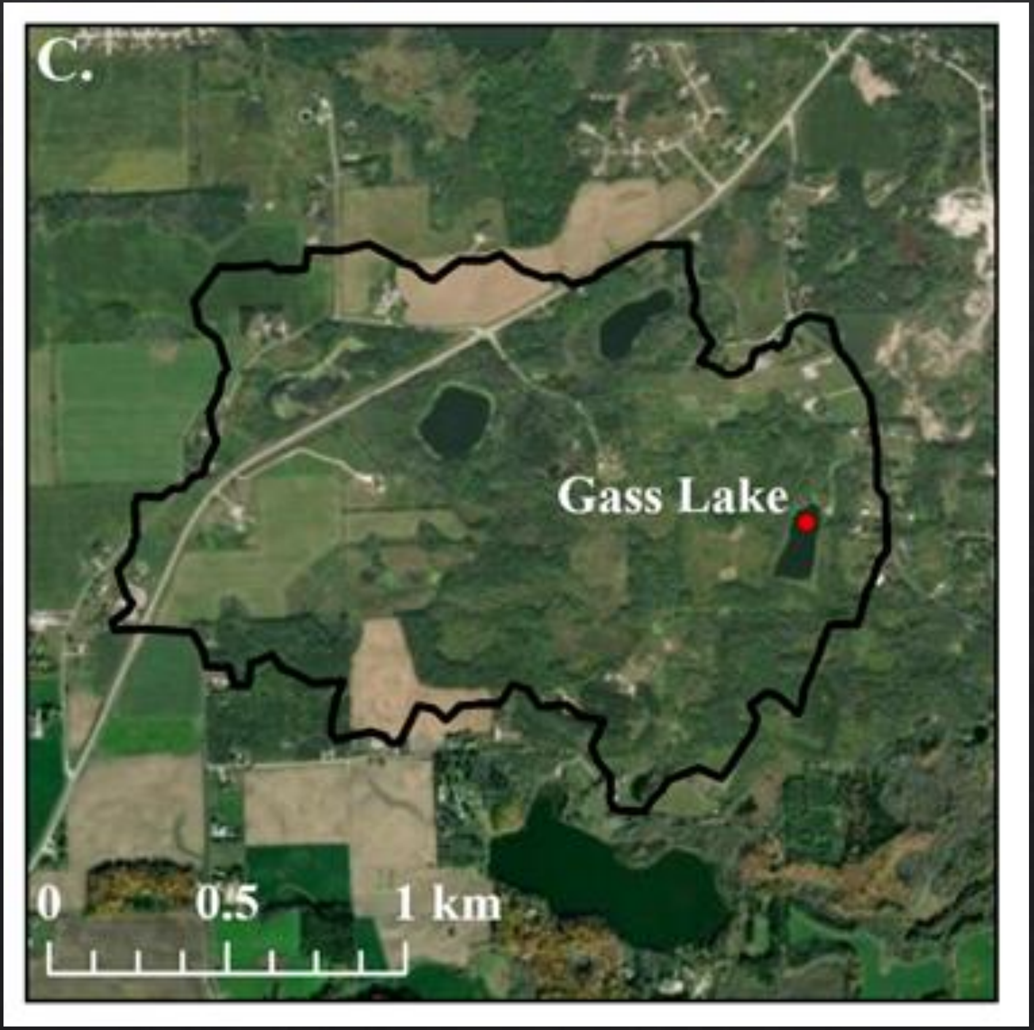
Why Gass Lake? Eutrophic

Date	TSI (TP)
02/11/1976	58
04/17/1985	57
09/15/2012	57
04/26/2013	57
06/28/2014	64
07/15/2017	68
04/25/2018	67
04/14/2019	65
06/21/2020	65
03/30/2021	69
07/29/2022	61
03/31/2025	64

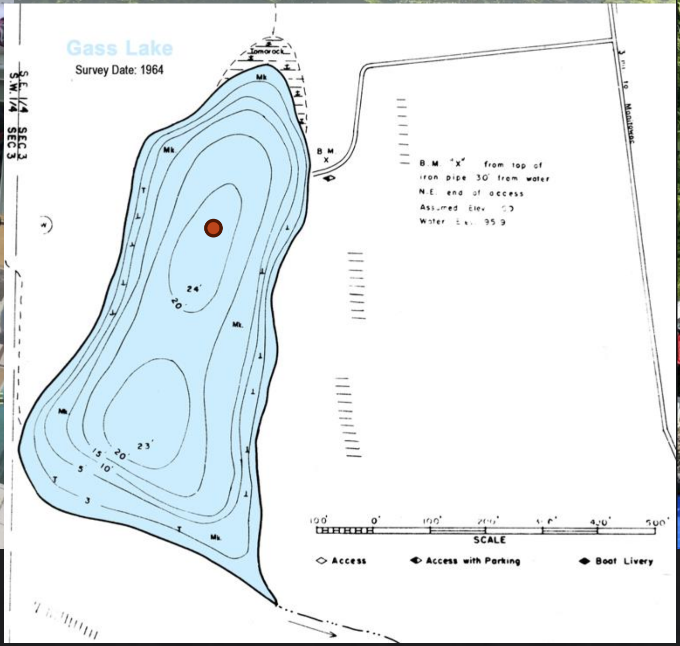
- Trophic Status Index (TSI) based on total phosphorus from 1976-2025 (WI DNR)
- 50-70 = Eutrophic

Why Gass Lake? Agricultural Land in the Watershed

- 2024 Land Cover (NLCD)
  - Agricultural land = 41%
  - Wetlands = 31%
  - Developed land = 13%
  - Forests = 11%
  - Open water = 4%



Sediment Coring



Radiocarbon and ^{210}Pb Dating

- Two terrestrial plant samples near bottom of core sent to WHOI NOSAMS for radiocarbon analysis (^{14}C half life = 5,730 years, useful for past ~50,000 years)

- ~20 samples from every 4-8 cm sent to LANSET at University of Ottawa for ^{210}Pb measurement (22.3-year half life, useful for past ~150 years)

NOSAMS | NATIONAL OCEAN SCIENCES ACCELERATOR MASS SPECTROMETRY

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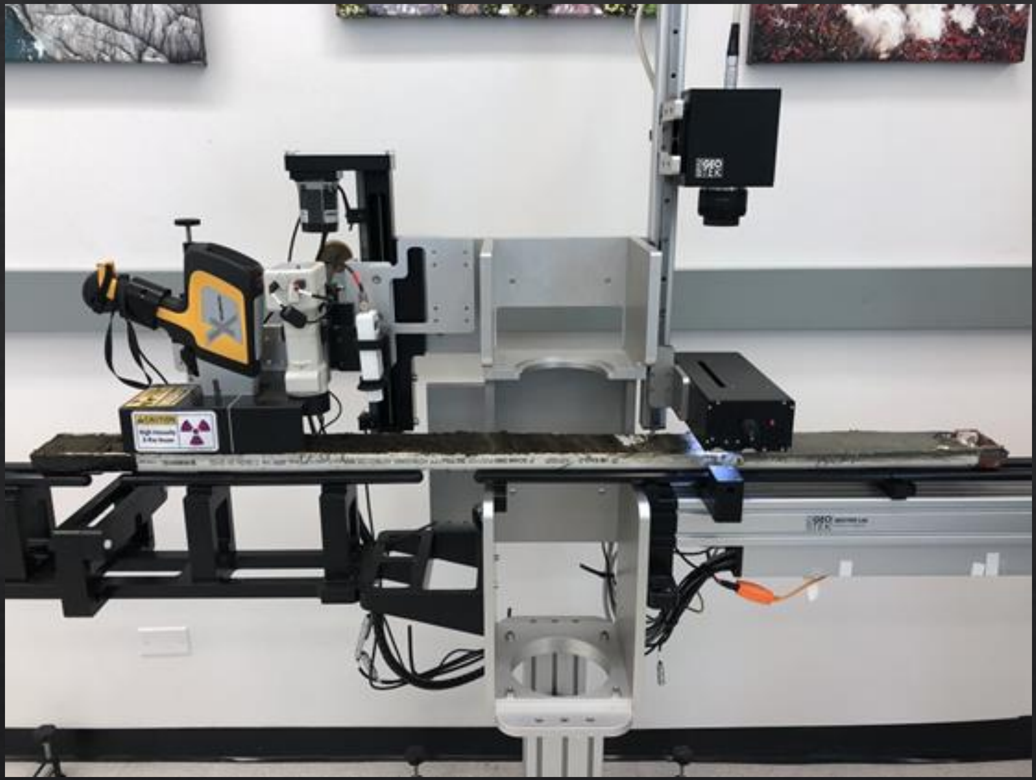
Core Scanning

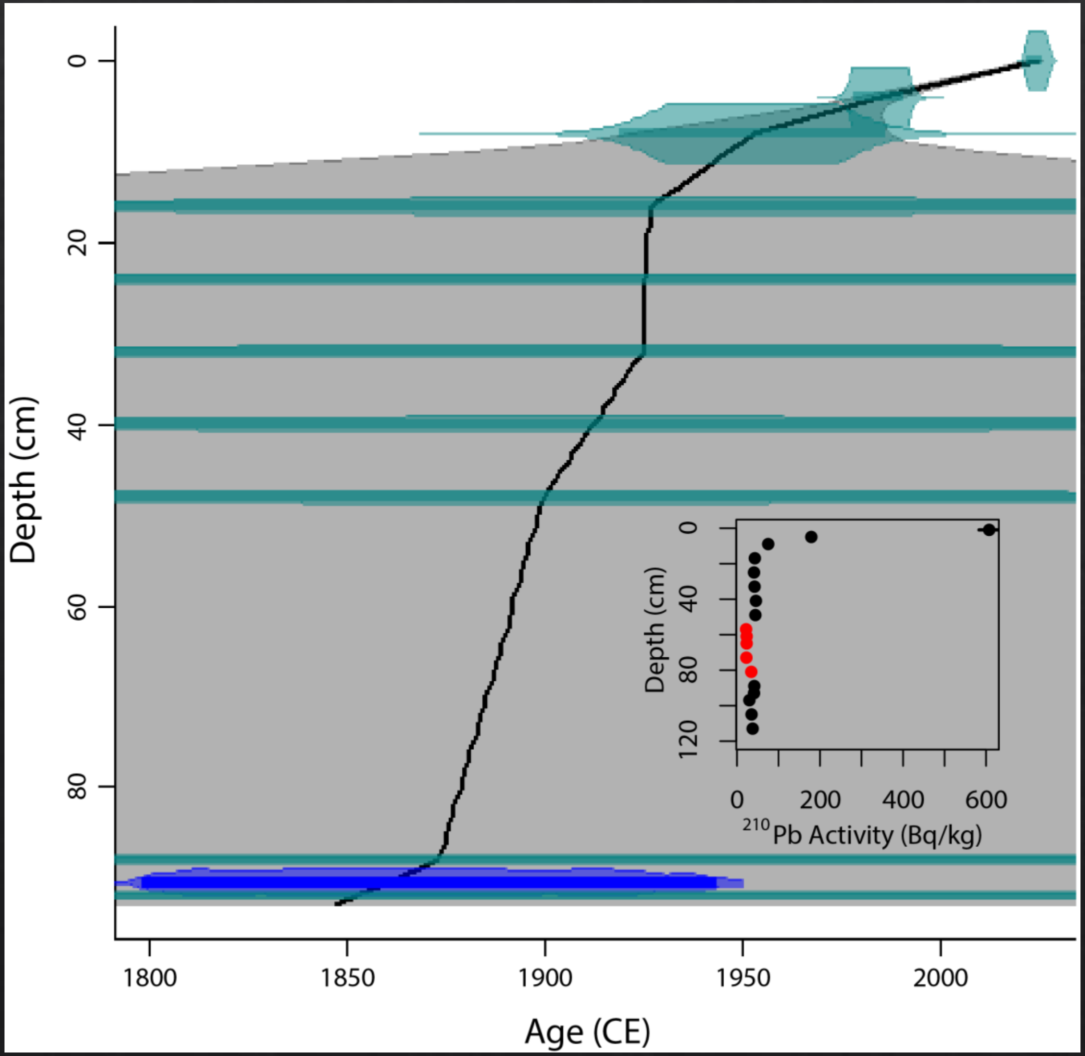
- Camera – High resolution image. Can indicate how sediment source changes (color)
- X-Ray Fluorescence (XRF) – Bulk sediment elemental concentrations of Mg-U. Rock forming elements (Ti, Si, etc.) can indicate clastic sources (Francus et al., 2009)
- Magnetic Susceptibility (MS) – Magnetizability of sediments. Can indicate magnetizable minerals (Dearing, 1994)



Carbon and Nitrogen

- Image shows Elemental Analyzer and Isotope Ratio Mass Spectrometer.
- Measuring Total Organic Carbon (TOC), Total Nitrogen (TN), stable carbon and nitrogen isotopes ($\delta^{13}C$, $\delta^{15}N$) can help us understand past productivity (Brenner et al, 1999).
- C/N ratio can help distinguish aquatic vs. terrestrial organic matter sources, as terrestrial plant matter has higher C/N values than aquatic plants/phytoplankton (Lamb et al., 2006).

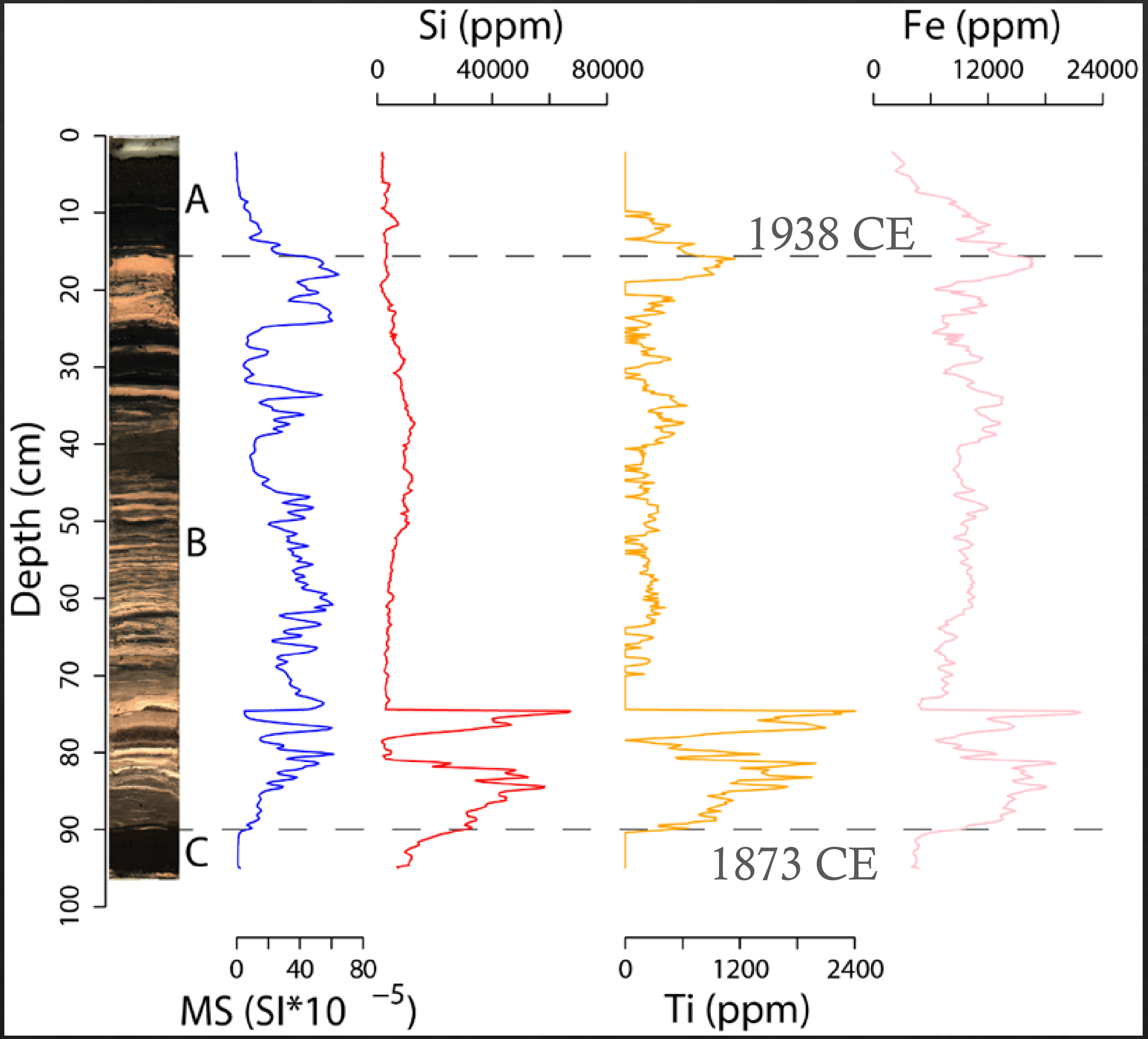
Chronology and Sedimentation Rate



- Sediments span 93.5 - 0 cm
- Radiocarbon (dark blue) suggests age of ~1827 CE at 90.5 cm while ^{210}Pb (teal) suggests ~1846 at 92 cm
- Relatively low sedimentation rate between 92-88 cm and 11-3 cm

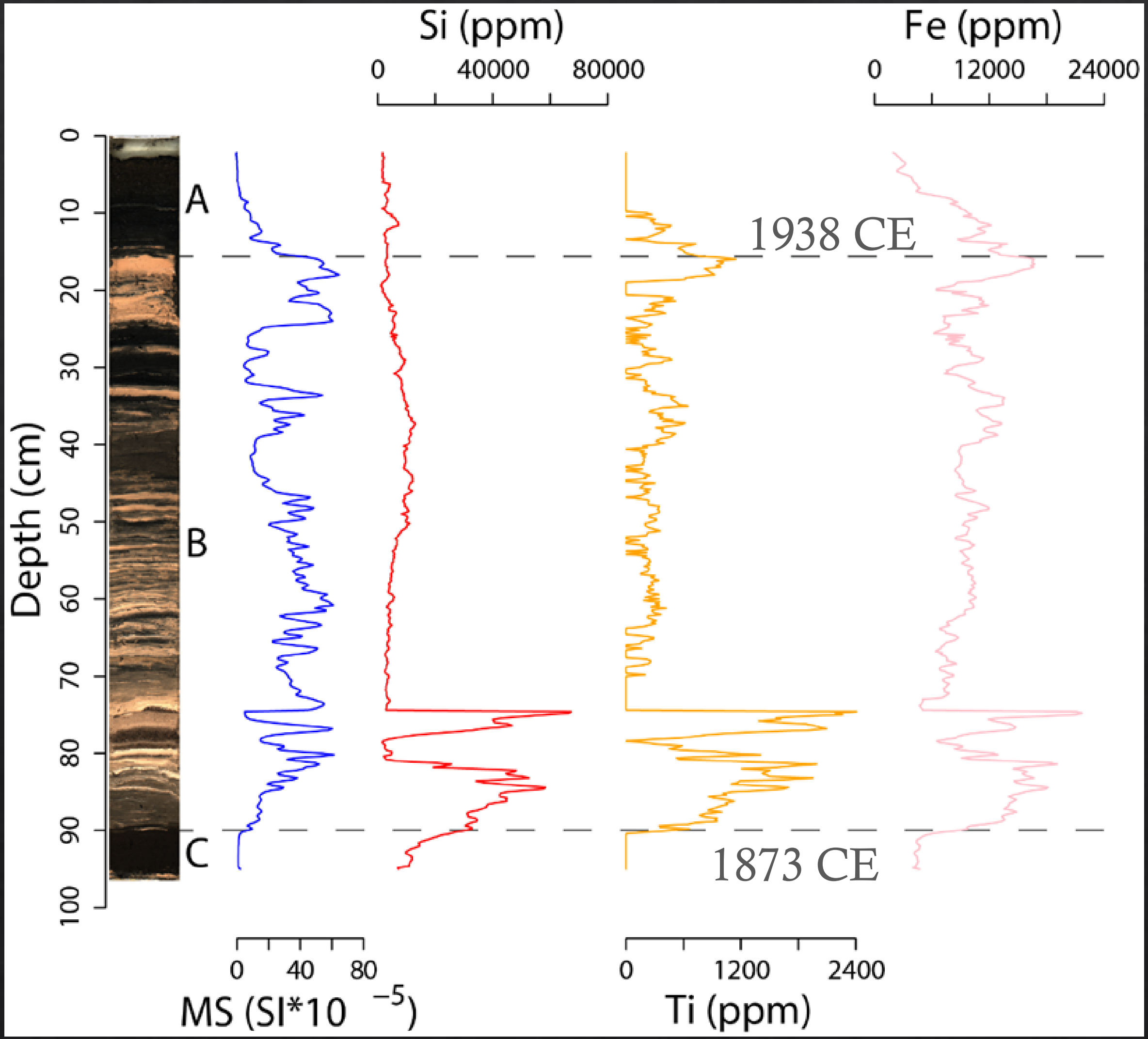
Core Image, Magnetic Susceptibility, and X-Ray Fluorescence

- Unit C (~1827-1874 CE)
  - Black/brown
  - Low MS, Si, Ti, Fe



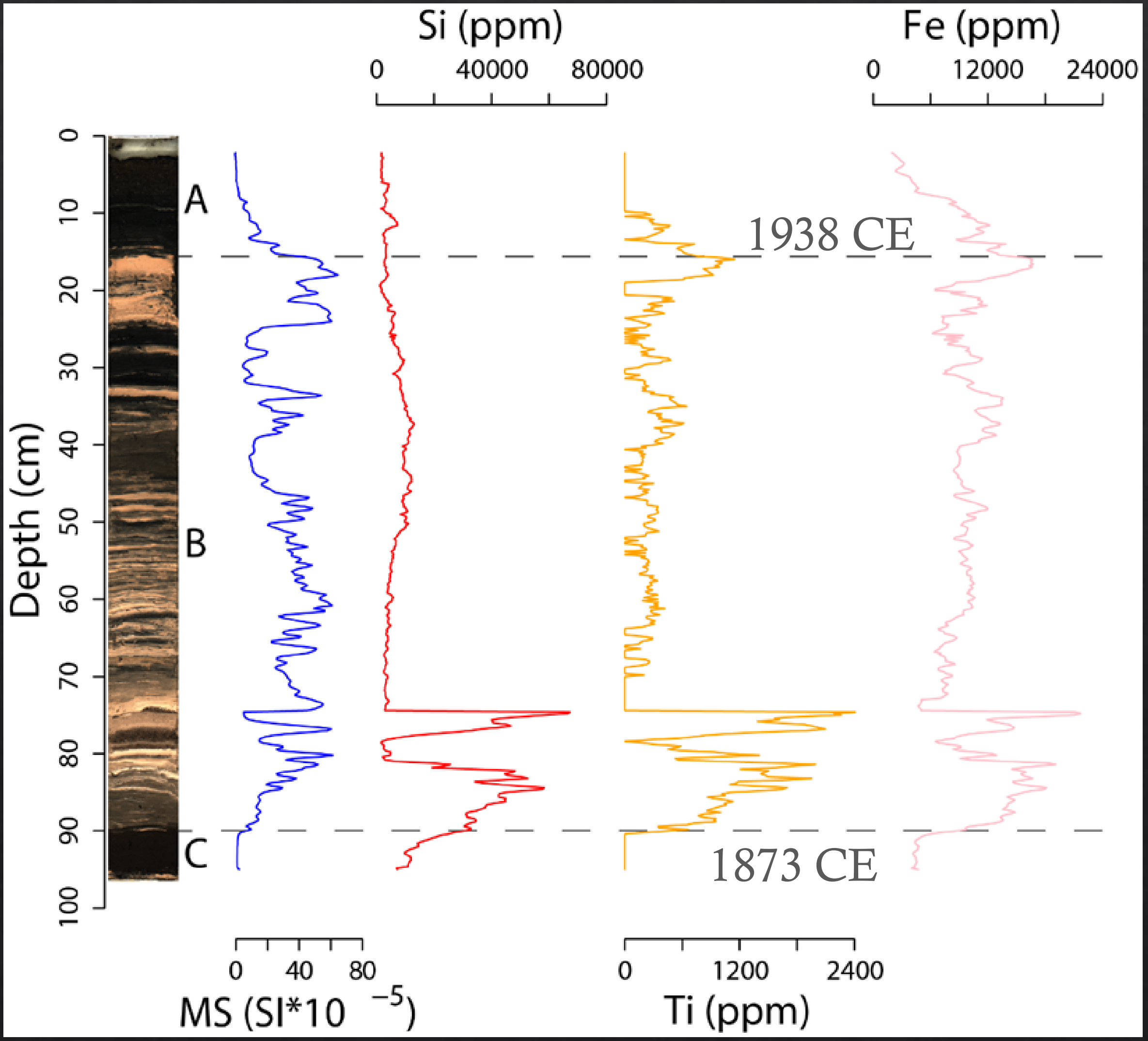
Core Image, Magnetic Susceptibility, and X-Ray Fluorescence

- Unit B (~1874-1937 CE)
  - Alternating tan and black/brown layers
  - Tan has high MS, Si, Ti, Fe
  - Black/brown has low MS, Si, Ti, Fe



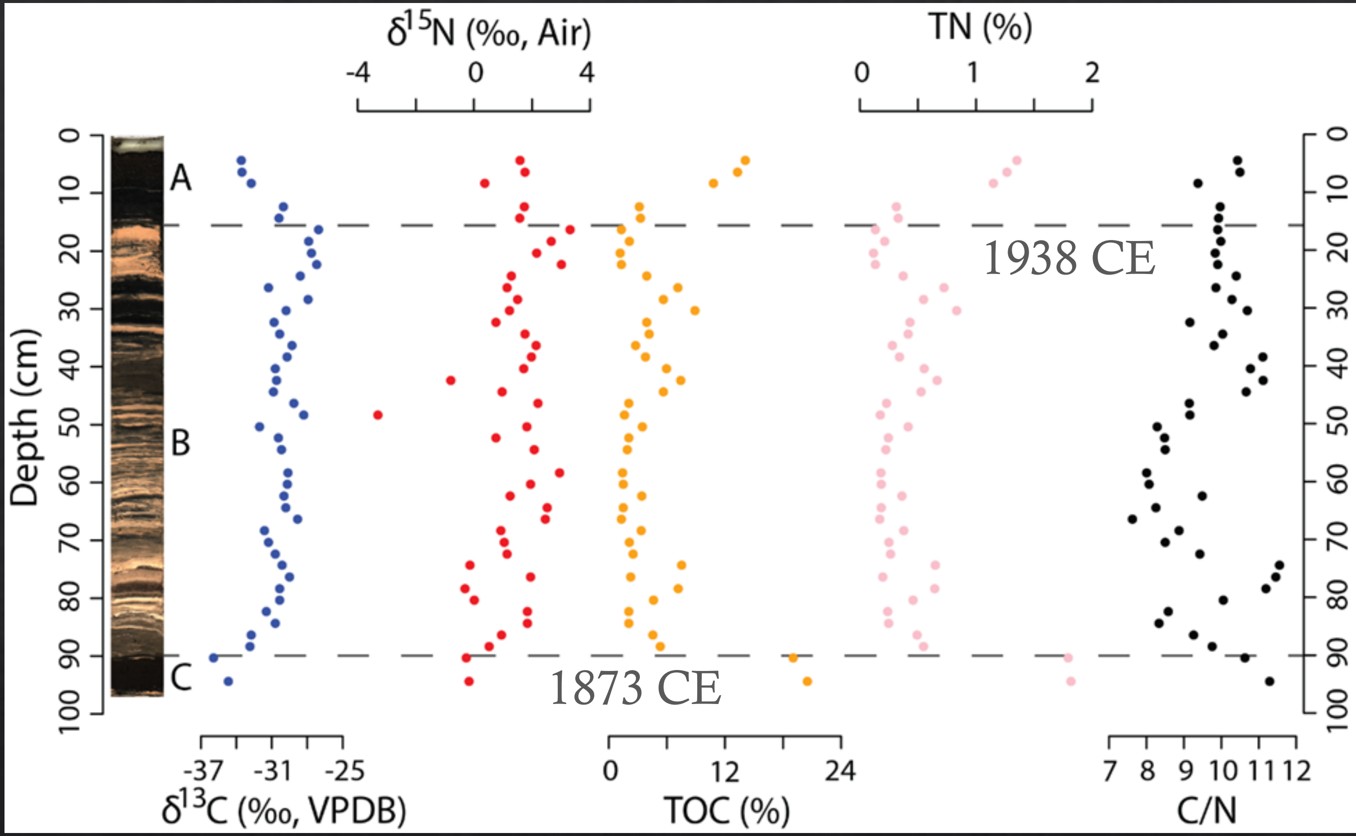
Core Image, Magnetic Susceptibility, and X-Ray Fluorescence

- Unit A (~1937-2024 CE)
  - Black/brown
  - Low MS, Si, Ti, Fe



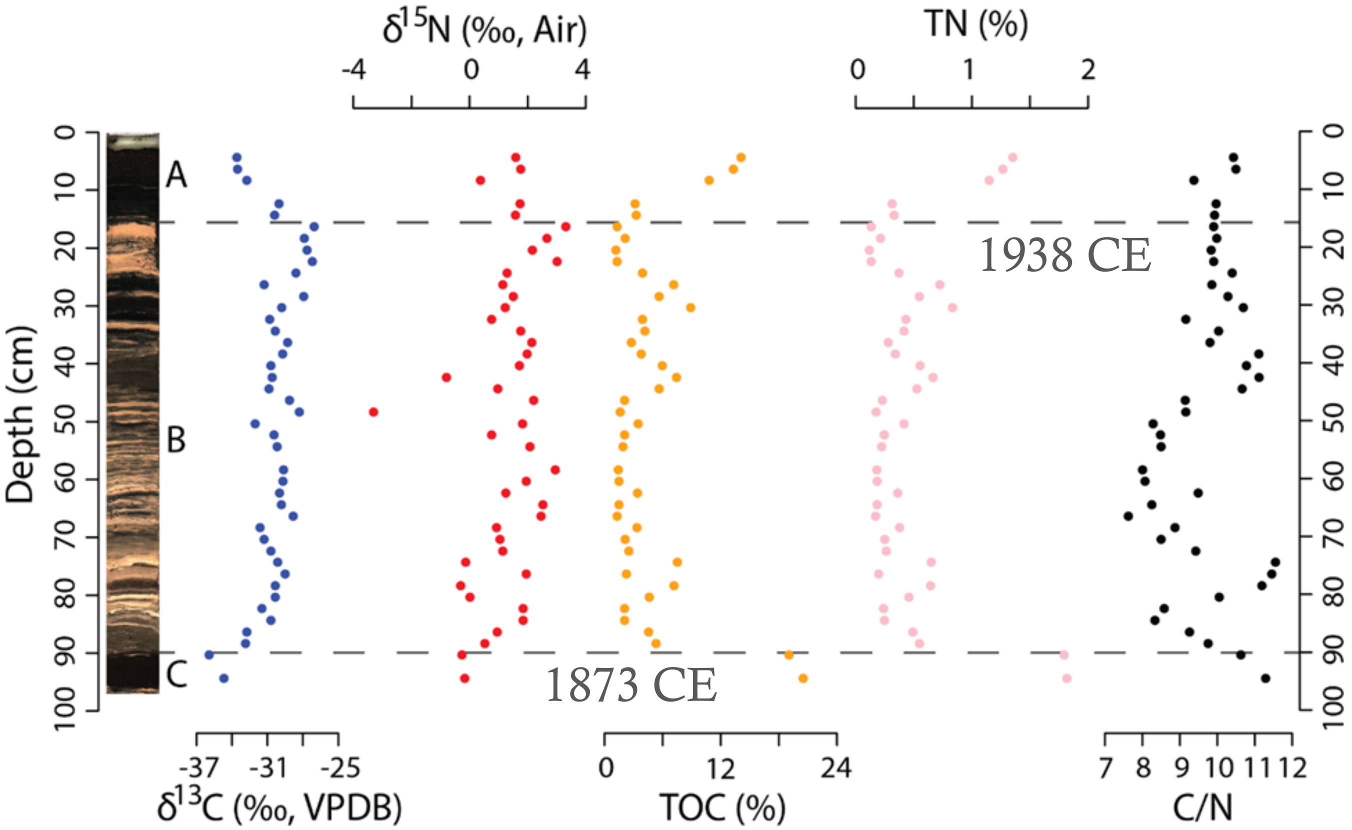
Carbon and Nitrogen

- Unit C (~1840-1874 CE)
  - Low $\delta^{13}C+\delta^{15}N$, high TOC+TN, high C/N



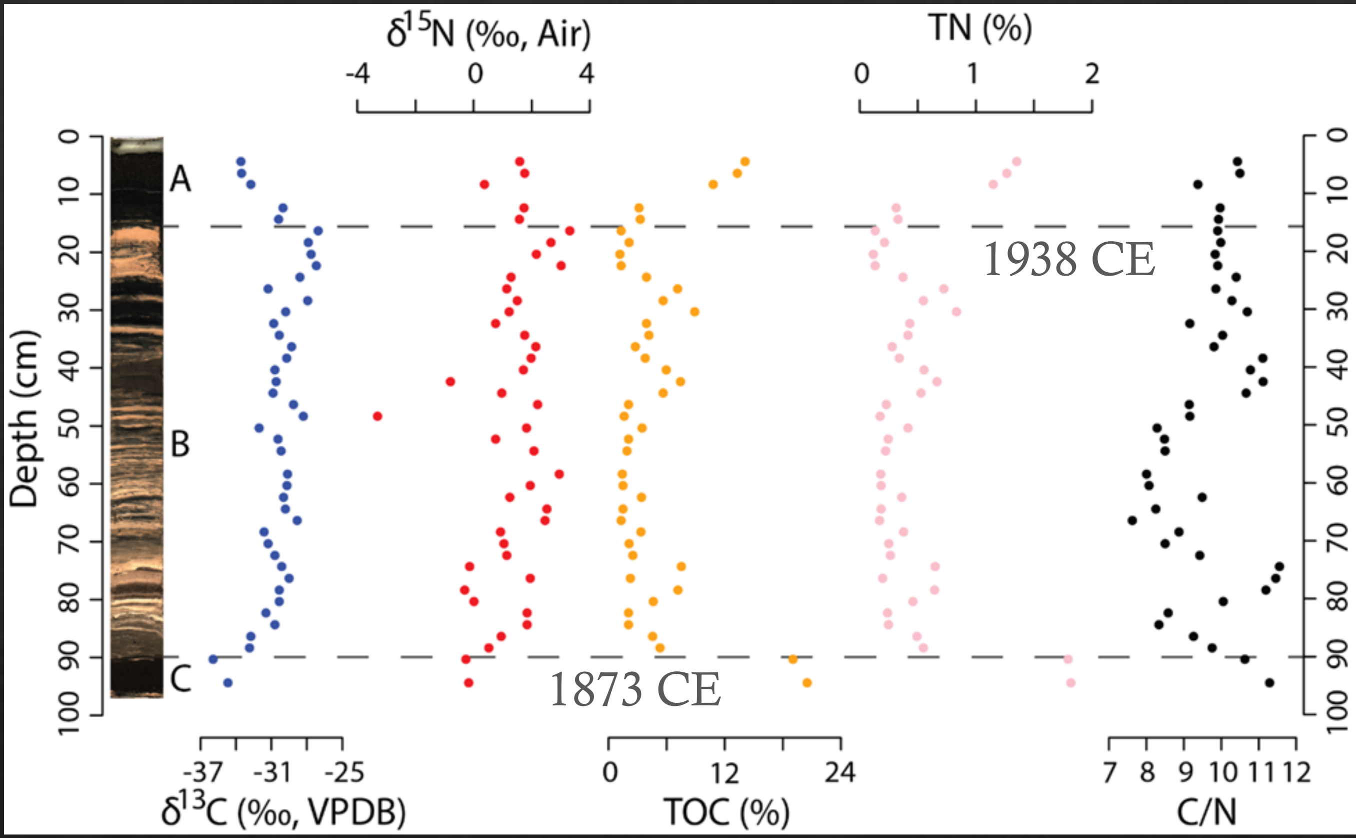
Carbon and Nitrogen

- Unit B (~1874-1937 CE)
  - Tan - High $\delta^{13}C+\delta^{15}N$, low TOC+TN, high C/N



Carbon and Nitrogen

- Unit A (~1937-2024 CE)
  - Moderate $\delta^{13}C+\delta^{15}N$, high TOC+TN, moderate C/N



Tan Sediment Layers: Gravel Pit?

- Just northeast of Gass Lake and potential major source of mineral material…

- Not likely source since R & J Fricke, Inc. opened ~1940 (after the tan layers end in the sediment core)

Tan Sediment Layers: Regional Soils?

- High sedimentation rates and high MS, Si, Ti, Fe indicate rapid deposition of mineral-rich tan sediments from ~1873-1938 CE

- Relatively high C/N ratios in tan sediments suggest less aquatic organic matter and/or more terrestrial organic matter (Lamb et al., 2006)

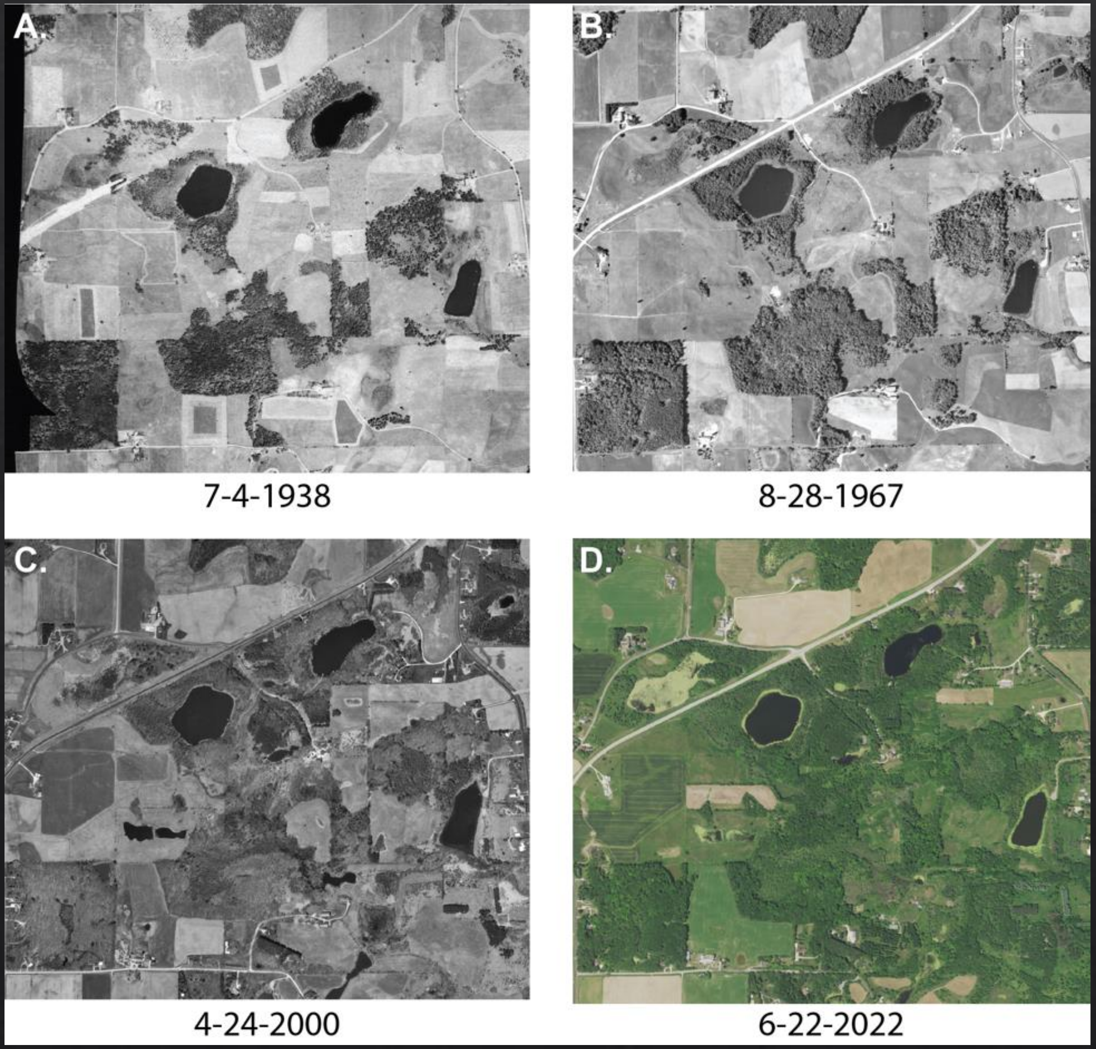
Tan Sediment Layers: Agricultural Soils

- Timing is consistent with agriculture becoming dominant in Manitowoc county in 1865 CE, peaking in 1880 CE, and declining to 1948 CE (Rappel et al., 1948).

- Relatively high $\delta^{15}N$ values in tan sediments could indicate agricultural soils as the source, since organic fertilizer is associated with a high $\delta^{15}N$ value (Kriszan et al. 2009)

Tan Sediment Layers: Reduced Agricultural Land Cover

- Agricultural land cover in the watershed declined after ~1938 CE to the present, reducing soil inputs to Gass Lake (Wisconsin State Cartographer's Office, 2011)



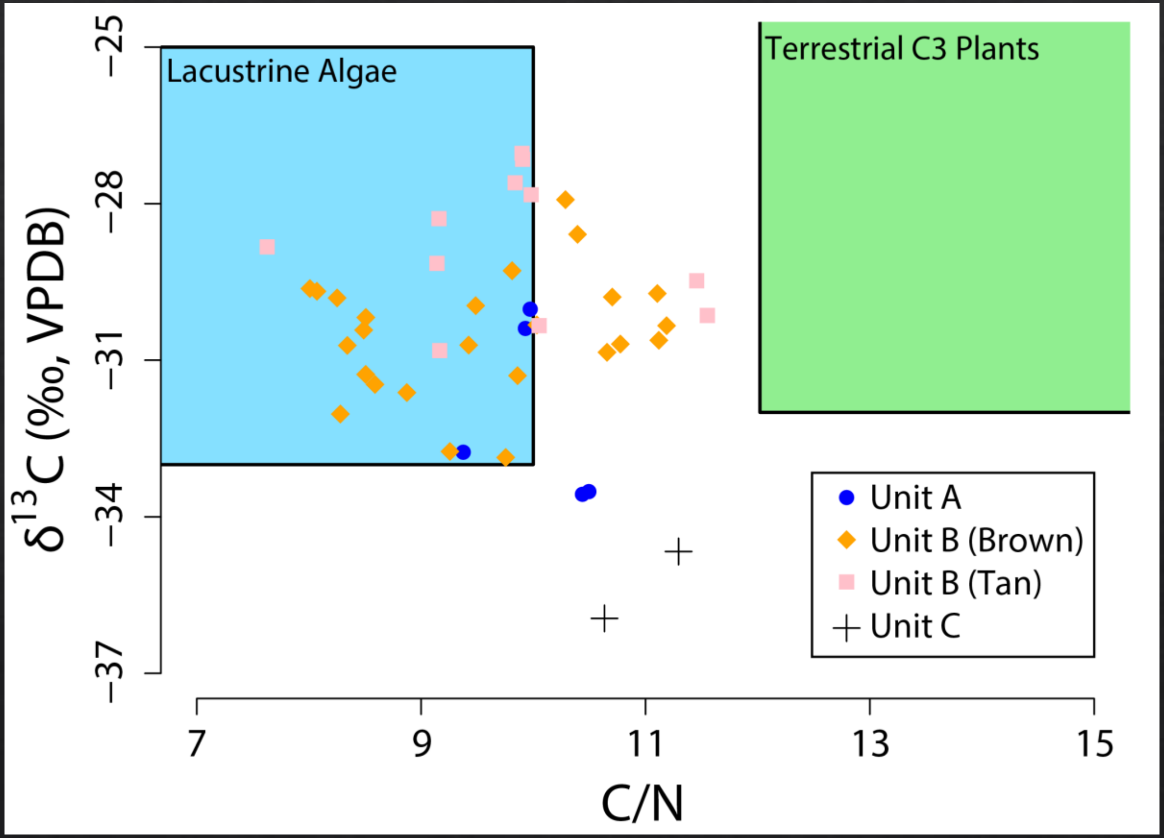
Tan Sediment Layers: Increased Soil Conservation Techniques

- We suspect soil conservation practices increased after ~1938 CE (following the Dust Bowl), reducing clastic inputs to Gass Lake

- These conservation practices were implemented in the Coon Creek Watershed of Southwestern Wisconsin in the mid 1900s and resulted in a drastic decrease in soil erosion (Trimble and Lund, 1982)

Changes in Organic Matter Source Over Time

- Unit C (~1840-1874 CE)
  - High C/N and low $\delta^{13}C$ suggest low aquatic/terrestrial organic matter ratio and low aquatic productivity
- Unit B (~1874-1937 CE)
  - Variable C/N + $\delta^{13}C$ suggests variable but increased aquatic/terrestrial organic matter ratio and high aquatic productivity
- Unit A (~1937-2024 CE)
  - Moderate C/N and $\delta^{13}C$ suggest moderate aquatic/terrestrial organic matter ratio and moderate aquatic productivity



Conclusions

- Gass Lake received major episodic, rapid inputs of clastic sediments from ~1873-1938 CE, likely from regional soil erosion increasing via deforestation and agricultural practices

- Modern aquatic productivity in Gass Lake appears high relative to pre-European settlement conditions but is likely lower than when agriculture dominated more of the watershed in the late 1800s and early 1900s

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Gass Lake: Soils and Geology

- The main soils of the watershed (Anderson et al. 1926) are Kewaunee silty clay loam (light reddish tan color, low organic matter) and Carlisle muck (dark color, high organic matter, calcareous)

- Below the soil is reddish-brown till topped by sand and gravel outwash deposits of the Valders Member of the Kewaunee Formation deposited by the Lake Michigan Lobe of the Laurentide Ice Sheet at ~14,600 cal yr BP (Mickelson and Socha 2017).