Geomorphology 303 (2018) 155–161

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Laurentide ice sheet meltwater routing along the Iro-Mohawk River, eastern New York, USA

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ARTICLE INFO

Article history:
Received 20 June 2017
Received in revised form 30 November 2017
Accepted 1 December 2017
Available online 5 December 2017

Keywords:
Pothole
^{10}Be dating
Strath terrace
Meltwater
Ice sheet

ABSTRACT

The rerouting of meltwater as the configuration of ice sheets evolved during the last deglaciation is thought to have led to some of the most significant perturbations to the climate system in the late Quaternary. However, the complex pattern of ice sheet meltwater drainage off the continents, and the timing of rerouting events, remains to be fully resolved. As the Laurentide Ice Sheet (LIS) retreated north of the Adirondack Uplands of northeastern New York State during the last deglaciation, a large proglacial lake, Lake Iroquois, found a lower outlet that resulted in a significant flood event. This meltwater rerouting event, from outflow via the Iro-Mohawk River valley (southern Adirondack Mountains) to the spillway at Covey Hill (northeastern Adirondack Mountains), is hypothesized to have taken place ~13.2 ka and disturbed meridional circulation in the North Atlantic Ocean. However, the timing of the rerouting event is not certain because the event has not been directly dated. With improving the history of Lake Iroquois drainage in mind, we obtained cosmogenic ^{10}Be exposure ages on a strath terrace on Moss Island, along the Iro-Mohawk River spillway. We hypothesize that Moss Island's strath terrace became abandoned during the rerouting event. Six ^{10}Be ages from the strath surface average 14.8 ± 1.3 ka, which predates the previously published bracketing radiocarbon ages of ~13.2 ka. Several possibilities for the discrepancy exist: (1) the ^{10}Be age accurately represents the timing of a decrease in discharge through the Iro-Mohawk River spillway; (2) the age is influenced by inheritance. The ^{10}Be ages from glacially sculpted surfaces on Moss Island above the strath terrace predate the deglaciation of the site by 5 to 35 ky; and (3) the abandonment of the Moss Island strath terrace relates to knickpoint migration and not the final abandonment of the Iro-Mohawk River as the Lake Iroquois spillway. Further study and application of cosmogenic ^{10}Be exposure dating in the region may lead to tighter chronologic constraints of meltwater history of the LIS.

1. Introduction

The Laurentide Ice Sheet (LIS) reached mid-latitude North America multiple times during Quaternary glaciations (e.g., Young and Burr, 2006; Balco and Rovey, 2010). While there, the time-transgressive LIS margin impounded various phases of proglacial lakes and led to significant meltwater rerouting (Muller and Prest, 1985; Muller and Calkin, 1993; Kehew et al., 2009). During the last deglaciation, meltwater routing events spilling into the North Atlantic Ocean have been proposed to be the cause of significant regional and global abrupt climate change (Rayburn et al., 2011; Carlson and Clark, 2012).

One region where meltwater flowed to the North Atlantic was across New York State, carving channels that document the complex interplay between the ice margin, the routing of its meltwater, and the spillover of former proglacial lakes (Fairchild, 1909; Muller and Prest, 1985). One such lake, Glacial Lake Iroquois (GLI), which occupied the present-day Lake Ontario basin and the adjacent low-lying areas (Fairchild, 1909; Muller and Prest, 1985; Pair and Rodrigues, 1993; Bird and Kozlowski, 2016), was involved in a major flood as its meltwater was re-routed (Franzi et al., 2016). Prior to the LIS retreating north of the Adirondack Uplands, the Lake Iroquois outflow was routed through a spillway near Rome, NY, and along the Mohawk River valley in central-eastern New York. The spillway subsequently reaches the Hudson River valley and eventually the North Atlantic Ocean (Pair and Rodrigues, 1993; Rayburn et al., 2005; Fig. 1). However, as the LIS retreated north of the Adirondack Uplands, a lower spillway of Lake Iroquois was uncovered at the Covey Hill col. This event prompted a significant flood event through the glacial Lake Vermont basin and eventually down the Hudson River Valley (Pair and Rodrigues, 1993; Rayburn, 2004; Rayburn et al., 2005; Franzi et al., 2007, 2016; Fig. 1). Rayburn et al. (2005) estimated a meltwater flux to the North Atlantic of 30–60 km^3/s (0.03–0.06 Sv) for this event. They credit this event with the drop of Lake Iroquois from its main level (Mohawk River valley spillway) to its Frontenac level (Covey Hill spillway) and estimated a volume change of 570 ± 85 km^3. Pair and Rodrigues (1993) determined that the lake level dropped ~120 m in total (though incrementally) as

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https://doi.org/10.1016/j.geomorph.2017.12.001

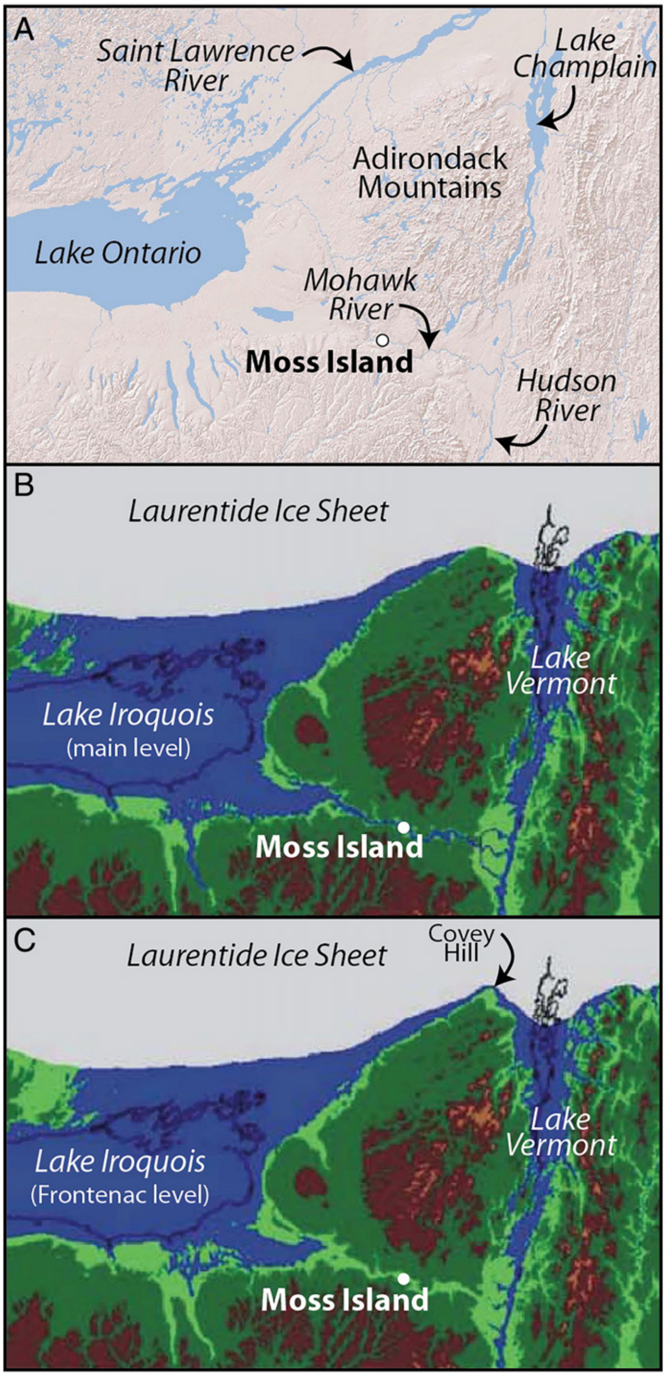

Fig. 1. The region surrounding Moss Island, New York. (A) Shaded relief map showing important place names in the region. (B) Lake Iroquois at its most extensive (main phase) level, when the lake drained into the Mohawk River valley. (C) Lake Iroquois at the Frontenac level, when a lower spillway was reached north of the Adirondack Mountains and into Lake Vermont. (B) and (C) modified from Rayburn et al. (2005).

the LIS retreated north of the Adirondack Uplands; and the largest drop, ~80 m, occurred when the Covey Hill spillway was initiated.

The age of the drainage event is constrained by maximum and minimum radiocarbon ages, and the flood history is described in detail in Donnelly et al. (2005), Rayburn et al. (2005), and Franzi et al. (2007). Balco et al. (2009) used ^{10}Be measurements from the boulder bar formed during the event as one of several ^{10}Be production rate calibration sites in the formulation of the northeastern North America production rate value. The flood event postdates radiocarbon-dated material from Lake Iroquois maximum highstand sediments, which is 13,730–14,230 cal YBP (Karrow, 1981). The flood also postdates a radiocarbon-dated musk-ox bone associated with a preflood ice margin position that is 13,440–13,020 cal YBP (Rayburn et al., 2007). The flood predates a drop in the level of glacial Lake Vermont, which took place prior to 12,995–12,793 cal YBP (Rayburn et al., 2007). In addition, the flood event pre-dates the eventual drainage of Lake Vermont and the establishment of marine conditions in the Champlain Sea that has been dated at 13,187–12,872 cal YBP (Richard and Occhietti, 2005) and 13,124–12,853 cal YBP (Franzi et al., 2007). Taken together, the best estimate for the flood age based on the above radiocarbon constraints calculated by Balco et al. (2009) was 13,180 ± 130 cal YBP.

To improve our understanding of the characteristics and chronology of this meltwater rerouting event, we have applied cosmogenic ^{10}Be exposure dating to a strath terrace within the Mohawk River valley that we hypothesize was abandoned during the meltwater-rerouting event (Fig. 2). The Mohawk River valley spillway was the initial drainage route from Lake Iroquois to the Hudson River valley (Brigham, 1897; Fullerton, 1980; Pair and Rodrigues, 1993). If the strath terrace was abandoned during the rerouting event, we might expect an age of around 13,200 cal YBP.

2. Moss Island, NY

Moss Island sits adjacent to the present-day Mohawk River in Little Falls, NY (Fig. 2). It is an island in the sense that it lies between the New York State Canal System (successor to the Erie Canal and other canals within NY) and the Mohawk River. The main body of Moss Island is ~500 m long and ~200 m wide. The Moss Island/Little Falls area is unique among locations along the Mohawk River because it flows across a fault-bounded, upthrown block of basement crystalline rocks consisting of charnockitic, granitic, and syenitic gneisses; whereas elsewhere the river flows across Paleozoic sedimentary rocks that are significantly more erodible than the crystalline lithologies (Fisher et al., 1970; Agle et al., 2005). The lithologies in the upthrown block are variably leucocratic (containing varying amounts of biotite, hornblende, and pyroxenes) and may contain interlayered amphiboles, metasedimentary gneisses, and migmatites. The lithologies at Moss Island itself consist of syenite with common quartz veins ranging in width from <1 cm up to a few decimeters.

The elevation of Moss Island ranges between river level [~98 m above sea level (asl)] and a crest of ~136 m asl. The southern slope of the island was blasted for the Erie Canal and Lock E-17, the tallest lock in New York (12.3 m lift) and one of the largest of its kind in the world (Bowers and McNulty-Bowers, 2010). Along Moss Island's northern margin, and parallel to the course of the Mohawk River, is an uneven surface notable for its large potholes that is ~5–20 m above river level. Above this surface is the upper portion of the island, which exhibits glacially sculpted and smoothed bedrock with glacial polish on quartz vein surfaces.

The glacial history of Moss Island is not completely known. However, despite a lack of chronological information from the Moss Island region, we can generally outline the timing of the last glaciation by drawing on regional studies. The timing of when the LIS advanced to the region during the LGM is not known with precision, but some data constrain the advance phase of the Hudson-Champlain lobe toward its maximum position to ~28–26 cal ka BP (e.g., Fullerton, 1986; Stone and Borns, 1986; Rayburn, 2015). Corbett et al. (2017) dated the terminal moraine in northern New Jersey, roughly due south of Moss Island, to 25.2 ± 2.1 ka using cosmogenic ^{10}Be exposure dating. This age is similar to ^{10}Be ages from the terminal moraine in southern New England of 27.5 ± 2.2 ka (Balco et al., 2002; Corbett et al., 2017).

In terms of deglaciation, the classical works by Fairchild (1909, 1912) outlined a history of ice lobes, proglacial lakes, and meltwater routing in New York State. Despite a lack of chronology, Fairchild (1909, 1912) depicted the overall pattern of the ice sheet configuration during the deglaciation of New York. Later work, summarized by Muller