# Sonar Imagery of Shoreline Tufa Deposits and Bathometric Mapping at Green Lakes State Park, NY

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## 1) Abstract:

Green Lakes State Park, located in Fayetteville, New York, holds two deep and narrow meromictic lakes which are hypothesized to be plunge pools associated with the retreat of the Laurentide Ice Sheet (~13,000 years ago). Today, the catchment area for Green and Round Lake is small and the lakes are mainly groundwater fed. This groundwater flows through the Syracuse formation and the gypsum-bearing Vernon Shale and discharges into the lakes rich in calcium, magnesium and sulfate. Tufa deposits are located at sites of groundwater discharge. Tufa deposits are thrombolitic microbialite structures, mainly composed of calcite accreted during cyanobacterial photosynthesis. The tufa deposits vary in size from meters to tens of meters and are found in various locations along the lakeshores. Here, we update the bathometric mapping using sonar techniques and provide the first sonar imagery of the nearshore environment to identify the locations of tufa deposits. Sonar data was collected with a Humminbird SOLIX 12 CHIRP MEGA SI + G2 with frequencies of 50/83/200/455/800 kHz & 1.2 MHHz during the summer and fall of 2019 and 2020. The sonar data was analyzed using Reefmaster, Sonar TRX, ArcGIS and Google Earth. Results indicate, both lakes exhibit steep slopes about 30° and the maximum depths detected at Green and Round Lake were ~175 feet and ~159 feet below the lakes' surfaces. Sonar imagery reveals numerous locations of woody debris and clearly shows tufa deposits. In Green Lake, we identify 14 locations of tufa deposition, those being previously discovered and newly discovered, most concentrated on the East and West shores. Tufa deposition was limited in Round Lake with 4 localities of tufa found each consisting of multiple distinct tufa heads all concentrated on the eastern and southern shore. Our work provides data needed to refine prior bathometric mapping and provides a new viewpoint for understanding tufa geometry and the locations of tufa formation. These data will aid in understanding the link between groundwater discharge and tufa formation. It will also help with ongoing and future conservation efforts of this unique site.


## 2) Problem:

The guiding questions in this research are:

A) What is the detailed bathymetry of Green Lake and Round Lake?

B) Can we identify and locate tufa deposits using sonar?

C) Is there a correspondence between terrestrial vegetation and tufa locations because both can be influenced by groundwater.

## 3) Study Area:

About 11 miles south of Oneida Lake, two glacially scoured plunge pools (Green Lake and Round Lake) are situated in Green Lakes State Park (Fig. 1). The landscape is mantled by glacial till from the retreat of the last ice sheet and the underlying bedrock of the site sits at the contact between argillaceous dolostone beds of the Syracuse Formation and Vernon Shale (Thompson, Ferris, & Smith, 1990). The lake water is a piercing blue green and the shore is heavily vegetated (Fig. 2). Skirting the shore and extending into the water of Green Lake, there are calcite mineral crusts precipitating in the water (Fig. 2). These structures, called tufa, tend to form in areas where the calcium carbonate ion rich groundwater is interacting with the lake water.

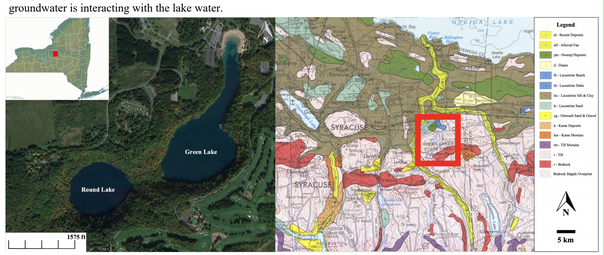



**Figure 1) Left:** Green lakes State Park is in central New York (Imagery, Google Earth October 10th, 2019). **Right:** Regional surficial geologic map indicates a glacial setting where till, lacustrine sands and bedrock are present (Muller & Cadwell, 1986).

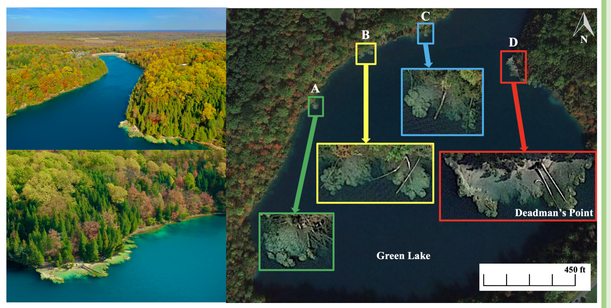



**Figure 2) Top:** Photo viewing to the Northeast and down the neck of Green Lake (note: bottom right corner, tufa visible in the water corresponding to location D) . **Bottom:** Photo viewing East – visible tufa formations correspond to location D. (images from October 2020). **Right:** Satellite imagery (Google Earth October 2019) shows some of the most prominent tufa formations in Green Lake. Those visible, are large and in shallow water. The tufa deposits encrust the shore and debris (i.e. trees and branches) in the water.

## 4) Methods:

We used orthoimages, aerial imagery, field observation, and sonar to map lake bathymetry and identify tufa locations.

***Imagery:*** We used orthoimagery from 2003 (24-inch resolution color infrared) and Google Earth imagery from 2019 to map vegetation cover in ArcMap 10.7.1. We also used this imagery and drone collected aerial images to identify and examine prominent tufa localities.

***Bathymetry and Sonar Mapping:*** We used a SOLIX 12 CHIRP MEGA SI+ G2 50/83/200/455/800 kHz & 1.2 MHz (Fig. 3) to collect down-looking and side-scan sonar images. We used Reefmaster 2.0 for bathymetric mapping and Sonar TRX to process and visualize the sonar data.

***Data Collection:*** During data collection, we took care to minimize rocking of the boat and to maintain a consistent speed (~1.5 mph). Throughout each data collection period, we were careful to ensure that the sonar transducer was placed 0.43 meters below the water surface to ensure measurement consistency. We also accounted for daily water level fluctuations by measuring the water level relative to a fixed benchmark (outflow drain).

***Data Analysis:*** We applied speed, depth, and angle corrections to the sonar data using SonarTRX. Mosaic imagery was exported to Google Earth for mapping.

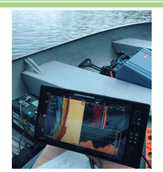


**Figure 3)** Data collection using a Humminbird SOLIX on Green Lake.

## 5) Results:

Bathymetric mapping (Fig. 4) indicates the maximum depth of Green Lake is approximately 53.33 m (~175 ft) and Round Lake is approximately 48.63m (~159.55 ft). Sonar imaging (Fig. 5) reveal multiple locations of tufa formation, and vegetation mapping shows several locations of coniferous trees (Fig. 6).

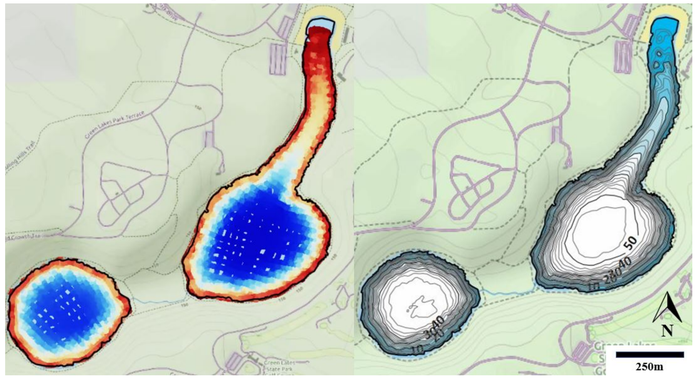
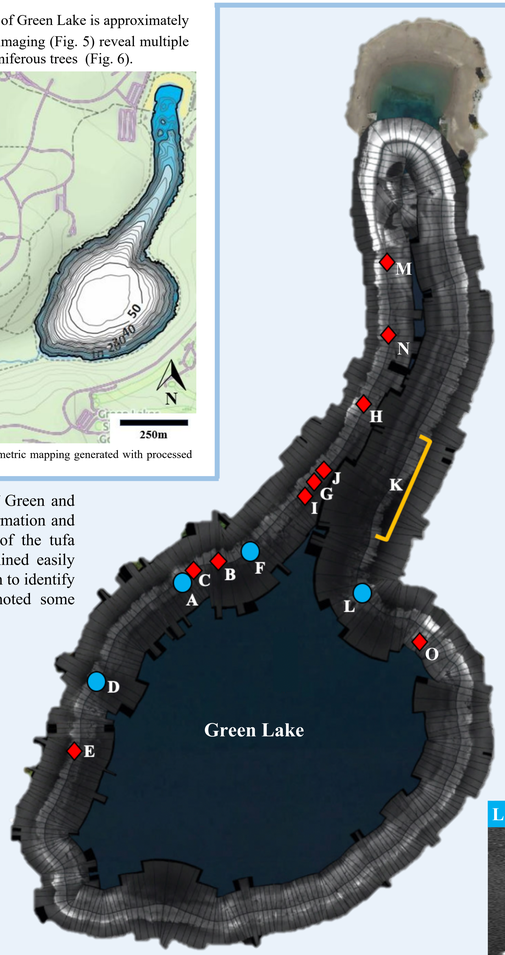
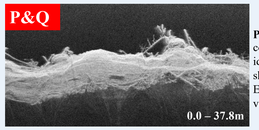


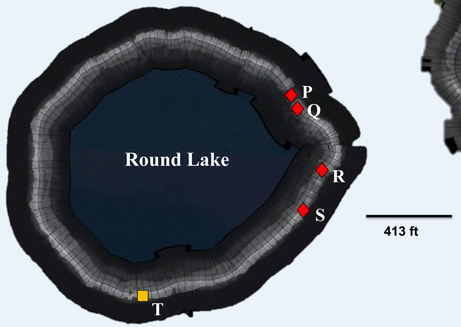

**Figure 4.** Bathymetric mapping. **Left:** data collection tracks color shaded by lake depth. **Right:** Bathymetric mapping generated with processed return data. Major contour interval = 10 m (~33 ft) and minor contour interval= 2.5 m (8.2 ft).

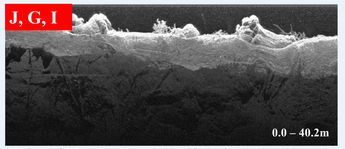
**Figure 5.** We used the processed sonar imagery to create a mosaic of Green and Round Lakes' perimeter which we used to identify locations of tufa formation and map woody debris. The sonar was able to provide detailed images of the tufa geometries and other features along the shore. We located and examined easily identifiable (known) tufa deposits (blue circles) and used this information to identify previously unrecognized tufa formations (red diamonds). We also noted some locations of extensive woody debris (yellow).



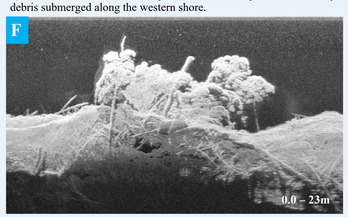




**P&Q)** A tufa locality containing two small newly identified tufa on the eastern shore of Round Lake. Encrusted woody debris is visible.

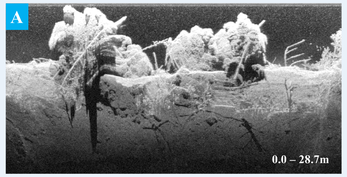


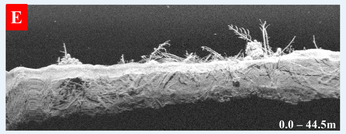

**J)** Three of Green Lakes' newly identified tufa deposits with woody debris submerged along the western shore.



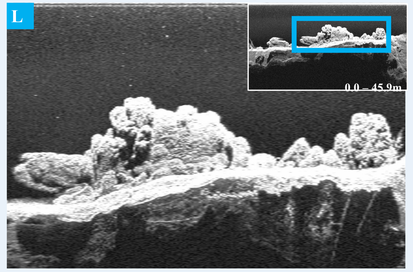

**F)** Known tufa deposit at Green Lake (Fig. 2C) jutting out from the lakeshore. Woody debris and encrusting is also visible atop the tufa deposit.



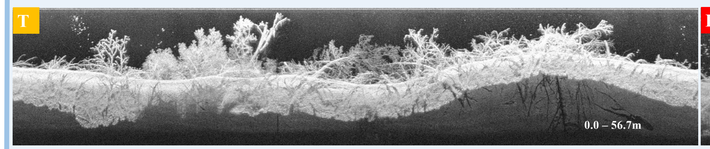

**A)** Previously recognized tufa deposits along the western shore of Green Lake encrusted with woody debris.



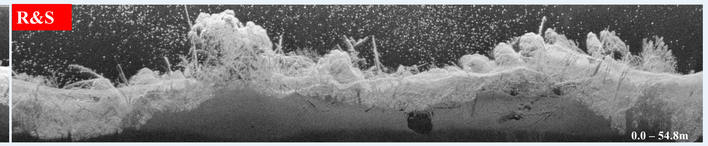

**E)** Small tufa deposits encrusting woody debris.




**L)** The most well-known tufa is located at "Deadman's Point" (Fig. 2D). This image clearly highlights the complexity and characteristic tufa morphology.




**T)** An area of extensive woody debris clearly visible on the southern shore of Round Lake. These trees are protruding into the water.




**R & S)** Two tufa localities on the southeastern shore of Round Lake contain approximately ten tufa heads. Woody encrusted material is visible along with other woody debris protruding into the lake.

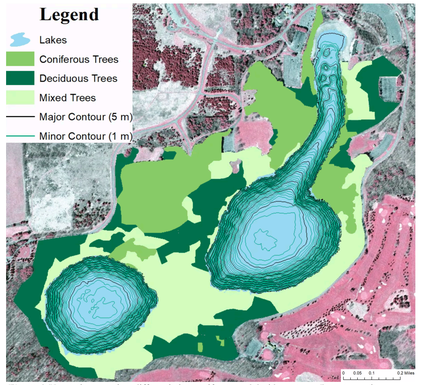



**Figure 6.** Vegetation mapping, differentiating coniferous and deciduous trees. Remote sensing was incorporated to document vegetative cover surrounding Green Lake and Round Lake. Mixed trees represent a mixture of both types. Green Lake bathymetry same as Fig. 4.

## 6) Discussion/Conclusion:

- We provide the first high resolution bathymetric map of Green Lake and Round Lake using sonar.
- We confirmed the locations of known tufa deposits throughout the lakes and documented their morphology with sonar imagery.
- We confirmed that sonar can be used effectively to identify and characterize tufa deposits.
- In Green Lake we identified a total of 14 tufa deposits, 5 greater than 10 meters and 9 were smaller and less prominent.
- In Round Lake we identified a total of 4 tufa deposits, 2 greater than 10 meters and 2 were smaller and less prominent.
- Correspondence between coniferous forest and tufa locations is imperfect as represented by broad scale vegetation mapping.
- The combination of various remote sensing techniques was powerful for mapping lake bathymetry, identifying tufa, and understanding Green Lake's association with the surrounding landscape.

## 7) Future Work:

- Differentiating vegetation types (ie. locating positions of cedar trees which are known to prefer local groundwater sources).
- Attempt to identify lesser known tufa deposits using drone imagery.


## 8) Acknowledgements:

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## 9) Citations:


Thompson, J. B., Ferris, F. G., & Smith, D. A. (1990). Geomicrobiology and Sedimentology of the Mixolimnion and Chemocline in Fayetteville Green Lake, New York. *Palaios*, *5*(1), 52-75.

Muller, E. H., & Cadwell, D. H. (1986). Surficial Geologic Map of New York, Finger Lakes Sheet. New York State Geological Survey.