Late Quaternary Reconstruction of Lake Iroquois in the Ontario Basin of New York

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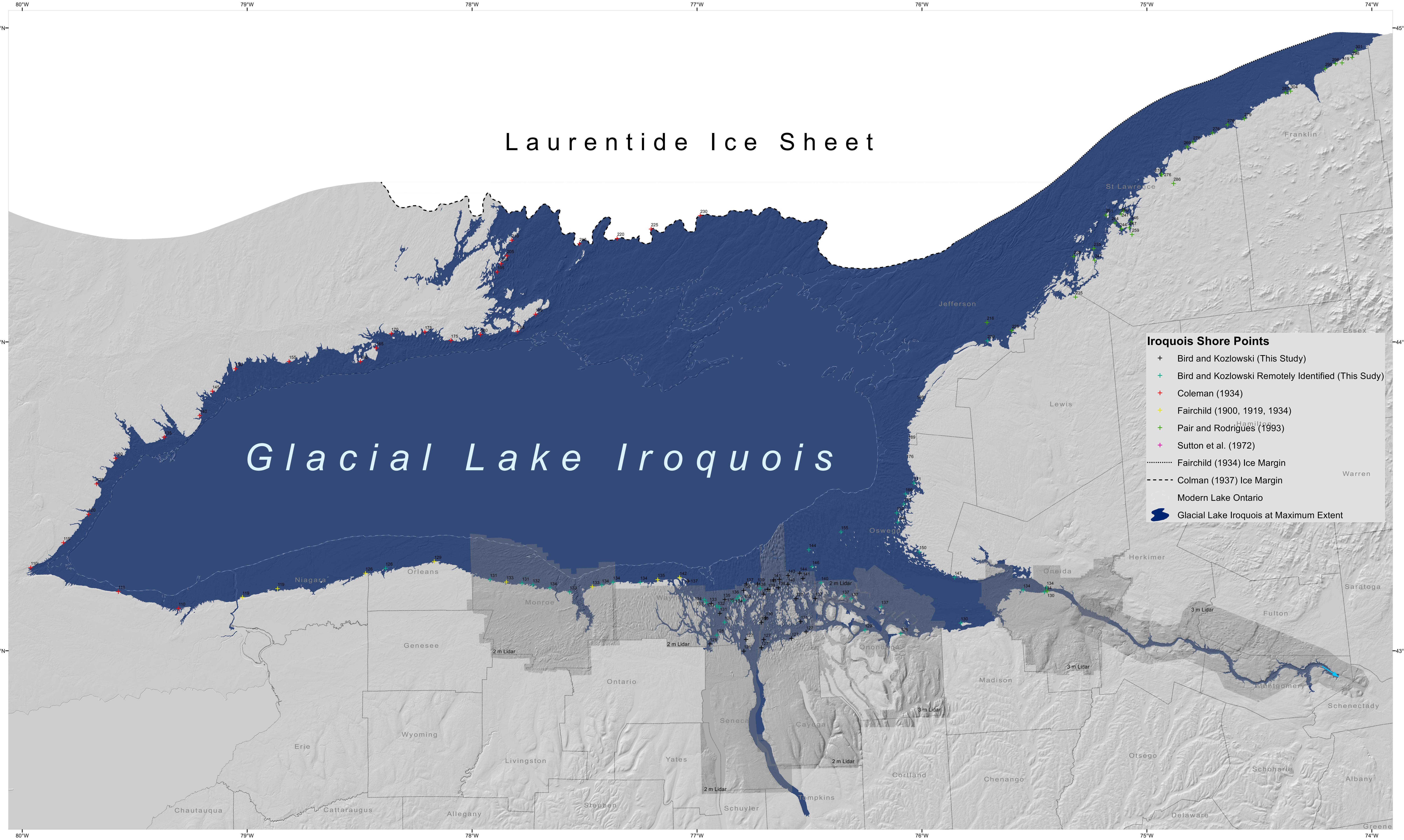
New York State Museum Map & Chart 80

2016



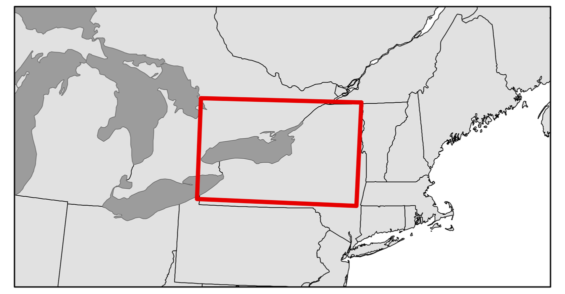
Universal Transverse Mercator, Zone 18 N
North American Datum of 1983

Base map data:
100-meter Resolution Gray Shaded Relief of the Conterminous United States from USGS
http://nationalmap.gov/small_scale/atlasftp.html?openChapters=chpgeol#chpgeol

New York State Counties and Lake Ontario shapefiles from Cornell University Geospatial Information Repository (CUGIR) http://cugir.mannlib.cornell.edu/index.jsp

Lidar Shaded Relief (2-3 m) NYS Orthos Online
https://orthos.dhses.ny.gov/

Lidar Shaded Relief (2 m) 2000 Cayuga County New York Lidar
https://www.ngdc.noaa.gov/metaview/page?xml=NOAA/NESDIS/NGDC/MGG/Lidar/iso/xml/2000_NY_Cayuga_m106.xml&view=getDataView&header=none



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Scale 1:750,000

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ISSN: 0097-3793; ISBN: 978-1-55557-348-5

INTRODUCTION

South of Lake Ontario, the Finger Lakes region of New York State is known for its diverse, glacially sculpted terrain. The renowned drumlin field in this area of New York is typically the focus of study; however this field is situated among glacial meltwater channels, glacial troughs, eskers, fans, and lacustrine features, all of which are grand in scale.

Detailed surficial mapping of Cayuga County started in 2008 by the New York Geological Survey as part of a StateMap project to map the area in and around the Montezuma Wetland Complex (Kozlowski, 2009). The initial mapping in Montezuma was expanded to include the rest of the county in subsequent years, and was being funded by the United States Geological Survey (USGS) through its StateMap program grant as well as with Great Lakes Geologic Mapping Coalition funds. Surficial mapping is at the 1:24,000 scale on 7.5 minute USGS topographic quadrangle base.

In 2008, Cayuga County was one of the few counties in New York to have complete coverage of a Lidar-based digital elevation model (DEM) image. Although features such as moraines, glacial lake shores, drumlins, eskers, etc., had been recognized on topographic maps, the enhanced detail of the Lidar-based DEM map displays these features in stunning detail as demonstrated in Figure 1. Annual moraines, ice walled lake plains, drainage channels and spillways, along with glacial lake shore features are clearly visible on the Lidar-based DEM (Kozlowski, 2011; Bird, 2014). Subtle lake shore features, difficult to see even in the field, are identifiable (Fig. 2) and were subsequently investigated across the northern portion of the county. Further investigation led to the discovery of more shore features that could be used to reconstruct glacial Lake Iroquois (GLI).

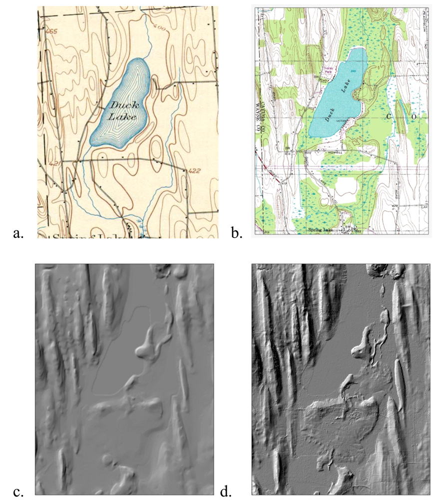

Figure 1: Comparison of an esker/fan complex on a (a)1:62,500 1905 USGS topographic map (b)1:24,000 1978 USGS topographic map, (c) a shaded relief 10 meter DEM, and (d) a shaded relief 2 meter Lidar-based DEM

The purpose of this project is to use newly acquired Lidar-based DEM data with existing data to create an updated model of GLI. For this project we used new Lidar-based DEM data from Monroe, Wayne, Cayuga, Onondaga, Seneca, Oneida, Herkimer, and Jefferson Counties to identify shore features as well as a precise elevation to reconstruct the maximum extent of GLI across the entire basin. This reconstruction capitalizes on the increased resolution of elevation to construct a map showing subtle features missed by coarser resolution maps including; Fairchild (1934), Coleman (1936), Pair and Rodrigues (1993), Rayburn (2004), Rayburn et al. (2005). The utility of this reconstruction is such that it provides a powerful tool to differentiate shoreline features associated with proglacial lakes predating and postdating GLI and also to assess proposed isostatic rebound models. Likewise a map showing the detailed extent of GLI can refine areas to investigate for late Pleistocene faunal distribution, Paleo-Indian migration routes, and assess geologic investigation sites as to the influence of GLI. Furthermore, the addition of the bathymetry from Lake Ontario and Cayuga Lake could allow for the volume of GLI to be estimated. Such estimates may prove useful for paleo-flood model reconstruction associated with the rapid drainage events proposed for the demise of GLI.

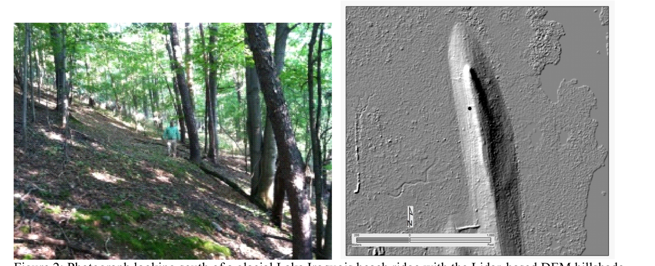

Figure 2: Photograph looking south of a glacial Lake Iroquois beach ridge with the Lidar-based DEM hillshade image of the area in the Montezuma Federal Wildlife Refuge (dot is location of photograph).

PREVIOUS MAPS

Beyond Cayuga County, the basin wide extent of GLI has been mapped by Coleman (1936), Fairchild (1900; 1919; 1934), Pair and Rodrigues (1993), Rayburn (2004), and Rayburn et al. (2005). Coleman (1936) described beach gravel, bars, and spits formed by GLI in Canada, from sites associated with mining operations near Lake Ontario. It is inferred from the manuscript that Coleman (1936) estimated shore feature elevations from 1:62,500 topographic maps published as early as 1926. Elevation of GLI shore features in Canada range from 362 feet (110 m) in Hamilton, Ontario to 730 feet (223 m) at Pancake Hill, Ontario (44.369°N, 77.434W) with the greatest rise trending N20°E (Coleman, 1936). Pivoting around a hinge line from Rome, NY to Quay, Ontario, Coleman (1936) asserted the unequal uplift across the area caused the rebound to be non-uniform. The ice margin along the northern shore of GLI was largely a calving margin and left subdued evidence of the location at the time it was creating an ice dam across the St. Lawrence River (Coleman, 1936).

Fairchild (1900; 1919; 1937) created a series of maps to illustrate the progression of lakes that covered New York as ice retreated and readvanced across the area. Using historical elevation data from railroads and canals for early works (Fairchild, 1919) later Fairchild (1934) would have access to 1:62,500 scale maps published in 1895 to use. Fairchild (1934) reports the GLI shore feature elevations in New York from 385 feet (117 m) in Lewiston, NY to 1030 feet (314 m) near Covey Hill, just north of the New York border in Canada, with the maximum uplift trending N20°E. This maximum uplift of 2.2 feet/mile (0.42 m/km) is nearly linear (Fairchild, 1919).

Rayburn (2004), working mostly in the Lake Champlain basin, identified strandline features like deltas, spits, berms, terraces and escarpments to generated a 80 m DEM of the various phases of lakes in the Lake Champlain basin and also GLI. Locations mapped with a differential global positioning system and barometric altimeter result in maximum uplift due north. Using data from Pair and Rodrigues (1993) the model was extended to the Lake Ontario basin. Pair and Rodrigues (1993) calculate the gradient of GLI to be 0.9 m/km (4.75 feet/mile) along the northwestern slope of the Adirondack Mountains.

METHODS

Shore Feature Location Points

Shoreline features, recognized on the Lidar-based DEM map in Cayuga County, were field verified and location noted with a Garmin 76CSx Golbal Positioning System while mapping the quadrangles near the Montezuma Wetlands Complex; notably the Cato, Cayuga, Fair Haven, Montezuma, Savannah, and Victor Quadrangles (Fig. 3). While many of the shore features identified in and around Cayuga County were field checked, outside the county, these were generally not field checked but assessed from the Lidar-based DEM. Elevations were determined from the Lidar-based DEM, where available, or 10 m DEM (all elevations presented are in meters above mean seal level (m)). Pair and Rodrigues (1993) elevations were used as published.

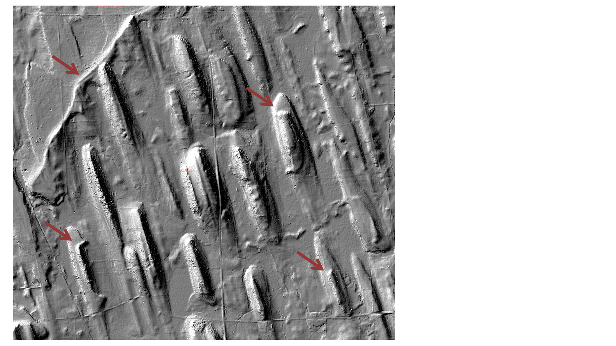

Figure 3: Wave cut terraces, bars and spits at an approximate elevation of 143 m in the northern region of the Cato 7.5 minute USGS Quadrangle. Arrows show main shore and drumlins with elliptical terraces indicating that water completely surrounded the drumlin for some period of time.

Shore location points outside Cayuga County were ascertained from previous works or identified remotely from the Lidar-based DEM. The shore of GLI in Canada was interpreted from Coleman's (1934) map of GLI. His paper map of GLI was scanned and rectified to align with a base map of roads, topography, imagery, and borders available through ArcGIS Online (2013). Rectification was accomplished by using the Georeferencing Tool in ArcMap 10.2 by importing the scanned map image and using 35 control points to align it with base map features like roads and municipal boundaries. Once the map image file was rectified and embedded with location information (NAD 1983 UTM Zone 18N for this project), it was oriented spatially in ArcMap 10.2. The partially transparent, rectified image of GLI was then draped over the DEM to identify the location of beaches, gravel and sand bars and deltas described by Coleman. As Coleman (1934) did not locate specific points on his map, only a drawn shoreline, specific points of a given elevation were generated on that line and the elevation noted.

Fairchild's (1919) map was rectified by the same method as the Coleman map. Points used to delineate the shore for this project from Fairchild's map (1919) were generated similar to Coleman's map. From the New York-Canada border eastward to Sodus Point, New York, this section of shore was marked by a prominent sand ridge approximately 4 m high stretching fairly continuous for 230 km. Near Sodus Bay the shore turns south and becomes much less continuous yet is still pronounced. Topographic profiles from the Lidar-based DEM using 3D Analyst in ArcMap version 10.2.1 of this ridge were used to determine the beach ridge elevation at each point. This method of using a topographic profile to determine the elevation of the shore feature was used for remotely identified locations as well. While Fairchild (1900) indicates some large islands on his map, these islands are absent from later maps (1919; 1934).

In Wayne, Onondaga, and Oswego Counties shore features are clearly visible on the Lidar-based DEM and the location and elevation for these features were identified from the map. Like Cayuga County, Wayne County has many drumlins across the landscape. These drumlins are often eroded at the GLI level and can be used as elevation points to further refine the model.

North of the outlet in Rome, NY, little Lidar-based DEM data exists so the shoreline is defined by data supplied by Stewart (1958) and Sutton et al. (1972) near Pulaski, NY, and by Pair and Rodrigues (1993), Rayburn (2004), and Rayburn et al. (2005) north to the Canadian border. While Stewart (1958) and Sutton et al. (1972) simply described the locations, Pair and Rodrigues (1993) and Rayburn (2004) each provided an appendix that indicates the location, elevation, and identification of the shore feature as beach, delta, or sand plain.

Isobase and Lake Extent Construction

Isobases (depicting contours of equal rise in elevation) were hand contoured at an interval of five meters (Fig. 4). The isobase elevation ranges from a low of 110 m along the southwestern shore to 310 m near Covey Hill to the northeast. The lines are oriented generally west-northwest to east-southeast direction. Maximum uplift across the basin trends N 13° E, close to Fairchild's (1934) and Coleman's (1936) value of N 20° E. These isobase lines were converted to a triangulated irregular network (TIN) using the default of Delaunay conforming triangulation, 1179 nodes, yielding 2341 triangles in ArcMap 10.2 to create a surface (Fig. 5). This TIN was used as an intermediate step to control the ultimate generation of a grid as the Topo-to-Raster Tool in AcrGIS 10.2 would not function properly if the cell size was fixed at 10 m because of computer limitations. A cell size of 10 m was chosen to match the detail of the coarsest input DEM. Isobase values along the drawn line constrain the distribution of points used in the TIN formation. The TIN was then converted to a raster grid with the intent to interact with the existing DEM. Using floating point, nearest neighbor sampling a 10 m raster grid was generated (Fig. 6). At this stage in the process the raster surface represents the surface of GLI, however, due to glacial rebound this surface is inclined northeast toward Covey Hill.

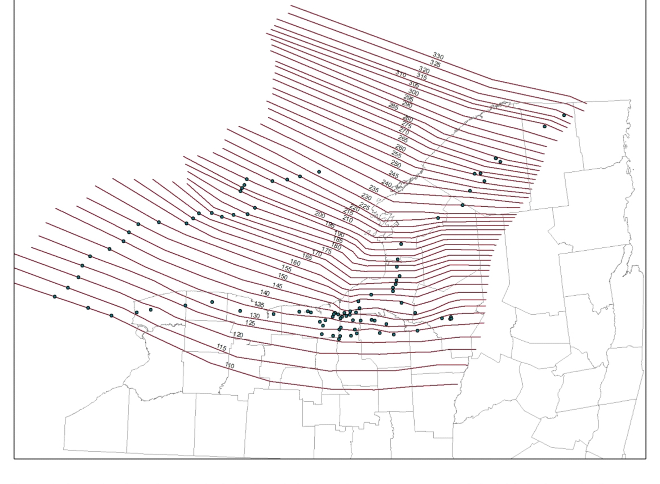

Figure 4. Isostatic rebound across the Lake Ontario basin at the maximum extent of glacial Lake Iroquois. Contour interval is 5 m.

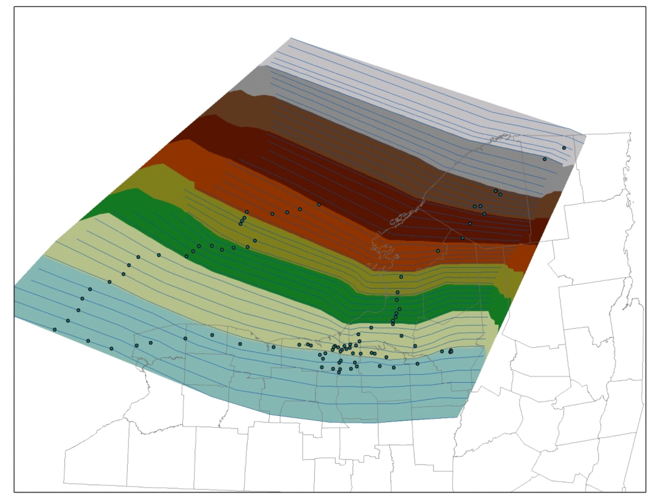

Figure 5. Triangular Irregular Network (TIN) created from the isostatic rebound isobases.

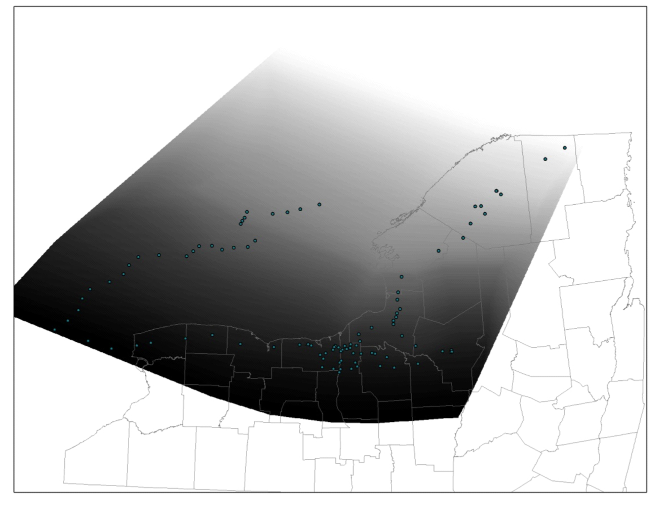

Figure 6. Raster grid created from the TIN with a 10 m cell size.

Subtracting this surface representation of GLI from the modern topography of the Lake Ontario basin yields an isostatically corrected surface representative of the topography during the time ice was pinned against the northern edge of the Adirondack Mountains. Areas below the intersection of the modern topography and the raster surface delineate the extent of GLI at this time (Fig. 7).

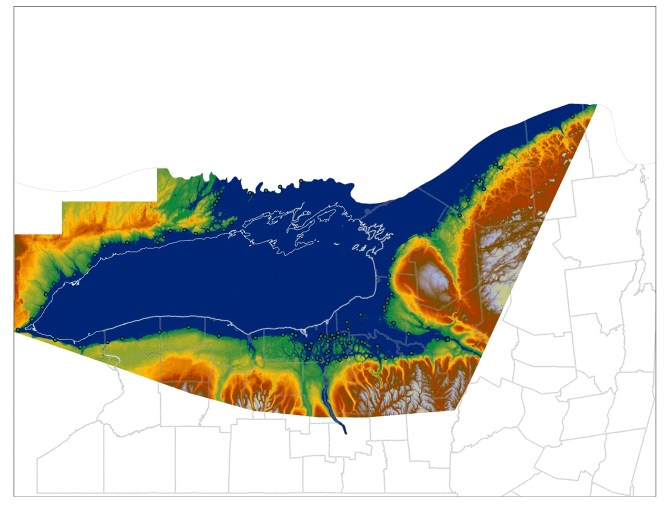

Figure 7. Topographic raster of the Lake Ontario basin corrected for isostatic depression. This raster subtracts the glacial Lake Iroquois isostatic adjustment from the modern topography to recreate the ground surface when glacial Lake Iroquois is at its maximum extent (in blue). White dashed line is modern Lake Ontario.

RESULTS AND CONCLUSIONS

The shore of GLI was roughly parallel to the modern shoreline of Lake Ontario especially along the western shore; typically 2 to 10 km onshore from modern Lake Ontario and approximately 35 meters above present lake level near Hamilton Ontario, Canada. Eastward, the shoreline of GLI extended farther from the modern shore and varies over a greater range in elevation. Modern elevation of GLI shore features range from 110 m near Hamilton, Ontario, Canada to 310 m near Covey Hill, Ontario, Canada, just north of the New York border.

General observations of GLI include: the southernmost extension into the Cayuga Lake Basin; drumlins and uplands in central New York including Wayne, Cayuga, and Onondaga Counties created an archipelago, and elevation of the lake at the outlet near Rome, NY was approximately 134 m (modern).

Strandline data were analyzed using Microsoft Excel™ by plotting the elevation of the point and its distance from Covey Hill. It was found that if distance was measured from the shore feature along a line trending N 13° E to a line passing through Covey Hill perpendicular to this trend (isobase representing the maximum rebound), the resulting best fit is linear. This trend line slope is 0.752 m/km (3.97 feet/mile) and defined with the equation; $y = -0.752x + 330$ with and R2 value of 0.9805 (Fig. 8). The intercept was fixed at 330 as a greater value would indicate water draining over land to the Champlain basin prior to the ice retreating past Covey Hill.

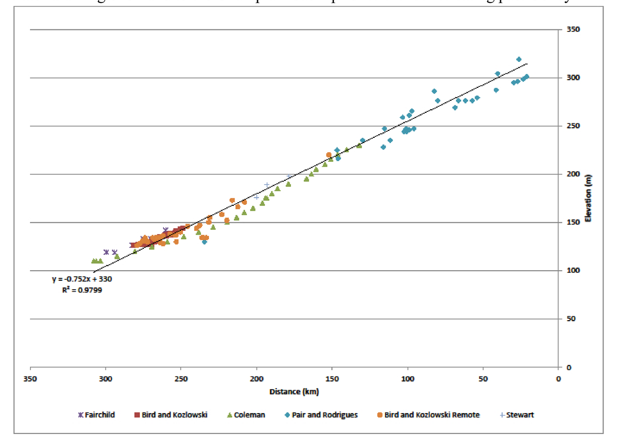

Figure 8. Strandline diagram for maximum extent of glacial Lake Iroquois.

Although the resulting trend line is linear, the southerly bulge in the isobase lines in the southeastern portion of the lake suggests that the isostatic depression was not completely uniform across the basin. Isobase lines previously have been depicted as generalized, uniformly spaced lines across the area either as straight lines (Fairchild, 1934), mostly straight in central and western New York but slightly curving across the state (Rayburn, 2004, 2005), or curves across the northern portion of the state (Pair and Rodrigues, 1993). Unlike previous models, this model shows more curvature to include elevation values from the western shore from Coleman (1936) and also displays a southerly bulge which may reflect the influence of the Oneida Lobe that readvanced to Rome, NY as suggested by Ridge (2004). This lobe of ice could have created a localized increase in isostatic depression, thus warping the isobase lines southward slightly in the Oneida Lake area.

To date this map reconstruction provides the most comprehensive and due in part to incorporation of Lidar-based DEM data the most precise depiction of GLI. Continued work can and should refine this map further as more Lidar-based data become available, most notably in Niagara, Orleans, St. Lawrence, Oswego, Madison, Jefferson, and sections of Wayne Counties. Lidar-based DEMs in the northern areas of the state will likely expose subtle shore features and the subdued ice marginal locations. As suggested earlier this reconstruction may serve as guide for future researchers evaluating sites for: late Pleistocene faunal distribution, Paleo-Indian migration routes and geologic studies. Furthermore the addition of the bathymetry of Lake Ontario and Cayuga Lake could allow the volume of GLI to be estimated. Such estimates may prove useful for paleo-flood model reconstruction associated with the rapid drainage events proposed for the demise of GLI.

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