Undergraduate Honors Seminar: The Black River Delta as Proxy Evidence for Easterly Winds in Glacial Lake Algonquin

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Abstract

This study was the focus of a freshman Honors Seminar at MSU, UGS 200H, supervised by Dr. Randall Schaetzl (Geography). Our study area consisted of a Late Pleistocene delta, formed by the Black River in Glacial Lake Algonquin, between about 13,100 and 12,500 years ago (Figs. 1, 3). The purpose of this study was to describe, map and interpret the physical characteristics of the Black River Delta, in northern Lower Michigan. The delta is composed of uniformly dry, well sorted sands, mostly within the medium and fine sand fractions. Sediment data taken at 153 sites across the delta show that coarser sands and gravels are concentrated near the shoreline, probably due to erosion of the bedrock and glacial till that outcrop there. The finest sands and silts are concentrated in the SE corner of the delta, and continue as a plume that traverses the center of the delta from SE to NW. This sediment plume is interpreted as the product of westwardly flowing longshore drift within the lake, driven by intense easterly winds. Spits in the SE part of the delta also suggest that strong easterly winds existed while the delta was forming. These winds were probably associated with a glacial anticyclone that existed above the ice sheet. Dunes on the east bluff of the Black River, dated between 9,300 and 8,300 years ago using optically stimulated luminescence techniques, confirm that winds had turned westerly by this time.

Methods

Soil samples, taken using an auger and located with a GPS, were taken at 153 sites on the delta (Fig. 4), exclusive of shoreline areas. Sediment sample composition was analyzed by dry sieving and laser particle size diffraction. After sediment analysis, kriged maps of particle size distribution and soil type across the delta were created in ArcGIS 10.

Three sand dunes on the bluffs adjacent to the Black River, thought to have formed shortly after the lake drained, were also sampled and analyzed using OSL dating. These samples were taken from pits exposing the C horizon of soils within the dune crests.

Clast samples were taken from two ridges on the delta thought to be spits. Sphericity and roundness were determined on 63-86 rocks per site, using a standard sphericity and roundness chart.

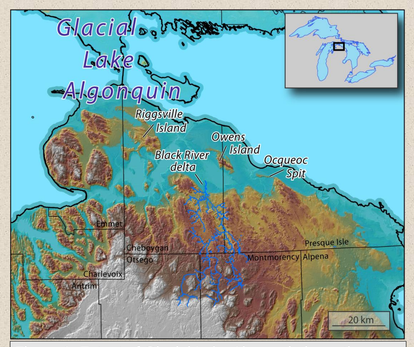

Figure 1. Extent of Glacial Lake Algonquin in northern lower Michigan, based on Drzyzga et al. (2012). This map shows the prominent physical features of the region, and the location of the Black River delta. The Black River and its tributaries are shown in blue.

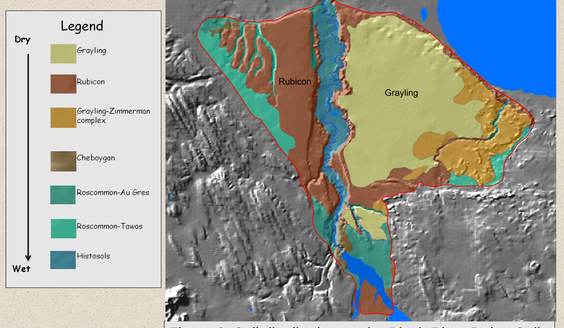

Figure 2. Soil distribution on the Black River Delta. Soils were mapped with the assistance of NRCS county soil survey data. Drier, sandier soils were observed near the center of the delta to the east of the river channel.

Study Area

Figure 3. The Black River Delta at the time of Lake Algonquin.

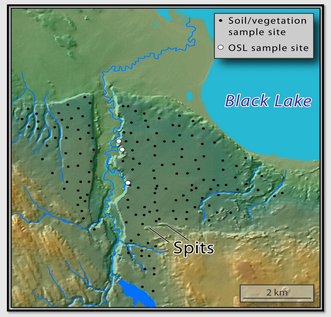

Figure 4. Locations of the 153 samples taken on the Black River Delta. OSL sample locations are highlighted in white.

Paleoclimate Scenarios for the Black River delta

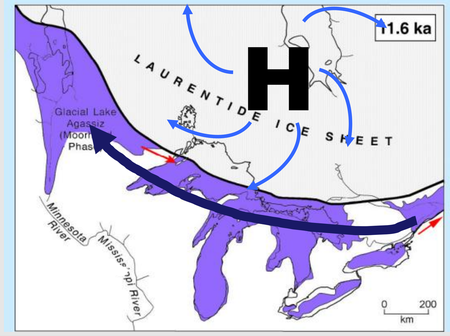

Figure 5. Hypothetical scenario showing how a glacial anticyclone above the Laurentide Ice Sheet could have resulted in strong easterly winds during the Late Pleistocene, for the study area. Red arrows indicate flow of water from lake-to-lake.

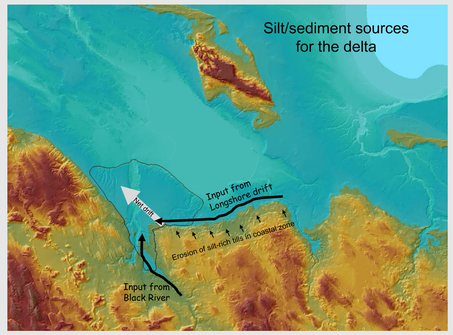

Figure 6. Directions of sediment input to the Black River delta. Silts and very fine sands are eroded from shoreline areas and transported, via longshore drift, to the delta. The river itself transports sediment mainly northerly. The resultant NW flow paths on the delta are reflected in the sediment data shown in Figure 3.

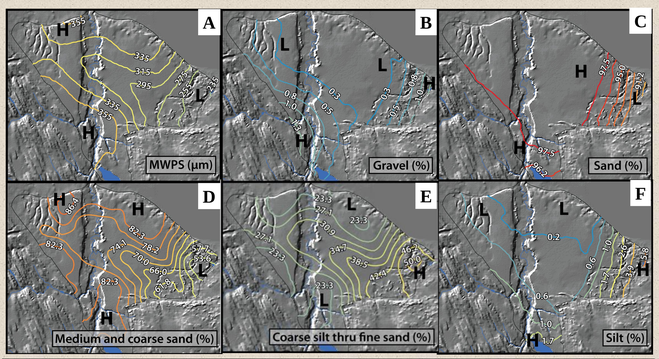

Figure 7. Sediment distribution of various particle size fractions, labeled in the lower left hand corner of each map. Sediment plumes show clear evidence of westerly longshore currents, as modified by westwardly flowing longshore currents (A, D and E).

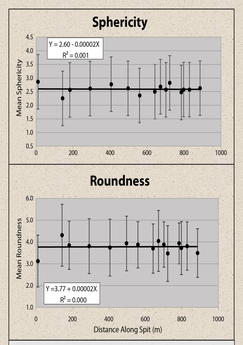

Figure 8. The lack of change in roundness and sphericity along the spits indicates that they were formed quickly, possibly by one storm, limiting the amount of time stones could have been worn down and rounded.

Acknowledgements

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Results and Discussion

Formation and incision

Sediment deposition on the Black River Delta originally began when Lake Algonquin's levels were at its high (Main stage) point (Fig. 1). When Lake Algonquin drained rapidly due to the opening of North Bay outlet in Canada, the Black River began to incise the delta, forming a deep valley. Sand dunes formed along the eastern margin of the valley only, suggesting that winds at this time had been westerly. OSL ages on sand dunes from the eastern bluff indicate range from 8,300 to 9,300 yeara ago, suggesting that this river incision event had largely ended by 8,300 years ago. These data also confirm that winds had become westerly by 9,300 years ago.

Soils and sediments

Maps created for the project show the details of this dry, sandy delta (Fig. 2). Delta sediments average 99.2% sand, dominated by medium and fine sands. Grain sizes rarely were outside of medium sand fraction, suggesting that the river was depositing well-sorted and washed, sandy bedload. Sediment deposition rates were calculated using the delta's estimated volume and the 1,700 year duration of Glacial Lake Algonquin. Deposition rates were astonishingly high, averaging 356,900 m^3 of sediment to the delta, per year, or ~4,500 tons annually. The smooth, symmetrical shape of the delta supports the assumption of rapid depositional rates.

Sediment distribution patterns across the delta reveal an unmistakable sediment plume traversing from SE to NW (Fig. 7). This pattern is explainable by two main processes (1) northerly transport of sands onto the delta, by the Black River, and (2) westerly longshore transport of silts and fine sands, driven by easterly winds (Fig. 6). The Black River Delta lies in a sheltered area, with longshore forces being deflected by the Ocqueoc headland, and impacted by Owens Island (Fig. 3). For such prominent east-to-west sediment transport patterns to have developed suggests that this region was dominated by steady, easterly winds rather than by strong waves driven by high force winds. These data may be the first proxy paleoclimate data of their kind for easterly winds near the margin of the Laurentide Ice Sheet.

Delta landforms

Deltaic structural analyses point to a wave-dominated, arcuate delta. Rapid deposition and westerly longshore drift contributed to the formation of the delta. Two spits, near the head of the delta, extend westward onto the delta proper, from a small headland. They, too, indicate easterly winds. Spit elevation and the absence of variation in roundness and sphericity among clast samples taken on the spits suggest that they were formed in one, or a few, large storm events, probably early in the development of the lake.

Conclusions

Sediment patterns on the Black River delta reflect, first, northward fluvial transport of large amounts of medium-fine sand bedload, onto the delta proper. Most of these sediments were widely distributed across the delta, although the delta front developed a steep but smooth margin, presumably due to string wave action. Shoreline erosion processes also contributed gravel, fine sand and silt to the margins of the deltaic system. Gravels and very coarse sands remained preferentially concentrated in these shorezone areas, while the finer sands were transported westwardly and northerly, by longshore currents, out, onto the delta proper. We suggest that this pattern developed because of easterly winds, driving westwardly flowing littoral currents. This research, using paloeclimate proxy data from the Black River delta, supports the notion, first put forth by the COHMAP Members (1988), of easterly winds coming from a glacial anticyclone during the Late Pleistocene, in this area.

References

COHMAP Members. (1988) Climatic changes of the last 18,000 years: Observations and model simulations. *Science,* Vol. 241, 1043-1052.

Drzyzga, S. A., Shortridge, A. M., and Schaetzl, R. J. (2012) Mapping the stages of Glacial Lake Algonquin in Northern Michigan, USA, and nearby Ontario, Canada, using an isostatic rebound model. *Journal of Paleolimnology*, Vol. 47, 357-371.