IMAGING OF A STRANDPLAIN ALONG LAKE SUPERIOR, HURON MOUNTAINS, MI: PRELIMINARY RESULTS FROM A GROUND PENETRATING RADAR STUDY

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ABSTRACT

The aim of the project is to study the subsurface stratigraphy of a strandplain located along the Huron Mountains, Marquette County, Michigan. The collected 600m-long shore perpendicular ground penetrating radar (GPR) transect started at the present Lake Superior shoreline and ended at the Nipissing level beach ridge. A pulseEKKO100 GPR system was utilized with 100 MHz antennae, 1.0m antennae separation, and a step size of 0.25m. The depth of penetration for the GPR profile was between 10-12m. A topographic dataset was surveyed using a Topcon RL-H3CL laser level to geometrically correct the GPR profile. The collected GPR data was processed with pulseEKKO software using trace-to-trace and down-the-trace averaging, dewow, and automatic gain control. The profile was then plotted in wiggle trace format to visualize the subsurface stratigraphy of the strandplain.

Preliminary results indicate that the lakeward inclined strandplain is progradational with periods of stillstand. The results help to better understand how Lake Superior shorelines have developed during a period of lake level drop. Knowledge of coastline processes and past development can aid in proper managing of coasts.

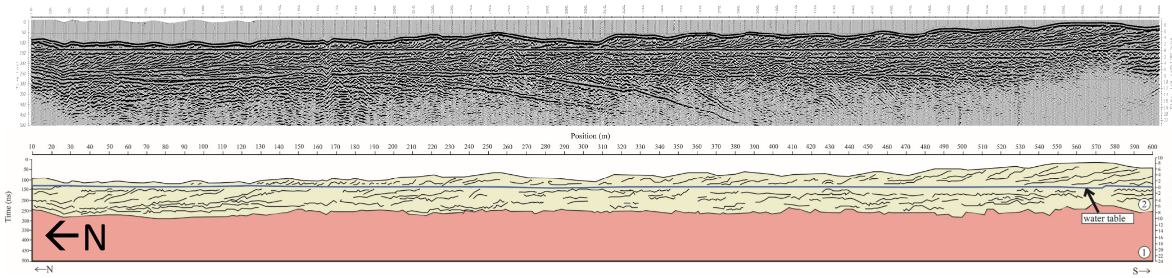

Figure 5: Processed data (upper) and interpreted data (lower) for the GPR transect. Processed data is interpreted with radar facies 1-2.

INTRODUCTION

Lake Superior is located in the central part of North America (Figure 1). It is the largest of the present-day Great Lakes and is the largest freshwater lake in the world by surface area (Farrand and Drexler, 1985). Water levels for Lake Superior have fluctuated over the years due to factors such as glacial isostatic rebound, erosion, and climatic factors (Blewett, 2012). Studying the subsurface stratigraphy of the Huron Mountains strandplain presents a unique opportunity to reconstruct how lake levels have changed on Lake Superior over the years.

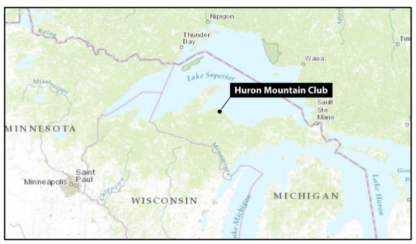

Figure 1: Small-scale map of the study area.

Figure 3: Large-scale map of the study area including the GPR line and well.

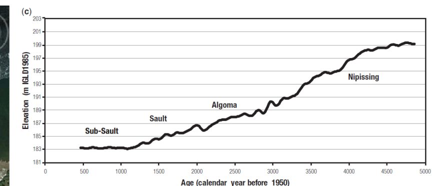

Figure 4: A paleohydrograph for Lake Superior shows the elevation of past shorelines (Johnston et al., 2012).

Formation Description	Thickness (m)	Depth to Bottom (m)
Sand	12.2	12.2
Silty Sand	3.0	15.2
Gravel & Coarse Sand	3.0	18.2
Red Sandstone White	57.3	75.5

Table 1: Well log information, provided by MacDonald Well Drilling, Inc., describes the composition of the study site.

METHODS

Ground penetrating radar (GPR) works by having antennae send out electromagnetic pulses into the ground. The pulses reflect off changes in dielectric properties of subsurface objects and sediments (Davis & Annan, 1989) and travel back to a receiver antennae on the surface. The GPR data is then stored in a computer and can be viewed in real time. While in the field, certain sampling parameters are followed when using the reflection mode for GPR. First, an appropriate step size is chosen based on the antennae frequency and horizontal resolution (distance between each collection point). For our project, a step size of 0.25m was used. Another important parameter is operating frequency, which determines the depth of penetration and resolution. Higher frequency antennae have higher resolution but smaller depths of penetration. Lower frequency antennae have lower resolution but greater depth of penetration. For our purposes, we used antennae with a 100 MHz frequency which provided the balance between depth of penetration and resolution. A third parameter is antennae separation, which helps determine the resolution of GPR images at certain depths. As the antennae separation increases, the depth resolution decreases (Jol & Bristow, 2003). Our research used an antennae separation of 1.0m. In addition, we used a common mid point (CMP) survey to determine the velocity of electromagnetic energy waves (Figure 2). The velocity, in combination with reflection time, can be used to calculate the depth of subsurface features (Jol & Bristow, 2003). Finally a Topcon RL-H3CL laser level was used to geometrically adjust the GPR data to the relief of the landscape. After the GPR data was collected in the field, it was taken back to the lab and processed using pulseEKKO software. Finally, the processed data was plotted in wiggle trace format to show the subsurface features of our research site. Subsurface stratigraphy was identified by looking at the black and white reflections on the GPR image.

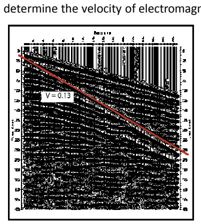

Figure 2: CMP survey determined the velocity to be 0.13 m/ns.

STUDY SITE

The strandplain under investigation is located within the Huron Mountains, Marquette County, MI (Figure 1). Marquette, MI, the largest city in the region, is roughly 30 miles southeast of the strandplain. Results from a well log determined that sand composes most of the study area (Table 1). The collected 600m GPR line started at the present Lake Superior shoreline and ended at the Nipissing level beach ridge (Figure 3). Lake Superior's water levels peaked during the Nipissing phase (Johnston et al., 2012) (Figure 4) 4,500 years ago (Fisher & Whitman, 1999). The lake level fell after the Nipissing phase until the present lake level (Johnston et al., 2012). The Nipissing phase and subsequent phases of Lake Superior influenced the formation of the investigated strandplain.

RESULTS

Facies	Radar Stratigraphic Description	Interpretation
1	Facies 1 (Figure 5) starts at 8m below the current lake level and likely descends below the depth of penetration. The facies contains hummocky reflections which toplap facies 2. Reflections in facies 1 are absent in the southern end of the transect.	We hypothesize facies 1 is red sandstone bedrock, as indicated by the well log in Table 1. Further research is needed.
2	Facies 2 is 14m thick throughout the transect. The water table runs through the middle of facies 2 at the current lake level of 0m in elevation. Above the water table the facies contains northward dipping inclined reflections which downlap the bottom part of facies 2 below the water table. Below the water table, facies 2 is concordant with facies 1. Additionally, facies 2 contains semi-continuous, subparallel reflections and inclined reflections. Periods of stillstand can be seen.	Facies 2 is the historic strandplain, and its age is unknown.

DISCUSSION

The strandplain exhibits a progradational pattern because the Nipissing ridge exists inland from the current shoreline (Figure 3). Additionally, northward dipping lines exist in the top facies of the strandplain (Figure 5), which indicate progradation (Johnston et al., 2007). The progradation cannot be fully explained, but hypotheses can be formed.

Lake Superior's lake levels have dropped since the Nipissing phase (Figure 4) (Johnston et al., 2012). Lake level drop was aided by the erosion of outlets along Lake Superior, which allowed higher water discharge (Farrand & Drexler, 1985). Also, changes in climate probably contributed to the lake level drop (Fisher & Whitman, 1999). Longshore drift, caused by wave and current activity, could have contributed sediment to the shoreline formation (Beirman & Montgomery, 2014). We hypothesize lake level drop in combination with longshore drift contributed to the progradation of the strandplain.

CONCLUSIONS

Preliminary results indicate that the lakeward inclined strandplain is progradational with periods of stillstand. The results help to better understand how Lake Superior shorelines have developed during a period of lake level drop. Further research is needed to develop a better understanding of how strandplains form.

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REFERENCES

Beirman, P.R., and Montgomery, D. R., 2014, Key Concepts in Geomorphology: New York, W. H. Freeman and Company Publishers, 494 p.
Blewett, W.L., 2009, Pictured Rocks Resource Report: http://www.nps.gov/piro/learn/nature/upload/August_2009_PIRO_Resource_Report_Blewett.pdf (accessed April 2015).
Blewett, W.L., 2012, Geology and Landscape of Michigan's Pictured Rocks National Lakeshore and Vicinity: Detroit, Michigan, Wayne State University Press, 115 p.
Davis, J.L., and Annan, A.P., 1989, Ground-penetrating radar for high-resolution mapping of soil and rock stratigraphy: Geophysical Prospecting, v. 37, p. 531-551.
Farrand, W.R., and Drexler, C.W., 1985, Late Wisconsonian and Holocene History of the Lake Superior Basin, *in* Karrow, P.F., and Calkin, P.E., eds., Quaternary Evolution of the Great Lakes: St. John's, Newfoundland, Geological Association of Canada Special Paper 30, p. 17-32.
Fisher, T.G., and Whitman, R.L., 1999, Deglacial and lake level fluctuation history recorded in cores, Beaver Lake, Upper Peninsula, Michigan: Journal of Great Lakes Research, v. 25, p. 263–274.
Johnston, J.W., Thompson, T.A., and Baedke, S.J., 2007, Systematic pattern of beach-ridge development and preservation: Conceptual model and evidence from ground penetrating radar, in Baker, G.S., and Jol, H.M., eds., Stratigraphic Analyses Using GPR: Boulder, Colorado,
Geological Society of America Special Paper 432, p. 47-58.
Johnston, J.W., Argyilan, E. P., Thompson, T. A., Baedke, S. J., Lepper, K., Wilcox, D. A., and Forman, S. L., 2012, A Sault-outlet-referenced mid- to late-Holocene paleohydrograph for Lake Superior constructed from strandplains of beach ridges, *in* Fisher, T.G., ed., Canadian Journal of Earth Sciences, v. 49, no. 11, p. 1263-1279.
Jol, H.M., and Bristow, C.S., 2003, GPR in sediments: advice on data collection, basic processing and interpretation, a good practice guide, *in* Jol, H.M., and Bristow, C.S., eds., Ground Penetrating Radar in Sediments: London, Geological Society, Special Publication 211, p. 9-27.

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