Remote Paleohydrograph Reconstruction for the Stockton Island Tombolo

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Abstract

Rising lake levels have become a concern for the coasts of Lake Superior and one such coastline is the Stockton Island Tombolo (SIT) that protects the Pine Barrens Habitat (PBH) in the Apostle Islands National Lakeshore (AINL), Wisconsin, U.S.A. (Figure 1). If the SIT is lost, then threatened and endangered species will disappear. For the AINL managers to make an informed decision on how to protect this unique and sensitive area, they need to understand how lake level and coastal sediments will change. Lake level trends and patterns for Lake Superior have been reconstructed from ancient, preserved shorelines, creating paleohydrographs that help to understand how lake level has changed in the past by comparing age and elevation (Johnston et al., 2012). Though fieldwork has been postponed due to COVID-19, there is an opportunity here to develop ideas mentioned in Johnston et al. (2012) and Heather (2021) using topographic elevations and a correction factor to reconstruct a paleohydrograph from the ancient shorelines at AINL. Elevations were retrieved from light detection and ranging (LIDAR) data, after a Digital Earth Model (DEM) was created. The DEM was divided into the East and West strandplains and one transect from each was chosen, the two were combined to form the SIT paleohydrograph. Then elevations were adjusted to estimate the base of the foreshore contact, normally obtained from cores. Trends and patterns in the representative paleohydrograph are compared to paleohydrographs from Johnston et al. (2012) to determine approximate ages for the ridges in the SIT. The more landward ridges are determined to be from the Nipissing phase while the lakeward ridges are from the Sault phase. This new remote paleohydrograph reconstruction for the SIT helps preliminarily interpret strandplain sequences in the SIT, potentially helping guide future fieldwork and better understand the context for managing the SIT and PBH in AINL.

Figure 1 Location of Stockton Island Tombolo. The red box indicates the location of Apostle Islands National Lakeshore in the Great Lakes along the coast of Lake Superior in Wisconsin, U.S.A.

Context

- Studies have been completed at AINL mainly focusing on plants and animals. One coastal study at the SIT showed a very high change potential (Pendleton et al., 2007)
- AINL management plan states sandscapes can go through erosion and deposition. For species on the PBH, the National Park Service mandates to conserve and protect (National Park Service, 2011)
- When many ancient shorelines are preserved strandplains will form and they are composed of ridges that are separated by swales
- A research group has reconstructed lake levels for the past six millennium in the upper Great Lakes with a multi-decadal resolution. One site is near the outlet for Lake Superior in Sault Ste. Marie (SSM). Paleohydrographs have been created from coring through ancient shorelines for past lake level elevation and age dating sediments using OSL (Johnston et al., 2012 and 2014)
- In Johnston et al. (2012) an idea is mentioned that uses topography and a correction factor to reconstruct an inferred paleohydrograph, further developed by Heather (2021)
- LIDAR is the most detailed and accurate remote sensing data for elevation and can go through most foliation to reconstruct ground surface or topographic elevations (Brock & Purkis, 2009)
- GIA causes vertical elevation changes through time and affect the elevation results and interpretations. GIA rates have been published using geological data from paleohydrographs (Johnston et al., 2012) as well as from water level gauge data (Mainville & Craymer, 2005)

Objectives

- Reconstruct a paleohydrograph with corrected LIDAR elevations and inferred ages for ancient shorelines in the SIT, AINL, adjacent to Lake Superior in Wisconsin, U.S.A.
- Correct selected LIDAR elevations to best represent past lake level elevations for each ancient shoreline and estimate the millennial lake level phase the ridges formed in

Method

- Elevation is collected from LIDAR data available through the National Oceanic and Atmospheric Administration's Digital Coast https://coast.noaa.gov/digitalcoast/data/
- LIDAR data is used to create a DEM in ArcGIS to obtain elevations for the ground surface points along transects (Figure 2)
- Ground surface elevations in swales between beach ridges are corrected to estimate subsurface sedimentary contacts (lacustrine deposits) used to infer lake level elevation
- Transects for the West and East strandplains were formed to find a representative for each strandplain
- The West and East strandplains representative transects are compared to find similar elevation trends and patterns needed to create one inferred paleohydrograph pattern for the SIT
- Different rates of GIA were evaluated by comparing them to paleohydrographs in Lake Superior from Johnston et al. (2012) to the SIT inferred subsurface elevations to estimate age

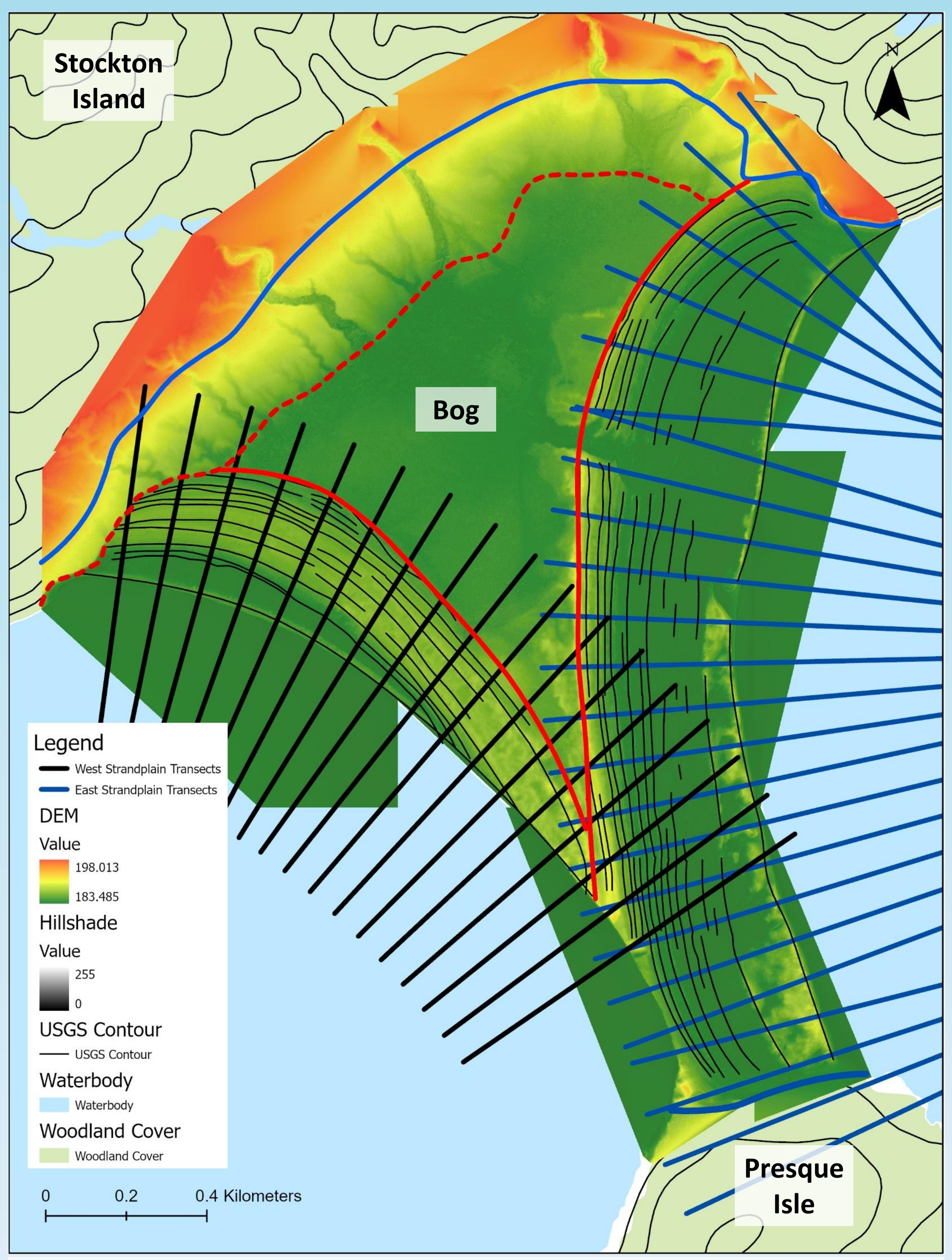

Figure 2 DEM with marked ridges and extent of the tombolo and strandplains. Ridges on both the East and West strandplains have been denoted by the thin black lines. The strandplains have been denoted by solid red lines with the bog meeting between them in the north. The northern extent is seen by solid blue line and dashed red line for a possible closer extent. Solid blue line at Presque Isle is the Southern extent. The thicker black straight lines are the West strandplain transects and the straight blue lines are the East strandplain transects.

Results and Discussion

- Sloughs and a bend in the creek on the East strandplain and position among lakeward ridges corresponds to a change in the active outlet for Lake Superior around 1060 years ago or between the Sub-Sault and Sault phases (Johnston et al., 2007, 2012)
- Compared to paleohydrograph data from Johnston et al. (2012) the lakeward (youngest) part of the remote paleohydrograph reconstruction for the SIT plotted below all others, fitting with a negative rate of GIA compared to the SSM outlet and estimated to form during the Sub-Salut phase (Mainville and Craymer, 2005; Johnston et al. 2012). The landward (oldest) part of the SIT plots above many others suggesting an older age (Figure 3)
- Data from the SIT was plotted with the outlet paleohydrograph for Lake Superior at SSM, the lakeward ridges seem to compare to the Sub-Sault phase. GIA rate of -15 cm/century appears to correlate best with evidence for the lakeward segment (Figure 4)
- Highest elevation for the Nipissing phase is 183.3m which is similar to the highest peak of the landward segment of 184.6m (Thompson et al., 2014)

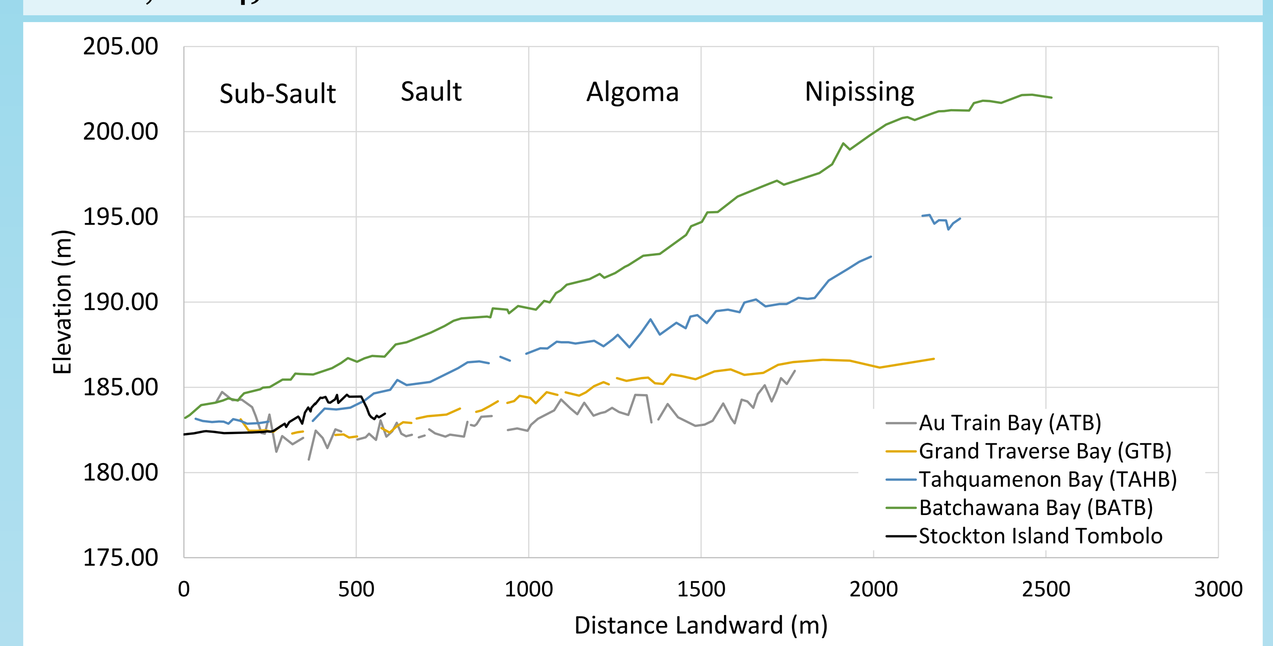

Figure 3 The Stockton Island Tombolo pattern compared to four previously reconstructed paleohydrographs. Comparison of distance versus elevation. Since the GIA is lower for the SIT than the other paleohydrograph locations the lakeward and landward SIT parts should both plot under all the curves. The lakeward part is lower in the Sault phase and the landward part is only lower in the Nipissing phase.

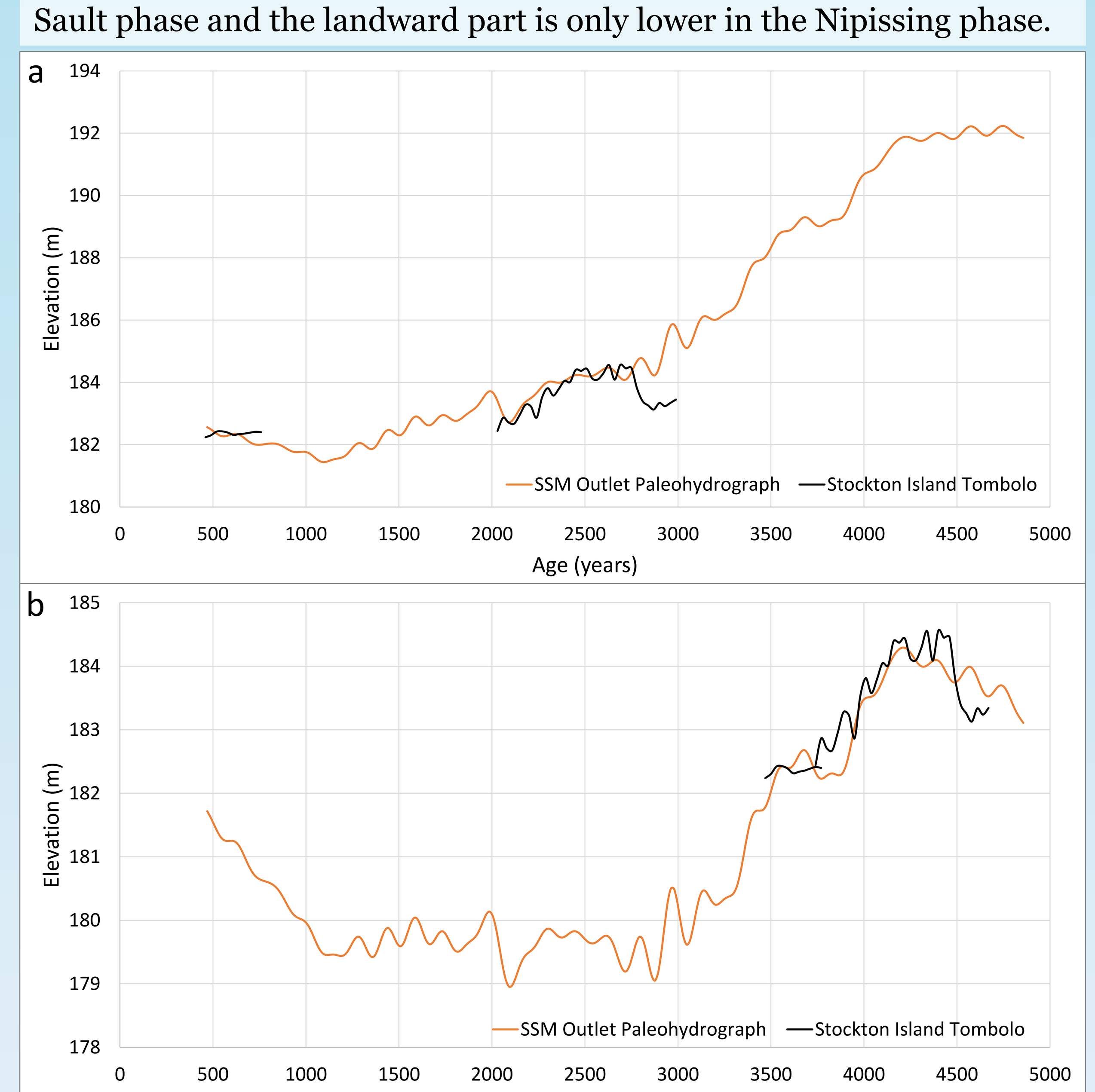

Figure 4 GIA applied to SSM outlet paleohydrograph to compare with the SIT pattern. a) Rate of GIA adjusted by -15 cm/century causing the landward and lakeward ridges to be in the Algoma and Sub-Sault phases, respectively. b) Rate of GIA adjusted by -33 cm/century causing the landward ridges to be in the Nipissing phase. SSM paleohydrograph data from Johnston et al. (2012)

Results and Discussion

- Landward ridges either corresponded to the Algoma (rate of GIA at -15 cm/century) or Nipissing (rate of GIA at -33 cm/century) phases (Figure 4). Since the active outlet during both phases is Port Huron/Sarnia and the peak Nipissing elevation at this outlet is similar in elevation at a common zero GIA isobase (Mainville and Craymer, 2005; Johnston et al. 2012) then the landward SIT segment is estimated to form during the Nipissing phase
- Since the active outlet regulating the water plane in Lake Superior is SSM, there is a continual risk of erosion and flooding at the SIT if the long-term rate of lake-level rise outpaces sediment supply. If sediment supply is faster than the long-term rate of lake level rise then the sediment may protect areas further inland

Conclusion

- The SIT landward ridges are estimated to be from the Nipissing phase while the lakeward ridges are estimated to be from the Sub-Sault phase
- The PBH mainly forms on the landward ridges, it is protected for now from erosion and flooding
- Paleohydrographic research in Lake Superior predicts lake levels are experiencing a relative rise at the SIT (long term due to GIA and short term due to climate) (Johnston et al., 2012), so the SIT and the PBH are expected to be in danger from future erosion and flooding
- The results from this thesis are expected to help guide fieldwork
- Fieldwork at the SIT can be used to evaluate methods presented in this thesis and potentially show another site, in addition to Heather (2021) where topographic elevation data can be used to reconstruct an inferred paleohydrograph

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