Needles in the haystack: particle characterization and the hunt for diatoms in Holocene lake sediment from upstate New York

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Abstract

Otsego Lake occupies a glacial trough in central upstate New York and is characterized as oligo-mesotrophic, with relatively low productivity. Sedimentation in the lake is due to terrigenous influx from tributaries and biologic activity in the lake. We initiated a sediment coring campaign to reconstruct environmental records for the lake. We extracted cores taken proximal and distal to a delta in shallow water (~1 m and 4 m depths, ~30 m and 200 m offshore respectively) to capture changes in terrigenous inputs, ostensibly due to flood events. Cores span the Holocene, based on five ^{14}C AMS dates of terrestrial plant material. The base of the longest core (5 m) is > 9 kyr BP. We report here on methods used to capture sediment characteristics, and focus on an anomalous section of core from ~6 to 2 ka. Sedimentation rates during that time decrease from ~1 mm/a to 0.12-0.15 mm/a; sediment exhibits a minor decrease in particle size, an absence of diatoms, an abundance of aquatic gastropod fragments (Hydrobiidae family) and carbonate material, and scattered plant roots. During this time interval sediment becomes more magnetic, the magnetic grain-size increases, and quartz/calcite ratio increases. We hypothesize that from 6-2 ka lake level was lower, or a long-lived avulsion of the stream on the delta delivered less terrigenous material to our core location.

Diatoms are abundant in core taken proximal to the delta, but are rare in the anomalous section of core taken distal to the delta. We employed automated particle detection to gather particle characteristics and to attempt to count diatoms in sediment smear photomicrographs using ImageJ and with a particle flow analyzer, FlowCam. We found that automated particle detection has a difficult time identifying diatoms. ImageJ could not detect diatoms as distinct from background, and FlowCam diatom images lacked detail. Automated particle analyses are helpful however in revealing grain size variations in muddy lake sediments.

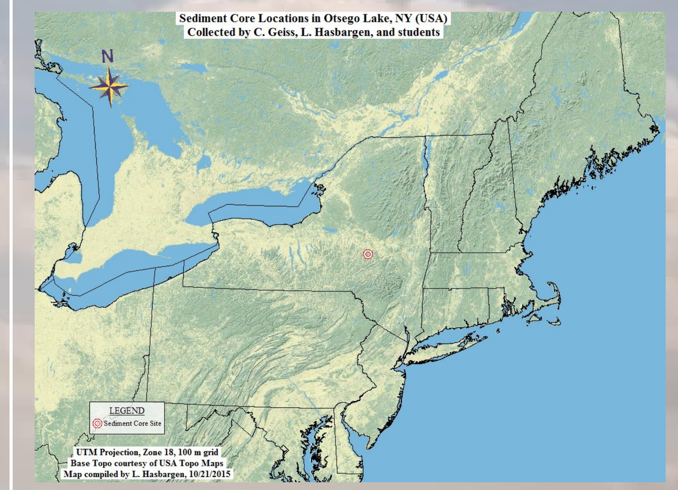
Talking Points

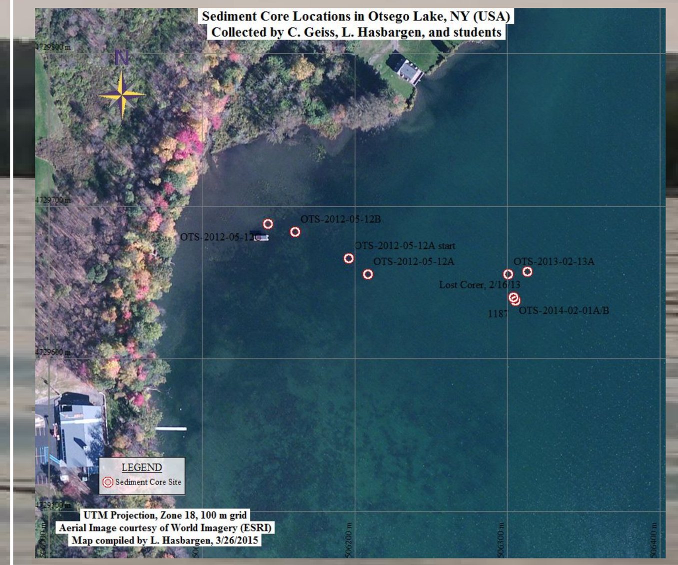
- Location and current state of investigation
- Slide smear generation: "the solution is dilution", droplets on glass slides
- ImageJ does a fair job at detecting and measuring particles on slide smears, so long as the particles are separable from the background, and don't overlap
- Automated detection fails to identify diatoms for ImageJ and FlowCam
- Probabilistic approaches to comparing distributions indicate that particle size and shape vary with depth, and are measurable
- The number of particles detected matters

Investigative Tools and Research Status

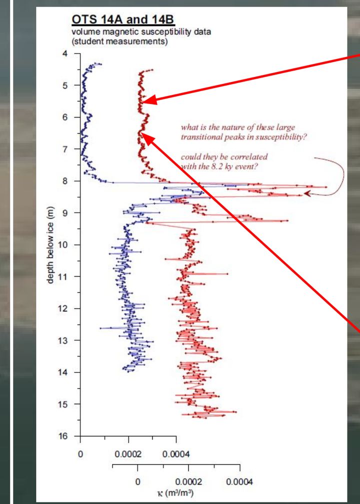
- Visual and descriptive logs of sediment cores
- Magnetic properties of sediment cores (completed)
- Particle characteristics (in progress; proof of concept…)
- Age dating: five ^{14}C dates, with base of core > 9 ka
- XRD: quartz/calcite ratios coincide with magnetic signals
- GPR: delta bathymetry plus some stratigraphy
- LOI (in progress…)
- Charcoal abundance (to be done…)

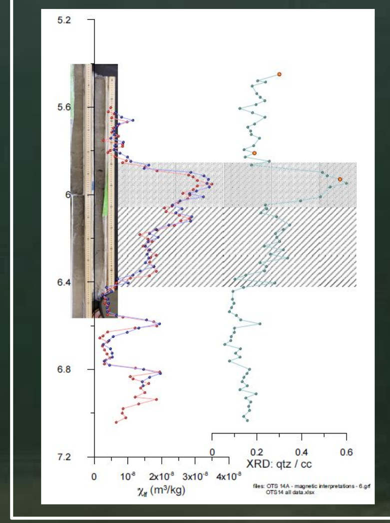
Where is this study taking place?





Where in the core are we?





So, Magnetic susceptibility changes…

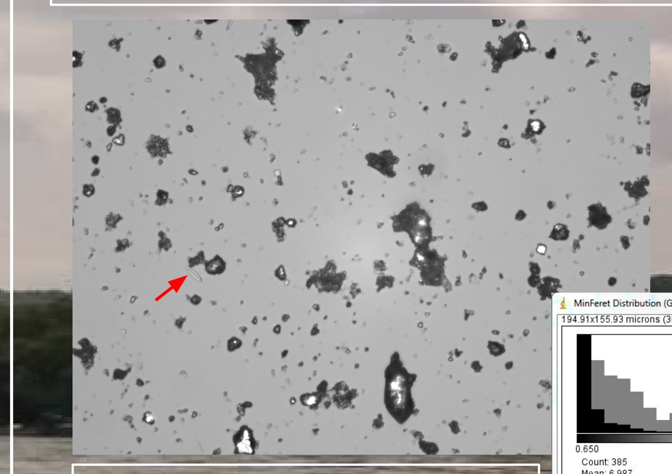
Do particle shape and size change in concert?

Do diatom abundances change in concert?

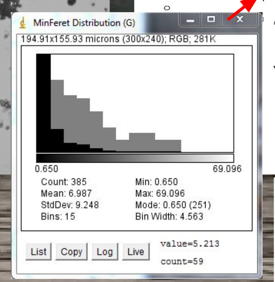
We target core with an Age model from 2 to 6 ka

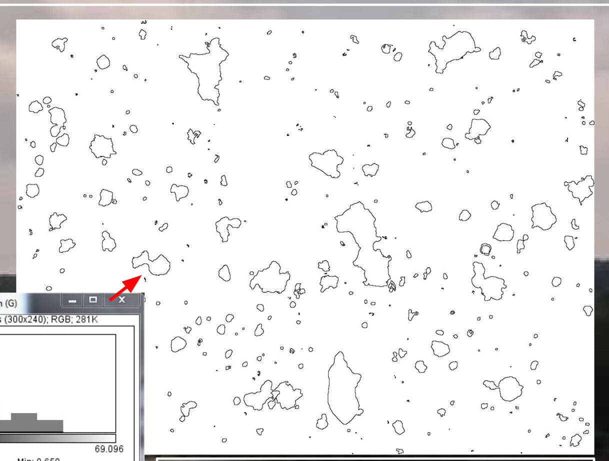
Observations about automated particle detection

- Particle dispersion on a glass slide works fairly well using low concentration sediment in a dropper bottle
- Diatom are not readily detected (below, left) by machines. A manual count of diatoms in 50 slides suggests there should be ~5-10 diatoms per thousand particles.

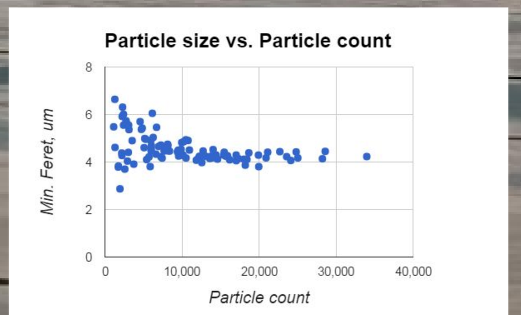


Photomicrograph (10x objective) showing dispersed particles from droplet method.

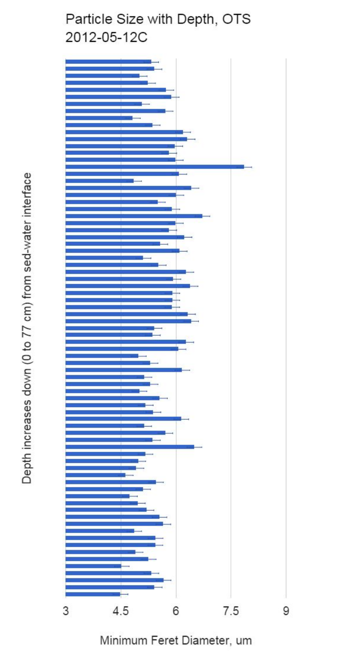


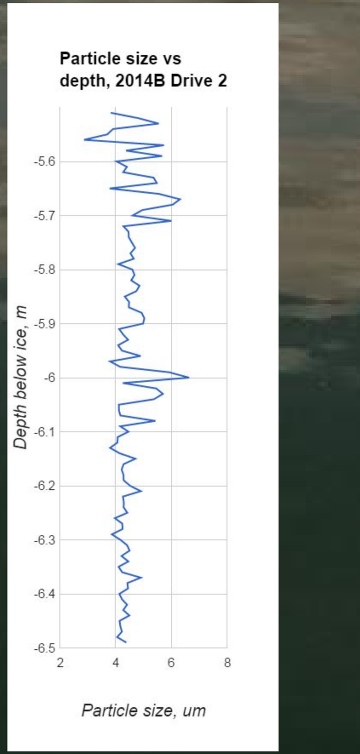


Particles detected by ImageJ. Note the diatom was not detected (red arrow).



At right: Grain size vs depth with 0.2 um error bars plotted.
At left: Small counts (<2000) lead to larger variances.





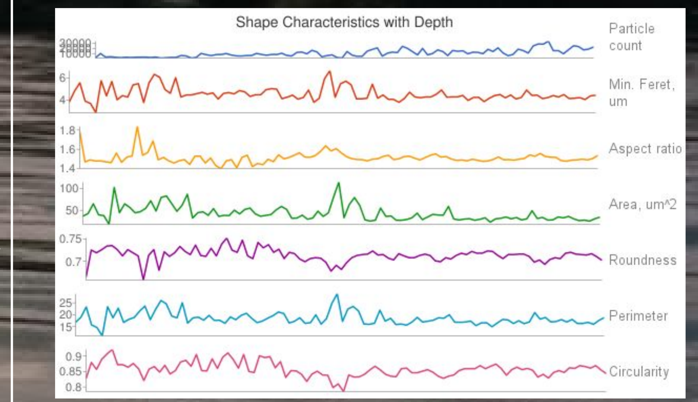
How do we know that grain size at one depth is different than another depth?

- This boils down to significance tests with statistics.
- We used a t-test function to compute the probabilities that two distributions are drawn from the same larger population, assming two-tailed, heteroscedastic distributions. The probabilities of similitude for three cases of two distributions is given in the table below. Even for averages with a difference of 0.14 um and standard deviations differing by 1.2 um (see Case 1 in the table below), the likelihood they are drawn from the same population drops to 0.12, so 0.2 um changes are significant statistically. This is for particle counts ~4000-5000.

Case	Average 1	Stdev 1	Average 2	Stdev 2	Probability
1	5.37	6.83	5.51	7.07	0.12
2	5.37	6.83	7.86	9.07	5.7E-47
3	5.37	6.83	4.83	5.61	1.9E-05

How do particle shapes and size vary?

- Particle counts do not appear correlated to depth or shape descriptors which is good! Though smaller counts yield less robust statistics
- Each shape descriptor appears to vary somewhat from the others
  - Roundness and circularity are quite similar to each other, as are diameter and particle area
  - Aspect ratio (particle length to width ratio) and diameter appear to be independent of each other



What do we know about low sedimentation from 2 to 6 ka?

- Very low diatom counts based on visual inspection of glass slide smears
- Abundant aquatic gastropod shell fragments throughout the interval
- Higher abundance of organic material and quartz
- Strongly magnetic horizon at top of the interval

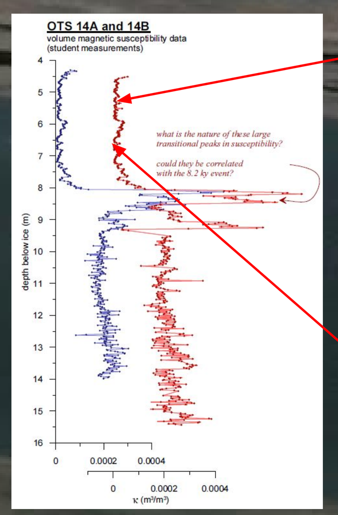
Causes

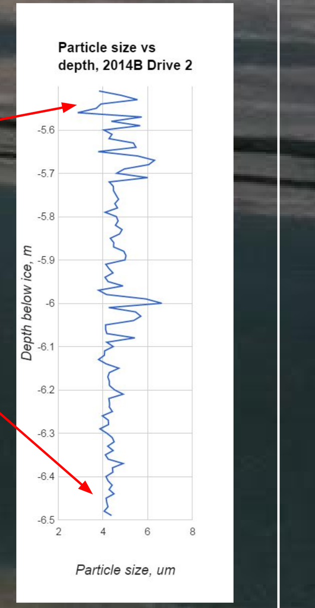
- Migration of sediment source on the delta, or environmental change?

We plan additional coring and GPR campaigns to determine if hiatus is regional

What about the large variations around 8.2 ka?

- Additional coring across this horizon could reveal local vs regional change





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