# NEW INSIGHTS INTO GLACIAL LAKES VERMONT AND ALBANY

By

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## INTRODUCTION

The first comprehensive study of the proglacial lakes in the Hudson and Champlain Valleys was published by J.B. Woodworth in 1905 (NYSM Bulletin 84). He noted that "*Lake Albany doubtless began on the south in the waters standing in front of the retreating ice sheet prior to the opening of the Mohawk outlet of the great glacial lakes to the west. As soon as the ice retreated in the valley to a position north of Albany and the drainage of Lake Iroquois came into the Hudson Valley Lake Albany properly came into existence*". While glacial lacustrine sediments in the Champlain Valley were originally attributed by Upham (1889), Baldwin (1894), Peet (1904), and others to be a separate Glacial Lake Champlain, Woodworth notes that its confines were somewhat larger and proposed the name of Glacial Lake Vermont, and that to the south it was certainly confluent with Glacial Lake Albany as he defined. "*The outlet of theses ice-dammed waters at this early stage of confluence across the present divide of the Hudson and Champlain basins is a matter which concerns the interpretation of Lake Albany on the south and is considered in that connection. Lake Vermont may be said properly to have come into existence when in consequence of a local lowering of waters south of Fort Edward a discharge began across a barrier into the Hudson Valley to the south.*"

While Woodworth (1905) only described one Lake Albany level, he noted under Lake Vermont that there were the Quaker Springs, Coveville, and Fort Edward levels. Of these, Woodworth stated that "*The question of the outlets of Lake Vermont … has not been completely exploited as yet by field work*". The Fort Edward level outlet, better defined by Chapman (1932) as the Fort Ann outlet (see also DeSimone et al., 2008 NEFOP Field Guide Stop "Chapman's Potholes"), is the only one that truly meets his definition of Lake Vermont. Although Chapman recognized several separate Fort Ann levels, only the lowest of these may actually have been confined north of the Champlain-Hudson divide. Woodworth and later Fairchild (1917), Stoller (1922), and Chapman (1937), suggested that the Coveville level threshold is represented by a channel overhanging the Hudson River near Coveville, NY. There are two significant problems with this hypothesis however: 1) the bedrock that this channel is formed in is generally too soft to have withstood the estimated steady-state discharge of the pro-glacial lake and 2) more recent mapping demonstrates that Coveville level strandlines exist south of this location.

## GLACIAL LACUSTRINE SEDIMENTATION

The large glacial meltwater reservoirs of glacial Lakes Albany and Vermont were aligned north-south along the Hudson and Champlain valleys of eastern New York (Fig. 1). Although separately defined, they were actually separate stages of the same reservoir, but because of a continuously receding northern margin and dropping levels caused by changes due to threshold variation, generally recognized as "Lake Albany" when primarily located in the Hudson Valley, and "Lake Vermont" when primarily located in the Champlain Valley. The separate levels of these lakes are also recognized by sub-stage names. There is some disagreement in the literature about the name when the body of the lake was primarily straddled across the Hudson-Champlain basin divide. This configuration has occasionally been recognized as "Lake Quaker Springs" or the Quaker Springs level of Lake Albany.

Sedimentation into the glacial lake was significant, coming either from the melting Laurentide ice, or from significant fluvial systems developing to the east and west of the lake. In the deeper areas along the axis of the Hudson and Champlain Valleys this resulted in sometimes hundreds of meters of clay or clay/silt varved deposits. These deposits, where exposed in the Hudson Valley following the complete drawdown of the glacial lake, later became the source material for brick manufacturing and within the exposed walls of these brickyards Antevs (1922, 1928) was able to make his measurements and correlations that began the high-resolution chronology for the lake.

In the Champlain Valley, these thick fine-grained deposits remain submerged in the deepest locations under modern day Lake Champlain (cf. Cronin et al., 2008). Shallower water sand and silt deposits are also often preserved as varves where they accumulated below wave-base. Broad shallow water lacustrine sands are evident in areas where the water was too shallow to preserve annual variation in sedimentation. These areas are now often expressed as dune fields, such as the large region of mostly parabolic dunes in the Albany Pine Bush and points north through Saratoga County.

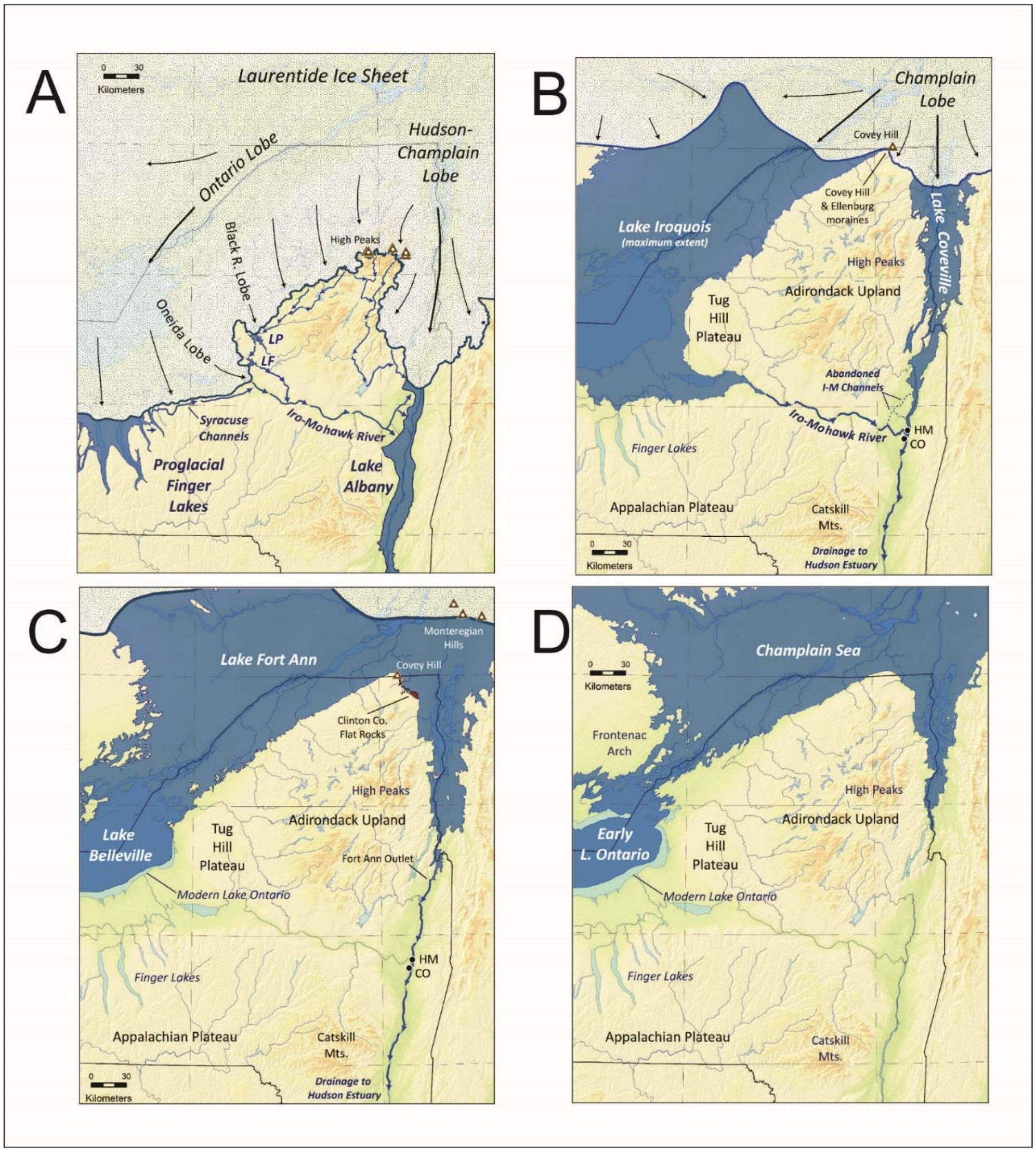


Figure 1. Development of glacial lakes Albany (A), Iroquois (B), Vermont (B&C) and the Champlain Sea (D). From Franzi et al. (2016).

Glacial lacustrine shoreline features include deltas, beach berms, and beach scarps. Of these, the deltas are the most prevalent and often easiest to locate (Figure 2). Large complex deltas are found in all major alluvial inputs to the valleys such as the Saranac, Ausable, Boquet, Winooski, Batten Kill, Hoosic, and Mohawk Rivers. The complexity of these deltas is primarily due to the progressive lake stage lowering which would initiate incision into the existing delta surface and deposition in equilibrium with the new level, sometimes along the edge of the delta and sometimes farther down-valley depending on the relative base level drop and the gradient of the valley floor. Smaller stranded deltas associated with creeks or streams have also been preserved but are sometimes harder to locate. Stranded beach berms can be found where there was less of a direct alluvial influence, a source of coarse material to rework, and sufficient fetch or current across the lake to generate the berm. Examples of these are easily seen along the eastern shoreline north of Troy, NY where the lake was quite wide and a primary west wind (in agreement with the parabolic dune morphology) allowed waves to act on thick glacial fluvial deposits. Beach scarps form under similar conditions, but where the sediments are cohesive fine-grained material.

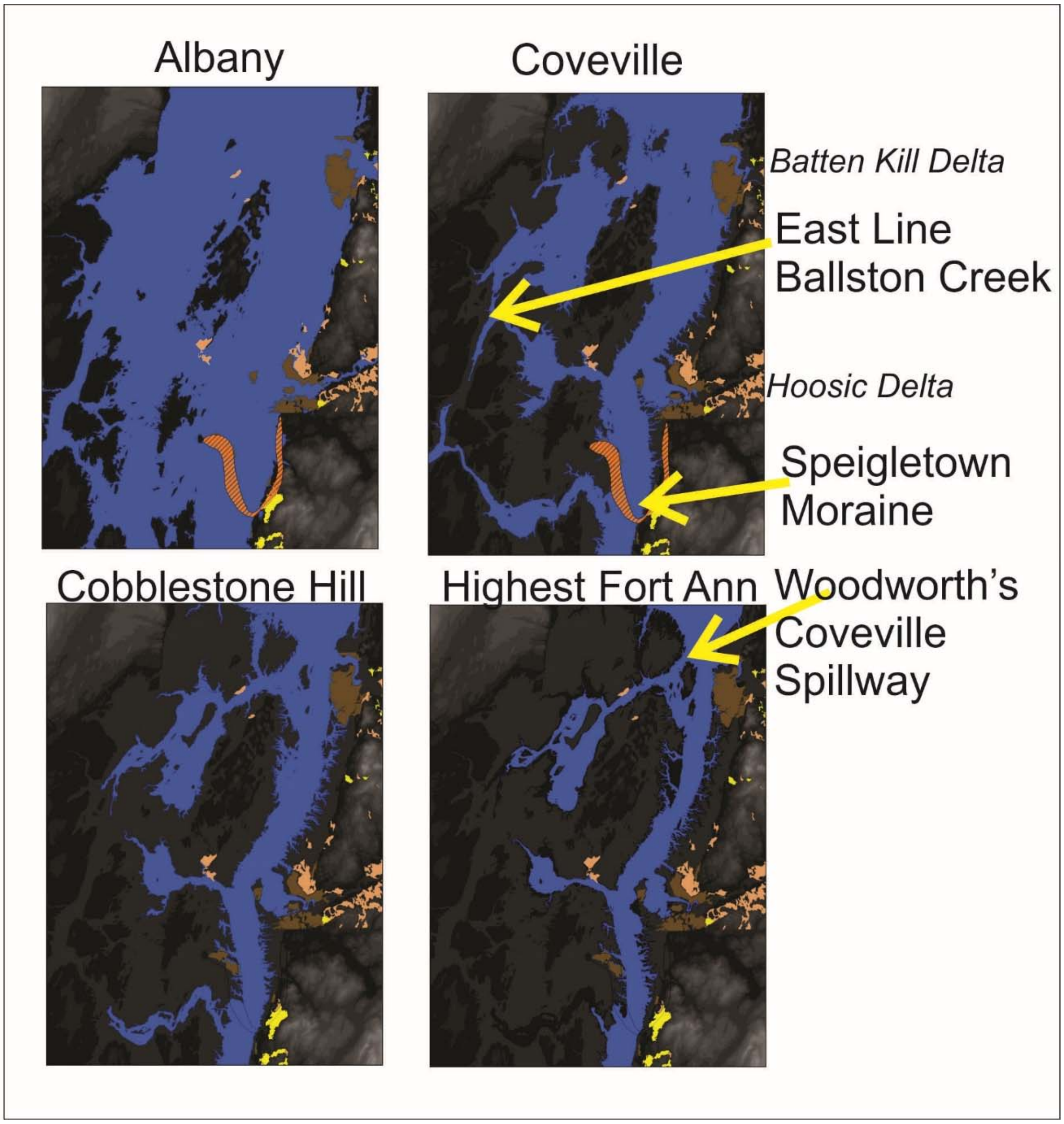


Figure 2: GIS models of lake levels in the Hudson Valley between Glens Falls and Troy. Mapped surficial geology from Schock (1963) and DeSimone (2016). Representation of the original full extent of the Speigletown kame moraine complex is estimated for Albany and Coveville levels.

Care must be taken, however when mapping lacustrine sediments in the Hudson and Champlain valleys to note the elevation, position in the valley, and relation to ice margin indicators before assigning the deposit to a level of Lake Albany or Lake Vermont. Glacial ice either behaving as a lobe around an upland, or melting in the uplands before the lowlands, is likely to trap meltwater in the lateral upland valleys as an isolated smaller and higher elevation glacial lake (cf. Franzi et al, 2016). These smaller lakes, dammed from the main valley by ice and controlled by local thresholds, may be significantly large, deep, and long lived to produce lacustrine features similar in scale to what might be expected by the main valley lake at that location. These lacustrine deposits will eventually be incised when the ice dam melts away but a significant area of stranded lacustrine deposits are likely to remain. The result in the Hudson and Champlain valleys is that those lacustrine deposits will pre-date the main valley deposits immediately adjacent, and the shoreline elevations will be higher, due to the local threshold.

## ICE MARGIN INDICATORS

We might conveniently distinguish between ice margin indicators typically found in upland tributary regions from the Hudson-Champlain lowlands. In the uplands, mapping ice margins often relies upon recognition of kame moraines, heads of outwash, kame deltas and less common till moraines. Identification of ice margins across the interfluves between tributary valleys has traditionally been much harder. However, the advancement in the use of Lidar hillshade maps has made inroads and turned often problematic correlations between tributaries into more confident correlations (Barclay, 2018). Kame moraines have been most helpful in the region adjacent to the middle Hudson lowland of this trip. Indeed, the term kame moraine was defined by Taylor (1903) during his mapping of the Hoosic River drainage basin in the early decades of the 20$^{th}$ century. Kame moraines have been more frequently identified than other upland ice marginal deposits in the Taconic Highlands and southwestern Vermont.

Hudson-Champlain lowland ice margins are most readily identified by kame deltas sourced from subglacial meltwaters that may be preserved isolated on the lowland floor surrounded but not completely buried by deeper water fine grained lacustrines. As an example, Schock (1963) mapped the Troy North 7.5 minute quadrangle and identified 2 adjacent kame deltas with different topset elevations. Kame moraines and kame terraces deposited along the junction of the lowland and uplands are another example of ice marginal deposits mappable in the Hudson lowland. LaFleur (1965) mapped these through the Troy 15 minute quadrangle along the shoreline of Lake Albany. Schock also mapped a portion of a now recognized kame moraine-kame terrace complex that is Stop 6 on this field trip. The largest mappable band of kame moraine in the field trip portion of the Hudson lowland is the Glen Lake kame moraine, a complex deposit that likely formed as the ice margin fronting Lake Albany receded over time while holding steady at the kame moraine (Connally and Sirkin, 1969; DeSimone & LaFleur 2008). Tributaries feeding from uplands into the lowland glacial lakes may have deposited a delta against a receding ice front but recognition of the ice marginal component of the delta may be difficult especially after the delta has been incised due to lowering lake levels. The ice marginal component may no longer be recognizable as a portion of the landscape but can only be found through stratigraphic analyses.

## ICE MARGIN AND LAKE LEVEL HISTORY

Early Lake Albany levels and thresholds in the southern and mid-Hudson valley are complex and have been most recently investigated by Stanford (2009). He suggested that early lake Albany was dammed by a moraine at the Hudson Narrows between Staten Island and Brooklyn sending discharge into Long Island Sound controlled by a bedrock exposure at Hell Gate in the East River. When ice retreat reached Kingston, NY about 150 km north, catastrophic drainage of the upland glacial Lake Wallkill (cf. Peteet et al., 2009) breached the moraine causing incision into the moraine and lake bottom resulting in an unstable threshold that worked its way north creating progressively lower levels of Lake Albany. He suggests that this would have been relatively fast initially, but later limited by marine incursion into the valley during the late stages of Lake Albany and the early stage of Lake Vermont. Previously, LaFleur (1979, NYSGA trip) suggested the uplifting lake bottom may have controlled Lake Albany. The relative rates of sea level rise and differential isostatic adjustment would have induced continued incision until Lake Vermont stabilized in the bedrock threshold at Fort Ann, NY.

This study will incorporate only glacial lacustrine levels from measured strandlines between the confluence of the Hudson and Mohawk Rivers at Cohoes, NY and Canada. All strandlines were measured using GPS for surface location and barometric altimeter for elevation. [Some data previously published in Rayburn (2004), DeSimone (2006) and DeSimone et al. (2008).] In Figure 3, all strandlines at elevations that suggest levels of Lake

Albany are colored blue with the lowest in black. All strandlines suggesting levels of Lake Vermont are in orange. The highest elevation Champlain Sea strandlines are in green. All strandlines that can be shown to correspond to isolated higher elevation lakes, or are of uncertain origin, are identified as "other". The levels are correlated with a best fit linear function.

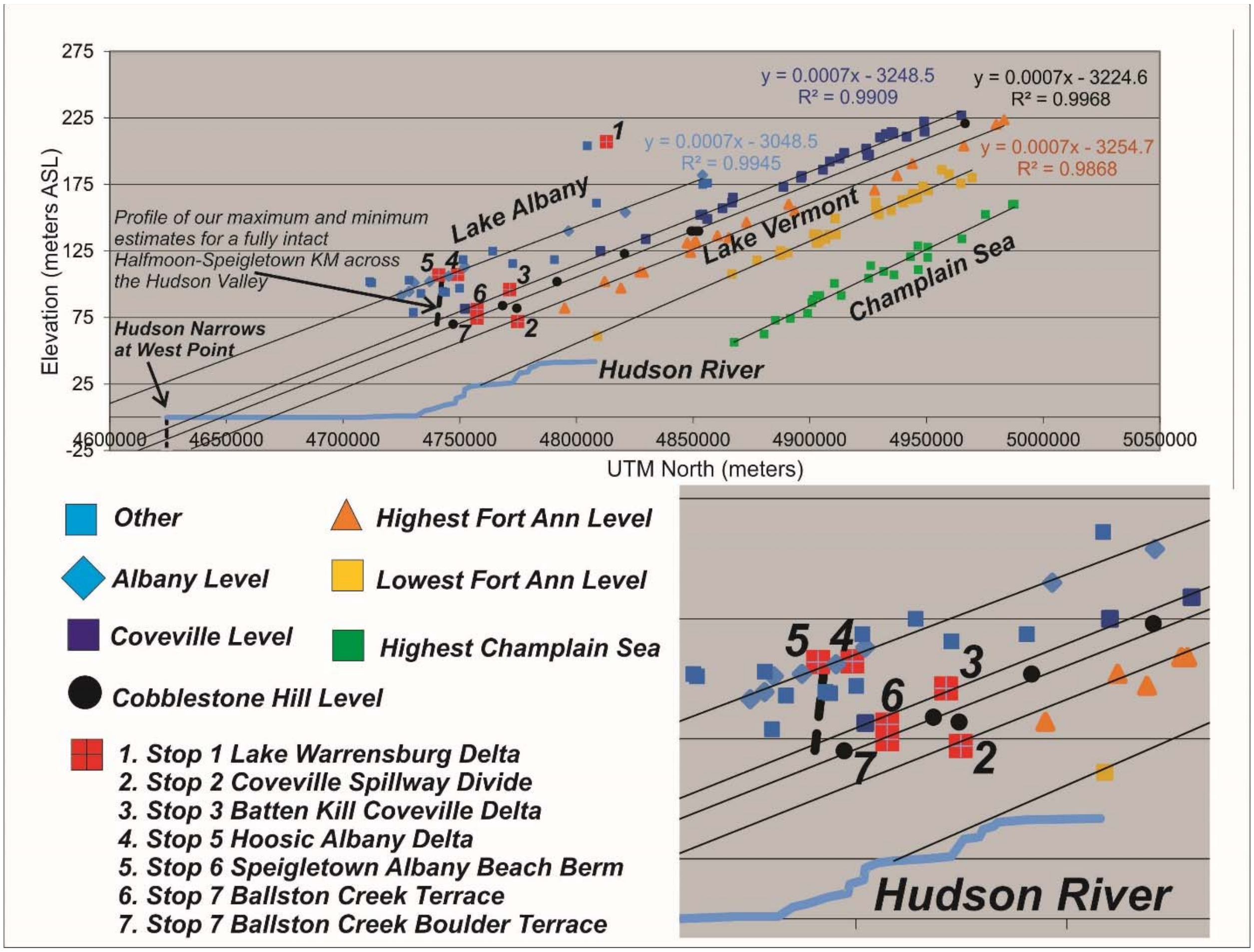


Figure 3. Glacial lacustrine strandline data with best fit linear trend lines to the major levels. Strandlines discussed in field stops are identified in red.

The data suggest that the highest Lake Albany level in the northern Hudson Valley is likely controlled in the southern Hudson Valley and may have been stable until the ice margin reached into the southern Champlain Valley. The northern most data point is the Forestdale, Vermont delta as originally mapped by Chapman (1932). At this location there may have been a significant lake level drop and grounding of the ice margin given the very large and clearly ice contact deltaic deposits on the Coveville Level at Street Road, NY and Brandon, VT. A projection of the Coveville level down-valley reaches the bedrock narrows of the central Hudson Valley at West Point, NY. There may have been a relatively stable threshold at/near this location because the Coveville level was stable for more than 300 years (Gonda & Rayburn, 2018). The next level below the Coveville level is the Cobblestone Hill level and may be associated with the Lake Iroquois flood along the ice margin at Covey Hill on the New York-Quebec border that redirected Lake Iroquois discharge from the Mohawk River valley to the northern end of Lake Champlain (Rayburn et al., 2005, 2011; Franzi et al., 2016). A prominent boulder bar at the Altona Flatrock north of Plattsburgh, NY confirms an immediate lake level drop associated with this catastrophic flood event (Rayburn et al., 2005).

Neither the Coveville level nor the Cobblestone Hill level, however, can be traced as far south as the Mohawk River confluence. In fact it has been demonstrated that base level for the Mohawk River must have been at the Hudson River channel while it still produced discharge from glacial Lake Iroquois (Wall *in* DeSimone et al., 2008). The knick point of Cohoes Falls at the distal end of the valley is graded to the Hudson River channel and has migrated more than 2 km up valley, yet the modern day Mohawk River discharge does not appear to have eroded the soft shale/graywacke mélange knick point during more than 250 years of human observation (Wall i*n* DeSimone et al 2008). Wall (1995) calculated the paleodischarge of the IroMohawk River. Therefore the threshold for the Coveville level must be north of Cohoes, NY. Given that the southernmost identified Coveville strandline is along the Hoosic River, this limits the geographical area for the threshold to a few quadrangles between the Hoosic and Mohawk Rivers.

It is apparent that following the Lake Iroquois outburst flood, the lake level was very unstable and likely incised through the glacial and lacustrine sediment filling the valley as it fell through the Cobblestone Hill level and through multiple "Fort Ann" levels. Note that only the highest (dark orange) and lowest (light orange) Fort Ann level strandlines are shown in Figure 2. The channel called "The Cove" at Coveville, which Chapman (1932) had suggested was possibly the Coveville level threshold is actually at Fort Ann level and may likely be a remnant of this incision in the soft mélange bedrock or of some flow out of the Saratoga Lake basin region. It's not until the threshold migrates to the stronger crystalline Precambrian rock at Fort Ann, NY does it stabilize and remain constant until the ice margin exposes a direct route to the sea through the St. Lawrence (Rayburn et al., 2005; Franzi et al., 2016).

## MOHAWK DISTRIBUTARY CHANNELS

If the northern Hudson Valley was sufficiently dammed by a huge kame moraine between Halfmoon and Speigletown, then discharge from the Coveville level would have to be up along the east or west flanks of the valley (Fig. 2). One likely possibility is a series of channels on the west side. These channels include the Ballston Lake Channel and Round Lake, Drummond Creek Channel, and the Kayderosseras Creek Channel. Although these channels had originally been suggested to be distributary channels for the IroMohawk River (Fig. 4; Stoller, 1911), it is conceivable that they could be later used in the reverse flow direction for Coveville level discharge. The elevation of the highest point of these channels at East Line, NY could, within measurement error, serve as a threshold for the Coveville level. For this to be true, there should be evidence to support this reversal of flow, and exposure of a sufficiently stable rock outcrop at the threshold elevation. Field investigation confirms the findings of Stoller (1911) suggesting that these channels we formed by discharge coming from the Mohawk River. No bedrock other than the soft mélange composed of shale with very little greywacke was found in the channels. The abundant stream terraces cut into the bedrock of the Ballston Creek channel between the Lake Albany the modern stream levels indicate that these channels incise rapidly and easily with falling base level (see Stop 7).

Falling Albany waters toward Coveville through levels previously identified that were not likely stable lakes such as Albany II and Quaker Springs may have contributed the lowering base level needed to initiate this erosion. This is a brief window of time when features lower than Albany but higher than Coveville form. The East Line to Anthony Kill and Drummond Kill to Fish Creek erosion may have occurred as base levels fell *<u>below</u>* Coveville but *<u>before</u>* the IroMohawk flow completely subsided. We traditionally envision that turning the Iromohawk off as if with a switch with flow going to the Champlain lowland and that event triggered the breach of the Coveville dam. Yet, must this be a cause and effect occurrence? Might the Coveville dam have been breached by IroMohawk flow and for a time the lake level lowered as the lake floor was incised…much the same as Stanford envisions for Lake Albany. The distributary channels formed as flow used all of the distributary channels - Stoller was correct for the most part. Then, the level stabilized at Cobblestone Hill but that was really only an interim when flow switched off the IroMohawk. Continued erosion of the lake floor to a stable Fort Ann level ensued controlled by hard bedrock.

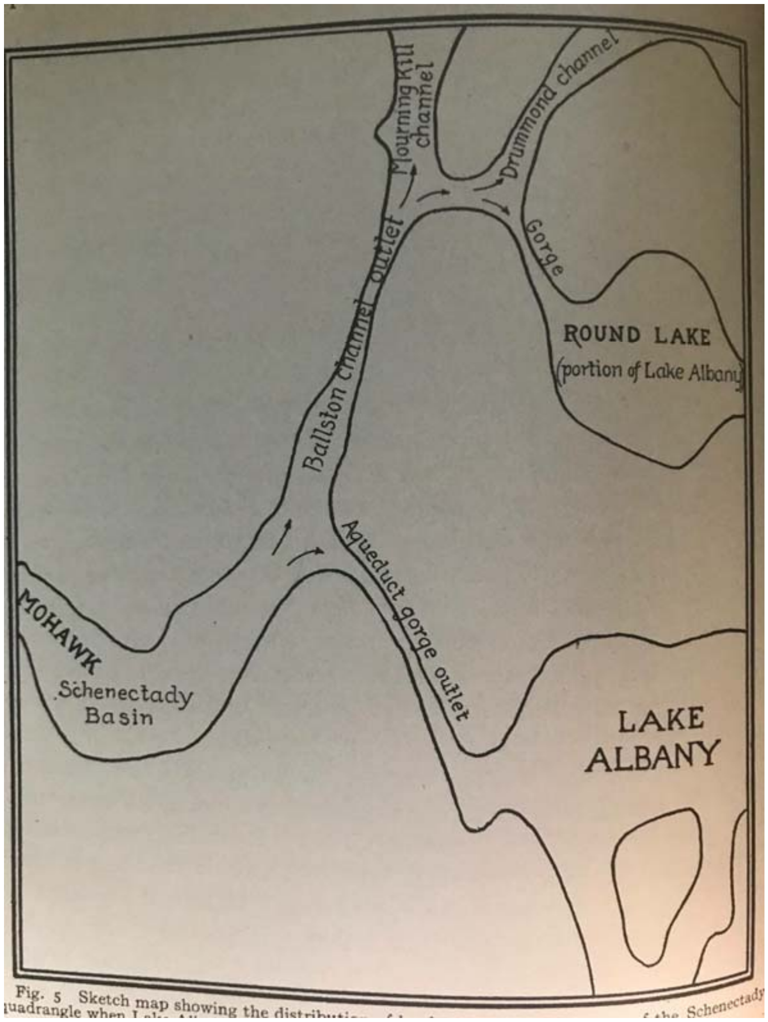


Figure 4. The IroMohawk distributary channels from Stoller (1911)

**ROAD LOG**

Assemble in the McDonald's parking lot west of Northway (Interstate 87) Exit 23 in Warrensburg. All roads for this trip are paved except for private drives into sand and gravel pits. This route is designed to be as efficient as possible between stops. Several alternate but more time consuming routes exist and provide a much better sense of regional geology, but our plan is to maximize discussion time at each stop.

**Mileage**

| | | |
|---|---|---|
| Start | | 3632 Main St. Warrensburg: Warrensburg McDonalds Parking Lot off Northway (87) Exit 23. |
| 0 | 0 | Right onto (West) US 9 |
| 0.3 | 0.3 | Left across Judd Bridge then Right onto River Street (NY 418) |
| 3.6 | 3.9 | Turn left to follow NY 418 |
| 3.0 | 6.9 | Park in pull-off on the left at the Thurman town line |
| End | | 5359-5377 Warrensburg Rd. Stony Creek |

**STOP 1: GLACIAL LAKE WARRENSBURG**

Along the upper Hudson between Luzerne and Warrensburg, the bluffs expose fine sand terraces, till, and bedrock. A few locations preserve elevated deltas and varved clays, in horizontal orientation and tilted large-scale slump blocks. Glacial Lake Warrensburg was named and mapped by Miller (1911, 1914), who inferred a single long, narrow ice-dammed glacial lake that integrated lacustrine features from Corinth in the south (Stoller's 1916 moraine-dammed Lake Corinth) through Warrensburg and into the upper Hudson and Schroon valleys north of North Hudson (Lake Pottersville, Miller 1914), including the Paradox Lake valley east of Ticonderoga. Figure 5 shows Miller's 1925 general map of the paleo-lake extent (dashed line indicates a Hudson-Champlain ice margin). Lake Warrrensburg must be older than the terrace at the Luzerne ice margin (Hanson, 1977). We infer that Lake Warrensburg flooded the Hudson-Schroon Valley north of Luzerne for a brief ~few-century period, beginning with the ice blockage around ~15.3-15.1ka.

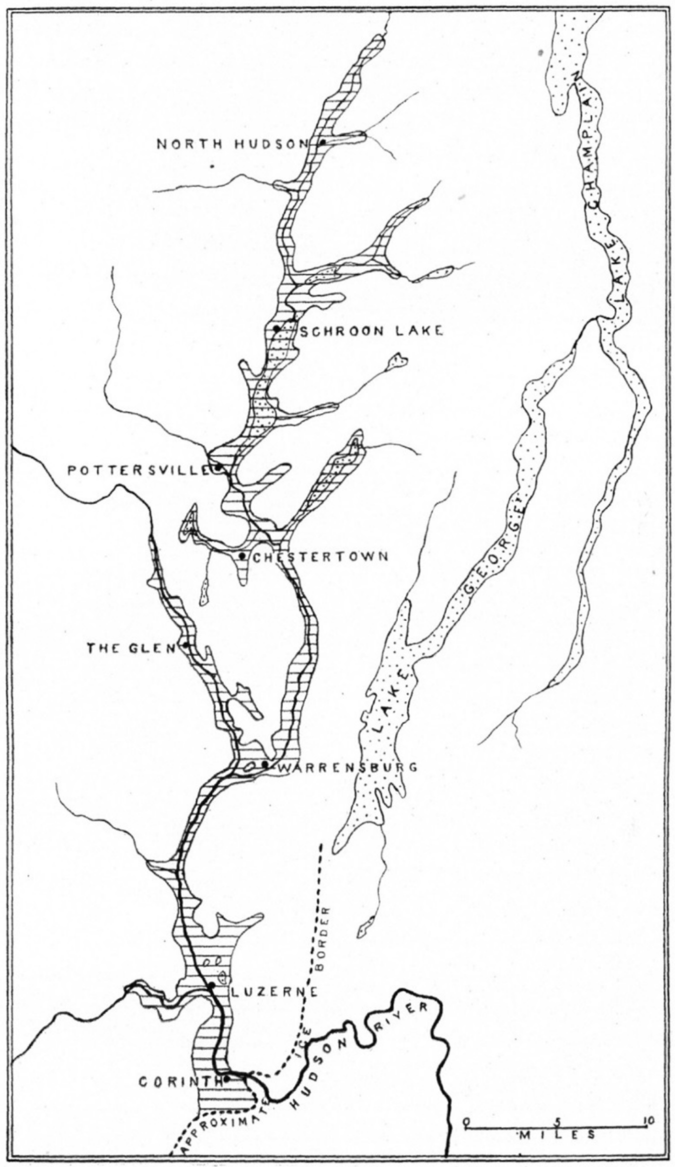


FIGURE 1.—*Map showing Extent of Glacial Lake Warrensburg*

The lined area indicates the location of the lake in southeastern Adirondack region of New York State.

Figure 5. Extent of Glacial Lake Warrensburg from Miller (1925)

Miller (1925) reports a graduated level of lacustrine deltas and sand plains, from 208 masl at Corinth to 300 m at Deadwater Pond about 110km to the north. He gives a slope estimate for the entire lake of 4.5 feet per mile, or about about 1 m/1.16 km. Miller locates the lake outlet between the ice and the Palmertown range highland pass "cut by a stream of large volume" near South Corinth. When the ice front retreated past Corinth into the Lake George valley, the upper Hudson outlet eroded below 194m, shifting flow to the east at Corinth through the Hudson valley into Lake Albany, or down the Kayaderosserass to the Milton delta. Lake Warrensburg presumably drained by ~14.7ka to 14.8ka, during retreat of the ice blockade in the Bølling-Alleröd.

In 2011-12, 2015-16, and 2017-18, undergraduate teams in Amy Frappier's Honors *Paleoclimatology Practicum* course have investigated GL Warrensburg varves using a series of short Ridge-style cores from a horizontal varve deposit overlain by a flat massive fine sandy unit several meters thick. The overlying unit is very silty, coarsening-upwards, and contains a kettle bog. Recent field observations of the varve deposits in this area by R.H. Lindemann, Frappier and students, and John Rayburn, indicate that varves can be found in protected locations in the upper terraces, along the banks of the Hudson, and into the river channel. The varve deposits form characteristically steep slopes, and are prone to slumping where undercut by stream incision. Our discontinuous varve cores from our upper terrace site reveal large ~10cm-scale and small ~1-2cm-scale varve sequences (Brill et al., 2012; Nolan et al., 2018). At least one low-sedimentation rate period a few decades in length occurring between ~1-decade-long intervals when annual deposition was higher (Khan et al, 2016). The data are insufficient to determine whether this general sequence relates to glacial melting directly, or to hydroclimate fluctuations at regional or watershed scale that may integrate glacial melting and postglacial sedimentary redistribution processes. Longer, more continuous varve records from this and other sites in the lake basin may help to resolve this and other questions related to deglaciation of the upper Hudson Valley.

Figure 6: John Rayburn investigates a tilted slump block with a Glacial Lake Warrensburg varve sequence incised by the Hudson River. Erosion of the outcrop has accentuated the grain-size contrast, revealing larger, possibly annual-scale summer layers, and smaller-scale sub-annual events.

Rock flour, silt, and fine sand deposited in Lake Warrensburg was most likely sourced, at least in part, from valley glacier outwash in the adjacent Adirondack highlands, rather than solely from the Laurentide ice sheet. This suggests that GL Warrensburg varve sequences are likely to reflect high-altitude local conditions in the upper Hudson/eastern Adirondack region, particularly in the southern and western Hudson parts of the paleo-lake basin. Whether these varve sequences can be successfully cross-dated to the NAVC remains to be seen, but recovering longer sequences are essential (Nolan et al, 2018). Varves in the tilted slump block (Fig. 6 above) provide a promising target for future work, and additional field scouting further north may reveal additional sites where varves are preserved, including sites with the potential for local pro-glacial conditions that may be sensitive to larger-scale Laurentide ice dynamics. The differing sensitivities of the southern/western and northern/eastern reaches of Glacial Lake Warrensburg present opportunities for future investigations of this interesting interval of deglaciation in the eastern Adirondacks.

En route to Stop 1, we pass by a typical elevated sand terrace in Warrensburg at ~720 ft (Fig. 7). Stop 1 offers roadside access to a Lake Warrensburg delta perched on the Western flank of the Hudson Valley. Topset beds with rounded river cobbles evident in the upper section are mostly obscured by grain flows down the exposed section. The delta clearly exposes tilted foreset beds (Fig. 8). Their southerly dip indicates flow from up-valley, rather than from a lateral tributary. Known varve exposures found below the sand unit outcrop just 1km downstream on the eastern side of the Hudson in the lee of a riverbend, but are not accessible by car. Split varve cores will be available for inspection along with the exposed delta, as we discuss the emerging picture of how Lake Warrensburg fits into the regional deglaciation history.

Figure 7: Lake Warrensburg sand terrace on the west side of the Schroon River Pond dam.

Figure 8: Foreset beds dipping southwest (left) and bottomset beds (right) in the Lake Warrensburg delta terrace at the Thurman town line.

**Mileage**

| | | |
|---|---|---|
| Start | | |
| 6.9 | 6.9 | Retrace route to Warrensbrug McDonalds |
| 0.1 | 7 | Continue to intersection with Diamond Point Rd and turn left. |
| 0.1 | 7.1 | Turn right onto 87 South |
| 15.5 | 22.6 | ***Northway Rest Area for optional restroom stop*** |
| 7.6 | 30.2 | Take Exit 16 to Ballard Rd |
| 0.2 | 30.4 | Turn left (East) onto Ballard Rd. |
| 2.1 | 32.5 | Continue across Rt. 50 following Taylor, Coldbrook, and Rugg Rd. |
| 3.3 | 35.8 | Keep Right onto NY 32 South |
| 3.3 | 39.1 | Turn Left onto Co Rd. 42 (Lock 5, Hudson Crossing Park) |
| 0.3 | 39.4 | Turn right into Parking area |
| End | County Rd. 42, Schuylerville - Hudson Crossing Park | |

**STOP 2: THE COVE AT COVEVILLE**

Woodworth suggested that the fully prograded Batten Kill delta into the Hudson Valley may have dammed lower lake levels, forcing discharge through the uplands onto the western uplands (Fig. 2). The flow would therefore have been forced between Bacon Hill and Northumberland and across a divide into the Fish Creek channel at Grangerville (Fig 9). From there it would follow the channel to Victory Mills, but then continue southeastwards and re-enter the Hudson Valley at the rock ledge at The Cove. His justification for this morphology is that "*The cove at Coveville in its relation to this hanging valley shows clearly that a large stream at one time flowed southward over* *the wall of the gorge at this place into the main gorge of the Hudson river, and was arrested after a slight amount of cutting had been accomplished*". Chapman (1932) sites Woodworth (1905), and further states that "*At Coveville, where the southern end of this channel overhangs the Hudson River by more than a hundred feet, is a rock ledge which acted as the controlling threshold for the waters during the Coveville stage of Lake Vermont*".

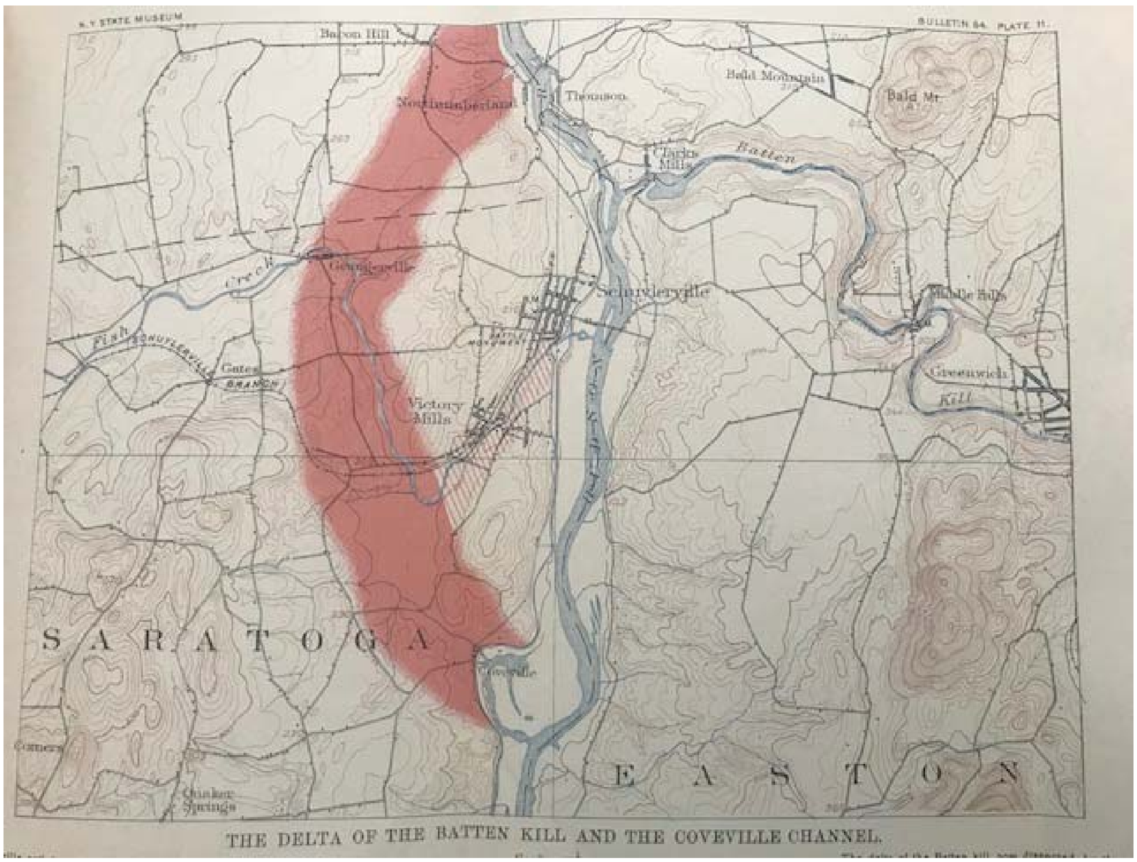


Figure 9. Proposed Coveville Spillway around the Batten Kill delta valley fill from Woodworth (1905)

There are several circumstances which strongly argue against the Coveville threshold being located in any part of this channel, however. The primary observation is that no part of this channel is at the Coveville elevation level. The highest modern divide elevation just off Grange Hall Road correlates to the highest Fort Ann level (Fig 3), and The Cove incision is only a little lower than the lowest Fort Ann level. Secondly, the bedrock type along the channel path is not sufficiently strong to have held up to steady state Coveville phase discharges. While some rock at the northern end of the channel is allochthonous (Starks Knob, for example), the primary rock type through the rest of the area is a weak shale that demonstrates significant incision in equilibrium with modern base level and discharges. Since the Coveville stage remained constant and steady for hundreds of years until the catastrophic discharge associated with the breakout of Lake Iroquois at Covey Hill, the threshold for this lake must be elsewhere. The formation of Woodworth's channel was more likely caused quickly by lake levels falling below the Coveville level with abandonment occurring as the discharge more easily cut through the Batten Kill delta and lacustrine deposits in the main Hudson channel. The Cove itself may just be an abandoned meander bend formed by Fort Ann level discharge through the valley.

**Mileage**

| | | |
|---|---|---|
| Start | | |
| 0.3 | 0.3 | Retrace route to NY 32 (US 4) and turn left (South) |
| 0.8 | 1.1 | Turn left onto NY 29 |
| 2.3 | 3.4 | Turn left into parking lot of The Ice Cream Man |
| End | 417 NY 29, Greenwich | |

### STOP 3: BATTEN KILL DELTA

One of the most well preserved deltaic landforms can be seen where the Batten Kill joins the Hudson River across the valley from Schuylerville. An excellent road traverse is to follow Rte 29 east from Schuylerville. Once across the Hudson River, the road rises moderately and climbs from bottomset beds through foreset beds to a large, delta topset flat. Minor drainage ditch exposures reveal the sediment of the delta that generally fines upward and reflects the pro-gradational nature of the landform. In 2008, the FOP trip (DeSimone et al., 2008) visited an active sand and gravel pit in the topsets and upper foresets but that pit is now long closed and well vegetated. A walking traverse along Windy Hill Road would give students an opportunity to follow the delta fore-slope and examine the sediment in drainage ditches.

An altimeter determined elevation of the topsets places them at 96m (315ft) correlating to the Coveville lake level (Fig. 3). Woodworth first recognized this beautiful delta does not fall on a Lake Albany water plane. Subsequent detailed surficial mapping by DeSimone confirmed Woodworth's placement of the delta on a lower lake level. The important factor here is that Woodworth first had the foresight to recognize a major delta was correlative to a lake level lower than Albany. A short distance farther east in Greenwich there is a remnant of a higher deltaic surface that records deposition in a 115m (380ft) lake, a level that would place it on an Albany II water plane. This is the highest deltaic surface recognized from mapping along the Batten Kill and it does not fall on the highest level of Lake Albany as correctly noted by Woodworth. Either a higher delta has been removed by erosion or Lake Albany lowered before ice retreat opened the Batten Kill valley.

**Mileage**

| | | |
|---|---|---|
| Start | | Retrace route to NY 32 |
| 2.3 | 2.3 | Turn left (South) onto NY 32 (US 4) |
| 0.2 | 2.5 | Turn left to follow NY 32 (Horicon/Gates Ave) |
| 2.6 | 5.1 | Turn left onto Hathaway Rd. |
| 1.3 | 6.4 | Turn left onto Coveville Rd. |
| 0.6 | 7 | Turn right (South) onto US 4 |
| 4.3 | 11.3 | Turn right onto Phillips Rd. (Saratoga National Battlefield) |
| 2.4 | 13.7 | Continue on Phillips/Saratoga National Battlefield Rd. to parking lot. |
| End | Saratoga National Historic Park | |

### STOP 4: THE SARATOGA NATIONAL HISTORIC PARK (Lunch Stop)

The short drive from Route 4, the old Colonial river road, up along the Kroma Kill to the park visitors center basically followed a transect perpendicular to the river. We went from flood plain alluvium up through a thick deep water glaciolacustrine clay section deposited in Glacial Lake Albany at its different levels. The fine grained lake silt and clay is capped along the flat river bluffs by a thin layer of lake sand deposited in the shallower waters of the last true lake in this section of the valley, Lake Coveville. We ascended to the gently rolling terrain at the top of the road where we parked and are in an area of generally thin till with rock outcrop.

Your vista from the terrace and lawn of the visitors center embraces a wonderful perspective across the Hudson Valley that is the consequence of both pre-glacial bedrock erosion that established the general geomorphology and Pleistocene glacial erosion and deposition that left the valley infilled with sediment (Fig. 10).

Subsequent Late Pleistocene and Holocene erosion carved into the sediment and bedrock and left the landscape we see today.

Figure 10: Looking east across the Hudson Valley from the Saratoga National Historic Park

The underlying bedrock topography and the more obvious glacial geomorphology were responsible for the terrain over which the 2 Battles of Saratoga were fought in September and October 1777. A single image is provided here to summarize the impacts of the geologic history on the battles (DeSimone 2016) and both bedrock and surficial geologic maps of the 4 quadrangles encompassing the SNHP will be available to view and discuss during lunch (DeSimone 2015a, 2015b). The maps are digitally published and those interested in the data layers can find them from the National Park Service and/or see the notations at the bottom of both maps.

The generation of the two maps is the result of a long, eight-year desire that finally came about in 2014-2015. DeSimone represented the Vermont Geological Survey at a two-day meeting held at UMass in 2007 to discuss the status of mapping in regional Park Service properties. Bruce Heise and Tim Connors represented the National Park Service (NPS). When the SNHP came up for discussion, DeSimone volunteered that most of the park had already been mapped by students of Bob LaFleur during the late 1970s. Eric Hanson (1977, 1980) mapped in the Mechanicville, Schaghticoke and Quaker Springs quadrangles, Jack Dahl (1978) mapped in the Mechanicville and Schaghticoke quadrangles, and DeSimone mapped the Schuylerville quadrangle (1977, 1985). DeSimone suggested it should be an easy task to finish a map of the park. Fast forward to late 2014; Bruce and Tim contacted DeSimone to see if he was interested in doing the project. However, the surprise was they wanted a map of the 4 quadrangles, not just the park and there were little funds to do much, if any field work (Fig. 11). In early 2015, they indicated they also wanted a bedrock map of the 4 quadrangles. The result is the 2 maps you have to view. Both maps largely represent compilations with editing on DeSimone’s part. Meshing the surficial maps together and field checking the contacts consumed nearly all of the allotted field time. Map units were re-designated in an updated fashion with some compromises and simplifications for clarity. Both printed maps were intended to be wall hangers for the SNHP staff and the text on the maps was intended to be educational to the non-geologist.

The bedrock map is work by Kidd, Plesch, and Vollmer (1995), Rickard (unknown date), Landing et al. (2003), Fisher et al. (1970), and a beautiful hand colored map of the Schuylerville 15-minute quadrangle attributed by Rickard to Reudemann (unknown date). My role was to compile and edit the data, merge and extrapolate contacts and convert map units in older terminology to those of Kidd et al (1995). DeSimone chose to add pre-glacial bedrock channels to this map using data from Dineen and Hanson (1983) and Bruehl (1969) with extensions from both data sources.

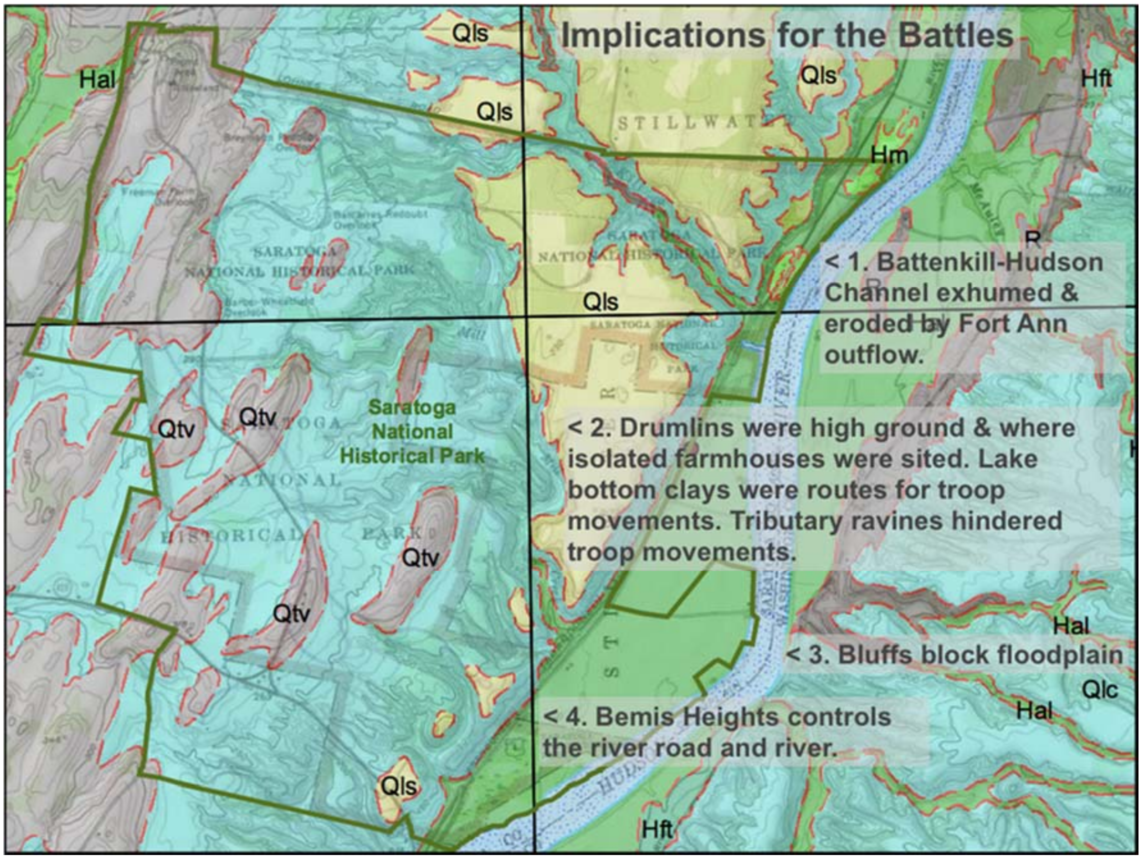


Figure 11. The geology had a hand in dictating the battle tactics.

The lunch view has the gently rolling to sloping till terrain of the visitors center giving way to the clay flats that were farm fields in 1777. The park has tried to maintain the vegetative cover as close to what it was during 1777. The Hudson Valley Lake Albany shoreline is both in the near distance and in the middle distance across the valley where the land slopes up abruptly into the Taconic highlands with the highest summit in view being Willard Mountain, a local ski area. That break in slope approximates the Lake Albany shoreline and follows Route 40 where we'll drive after lunch. The track of Route 40 also largely coincides with the trace of the Taconic Frontal Thrust or TFT as seen on the bedrock map. On a clear day, the view extends into the far distance where the summit ridge of the Green Mountains is visible.

**Mileage**

| | | |
|---|---|---|
| Start | | Retrace route to US 4 |
| 2.4 | 2.4 | Turn right (South) on US 4 |
| 4.9 | 7.3 | Turn left onto Stillwater Bridge Rd. (Rt. 125) |
| 4.7 | 12 | Turn right onto Main St. (Rts. NY 40 & 67) |
| 1.5 | 13.5 | Turn right onto Farm to Market Rd. (NY Rt. 67) |
| 1.1 | 14.6 | Turn at gravel pit entrance |
| End | 895 Farm to Market Rd., Schaghticoke | |

**STOP 5: HOOSIC DELTA**

The Hoosic River and the Batten Kill are two large Hudson River tributaries that drain the Taconic Mountains along the east side of the valley. From the Batten Kill, we proceeded south along Rte 40 following the shoreline of Glacial Lake Albany and also largely following the trace of the Taconic Frontal Thrust or Emmons's Line. A very distinct lowland to upland break in slope is present.

We continued south to the junction of Rte 40 and Rte 67W and turned west to head back toward the Hudson River. We drove across several of the four readily distinguishable deltas of the Hoosic River deposited into different glacial lake levels. Each succeeding delta breached the older, higher delta. The expression of the deltas as landforms is harder to discern. However, this trip stop lets you see some deltaic sediment stratigraphy. There are two pits across the road from each other and at the time of this writing, we cannot know for certain which pit we can get access to on the day of the trip. Both pits are fairly small and if they are working in them, there will be no permission granted.

The sediment exposed is largely medium to fine sand with predominantly horizontal thin beds, some ripple laminations and no evident ice contact deformation. The sand beds are overlain by variably thick pebble gravel beds with medium to coarse sand. The pebble gravels are cross bedded with some cut and fill structures. The pebble gravels truncate the underlying sand beds. At the smaller pit on the north side of Rte 67, the gravel beds are thin and some of the topsoil has been removed from the exposed face. The original thickness of the gravel facies cannot be determined. At the larger pit on the south side of Rte 67, the gravel facies appears to be intact in the high wall of the pit beneath the more mature vegetation. Here, the pebble gravel facies is approximately 2m thick.

The elevation of the flat top of the landform in the south side pit is 107m (350ft) using the topographic map spot elevation. The pit has been excavated into an isolated terrace within the 107m (350ft) Hoosic delta (Fig. 3). The north side pit was excavated into a lower 98-99m (325ft) Hoosic delta. The largest preserved fragment of the Hoosic deltas has an extensive topset plain between the 113-118m (370-390ft) elevations. A lower terrace of the Hoosic River that may be deltaic lies at 82m (270ft).

**Mileage**

| | | |
|---|---|---|
| Start | | Retrace to route to NY Rt. 40 |
| 1.1 | 1.1 | Turn right (South) on NY Rt. 40 |
| 5.7 | 6.8 | Turn right at gravel pit entrance |
| End | 449 NY 40, Troy | |

**STOP 6: SPEIGLETOWN KAME MORAINE & STRANDLINE**

This large pit with multiple open excavations exists in the Speigletown kame moraine-kame terrace (Fig. 12). The entrance to the operation is from NY Rte 40. Route 40 follows the old Mahican Indian trail later used as a Colonial coach road. The road generally follows the eastern shoreline of Glacial Lake Albany. Along this route from the Batten Kill south to the Hoosic River and continuing south to the pit, your drive follows the glacial lake shoreline. The shore face is sometimes veneered with beach sand overlying finer grained sediments. The Fane pit began decades ago at the road level. The landform is a kame terrace here that caps bedrock sometimes visible in deeper excavations. Across the road from the pit entrance, shale bedrock is exposed. The depositional environment was that of a classic kame terrace deposited between the Hudson-Champlain ice and the valley wall. The deeper parts of the pit reveal sedimentation from subglacial meltwaters that represent an esker distributing sediment into a subaqueous fan. There are remnants of ice contact sand and gravel deposits that can be seen north of Rte 142, west of Rte 40 and continuing down to toward the Hudson River in Pleasantdale. However, these are not shown on the 1963 surficial map of Schock. Mr. Fane reports hunting along trails leading down to the river and finding a large area of gravel buried by the silt-clay. In contrast, the kame terrace likely received sediment from a meltwater and meteoric water stream following the ice margin. Indeed, some of the sediment may be from the Hoosic River to the north as ice still blocked the river outlet.

Figure 12. Sands and gravels from large flow events along the east valley wall.

Beach sand and even pebble gravel caps the sequence and will be our first vantage point in the pit along the power line. There is a pocket of silt-clay below the beach berm that may represent a small pond behind a sand spit. This is one of the finest sections of Lake Albany beach preserved in a still rural setting. Look across to the road bordering the south face of the pit and you can see the beach profile. The berm here is exceptionally high and this appears to be a natural feature, not built up at all for the power line construction.

Wander to the deepest excavations in the pit. Excavations have reached bedrock at least locally capped with a veneer of till. Ground water seeps out along the base of the gravel and sand as further downward infiltration of ground water is inhibited by the comparatively impermeable till and bedrock. The deeper portions of the pit reveal subaqueous fan sand and gravel. Previously, we could observe arched anti-form bedding from a classic esker. Finer grained lacustrine sediments have an on-lap relationship to the ice contact sediments indicating the quieter water facies were deposited after retreat of the ice removed the source of the proximal gravel and sand facies. One can think of the subglacial meltwater source as a fire hose discharging water and sediment from beneath the glacier into the bottom of Lake Albany. The point source of sediment deposits coarse grained sediment in one locale while adjacent areas have finer grained sediment. The fire hose analogy works if you think of the hose spraying sediment first in one direction and then in another.

We'll work our way up section toward the east where the sediment is interpreted to have been cascading from the kame terrace environment into the deeper lake waters. Slope instabilities and debris flows must have been common. At any given moment, the pit face may show soft sediment deformation, load deformation and evidence of subaqueous sediment flows. Nearshore sediments in the higher parts of the pit truncate and overlie an ice contact facies composed of interbedded gravel and sand with typical ice contact deformation.

**Mileage**

| | | |
|---|---|---|
| Start | | Retrace route to Stop 5 |
| 6.8 | 6.8 | Follow NY Rt. 67 West through Mechanicville to Maltaville |
| 11.1 | 17.9 | At the second traffic circle take the first exit (North) onto US 9/NY 67 |
| 0.9 | 18.8 | At the following second traffic circle take the third exit (West) to follow NY 67 |
| 1.7 | 20.5 | Turn left onto East Line Rd. |
| 0.5 | 21 | Turn left into Shenantaha Park entrance |

0.3 21.3 Turn into Parking Lot
End 3 Horseshoe Bend, Ballston Spa

**STOP 7. BOULDER MORAINE & LAG TARRACE IN BALLSTON CREEK CHANNEL AT SHENANTAHA CREEK PARK**

This last stop takes us to the Shenantaha Park on the Round Lake quadrangle that was most recently mapped by Hanson (1977b). A possible alternative to the Fish Creek/Coveville channel as a threshold and discharge channel for the Coveville level is a drainage divide at East Line between the Morning Kill, Drummond Creek, and Ballston Creek. Besides being at an elevation consistent with the Coveville level it would provide a threshold and drainage network that would effectively control the Coveville level if the main Hudson Valley were dammed between Speigletown and Halfmoon (Fig. 2). This network together with the Ballston Lake channel is all part of the Mohawk distributary channel network and may have been earlier formed in equilibrium with both northward discharge from the IroMohawk as well as southward discharge from glacial Lake Warrensburg. Early investigation of this system was published by Stoller (1911) who inferred that: "*A flood of waters once swept northward through Ballston channel, dividing in the vicinity of East Line into three currents which pursued the several courses described above. The time in glacial history when this took place was subsequent to the general disappearance of the ice and also subsequent to the stage of maximum development of Lake Albany*" (Fig 4). Stoller (1916) recognized the southern end of a lake that he named Lake Corinth that the Hudson River drained via Kayderosseras Creek southward into Lake Albany forming the Milton delta (Fig. 13). However at 125m (410ft) it is significantly above the Albany water plane (Fig 3) and may actually represent a separate higher-elevation ice marginal lake.

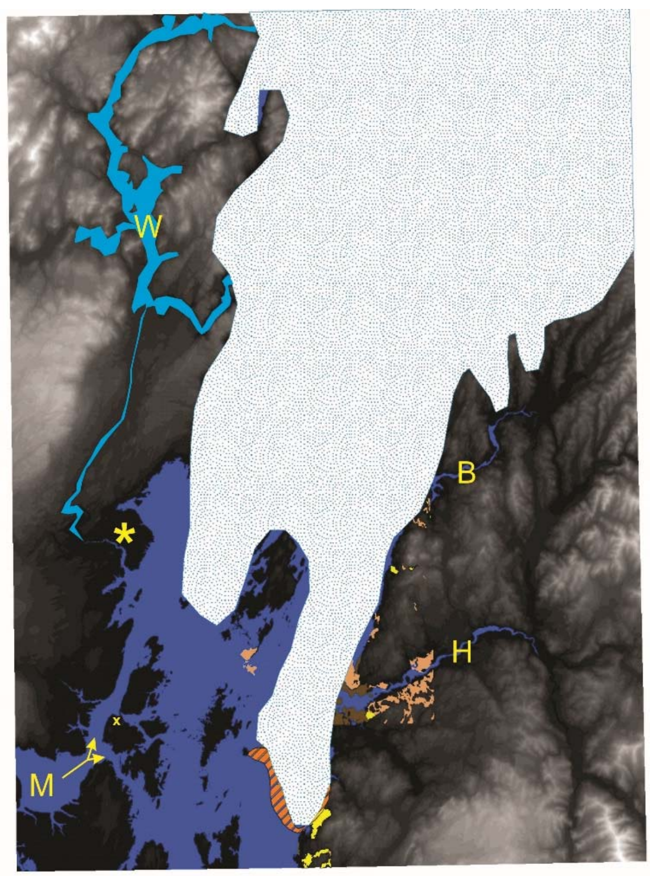


Figure 13. GIS model of Lake Albany level with the ice margin at Speigletown and Lake Warrensburg discharge forming a delta at Milton. M: IroMohawk discharge into Lake Albany, W: Lake Warrensburg, *: Milton Delta, H: Hoosic Valley, B: Batten Kill Valley, x: Location of Stop 7. Representation of the original full extent of the Speigletown kame moraine complex in orange.

The much larger extent of Lake Corinth was recognized by Miller (1925) and renamed Lake Warrensburg (Stop 1), and that its existence must have been caused by ice damming the modern Hudson channel east of Corinth. It is possible that when the ice was farther south than depicted in Figure 13 the western region of the Hudson Valley including Milton and the distributary channels was confluent with a higher elevation glacial lake in the Mohawk Valley. Northward recession of the ice margin would subsequently drain this lake to Albany level allowing Mohawk Valley discharge directly into Lake Albany through the distributary channels. Eventual ice margin retreat to Glens Falls would open the modern upper Hudson channel to Lake Albany completely draining Lake Warrensburg.

For the distributary channels to form the threshold and drainage route for the Coveville level around the Speigletown moraine (Fig. 2) they would require flow southward through the Morning Kill and/or Drummond Creek channels, and/or westward drainage through the Ballston Creek channel to Ballston Lake to the Mohawk Valley. This would in turn necessitate that the IroMohawk flow directly eastward to the Hudson Valley through its modern channel at Cohoes rather than the distributary channels. It would also necessitate a bedrock exposure of significant strength to withhold steady state discharge from Lake Coveville. These conditions lead to a series of problems. First, like Woodworth's proposed Coveville outlet, the local exposed bedrock is a weak shale/greywacke mélange that demonstrates easy incision to base level even under modern discharge conditions. Second, like Stoller, we observe no southward flow indicators in the channels and only very strong eastward flow indications in the Ballston Creek channel. This includes an imbricated boulder terrace (also recognized by Stoller, 1911) near the head of the Ballston Creek channel that could only have resulted from strong eastward flow towards Round Lake (Fig. 14).

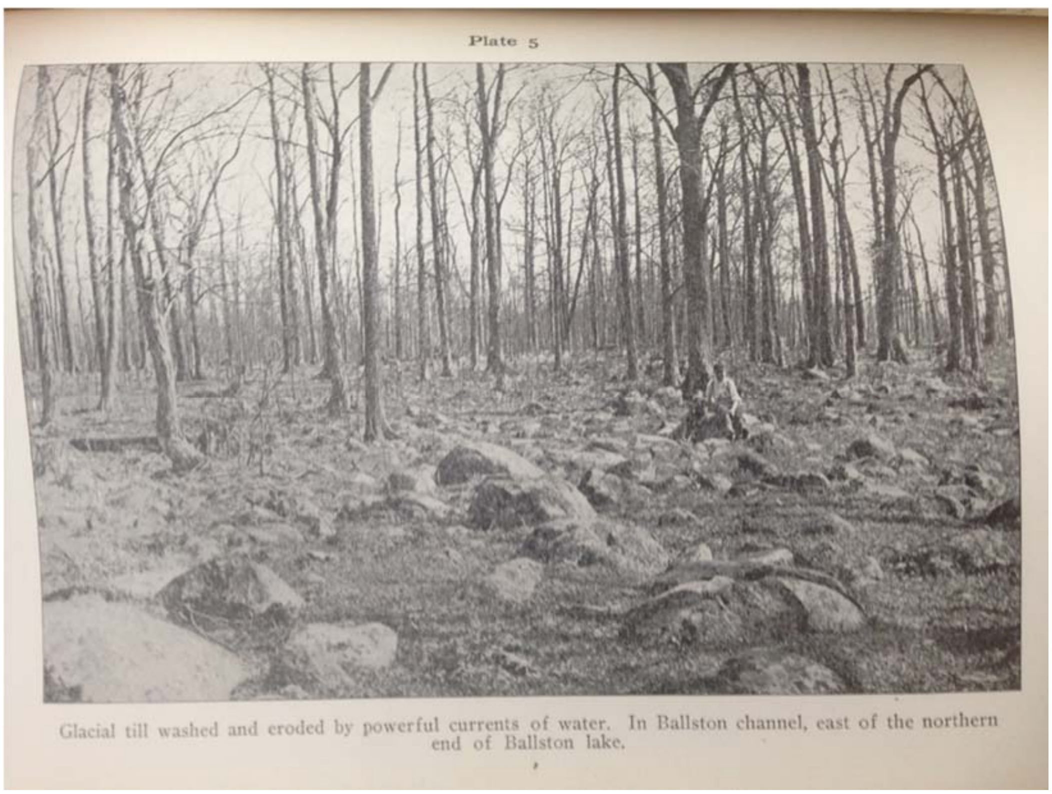


Figure 14. Boulder terrace formed into a moraine near the head of the Ballston Creek channel. Imbrication indicates eastward flow through the channel towards Round Lake. (From Stoller, 1911)

On the positive side, however we have evidence that the IroMohawk must have been flowing directly eastward through the modern channel at least at the very end of the Coveville Phase. As stated in the introduction, the base level for Cohoes Falls which clearly migrated back through the shale-rich mélange from the Hudson Valley is at Hudson River level, and that discharges only on the scale of the IroMohawk could have caused this knick point migration. This now under-fit falls is apparently frozen in time with the reversal of drainage of Lake Iroquois at Lake Iroquois into Lake Vermont causing it to drop from Coveville level to Cobblestone Hill and Fort Ann levels (Rayburn et al., 2005; Franzi et al., 2007; DeSimone et al., 2008; Franzi et al., 2016). Interestingly there are a number or terraces carved into the shale of the Ballston Creek channel ranging in elevation from Coveville level at the head of the channel Shenantaha Creek Park near East Line down to through the Fort Ann levels and below to the east, suggesting that this channel was at baseline equilibrium with Lake Albany and Lake Vermont (Fig 15). Also the imbricated boulder moraine surface along the creek at the edge of the park correlates to Cobblestone Hill level, suggesting that it may have been the Lake Iroquois breakout flood that caused the lagged surface in the boulder moraine and that flow was eastward into the Hudson Valley at this location.

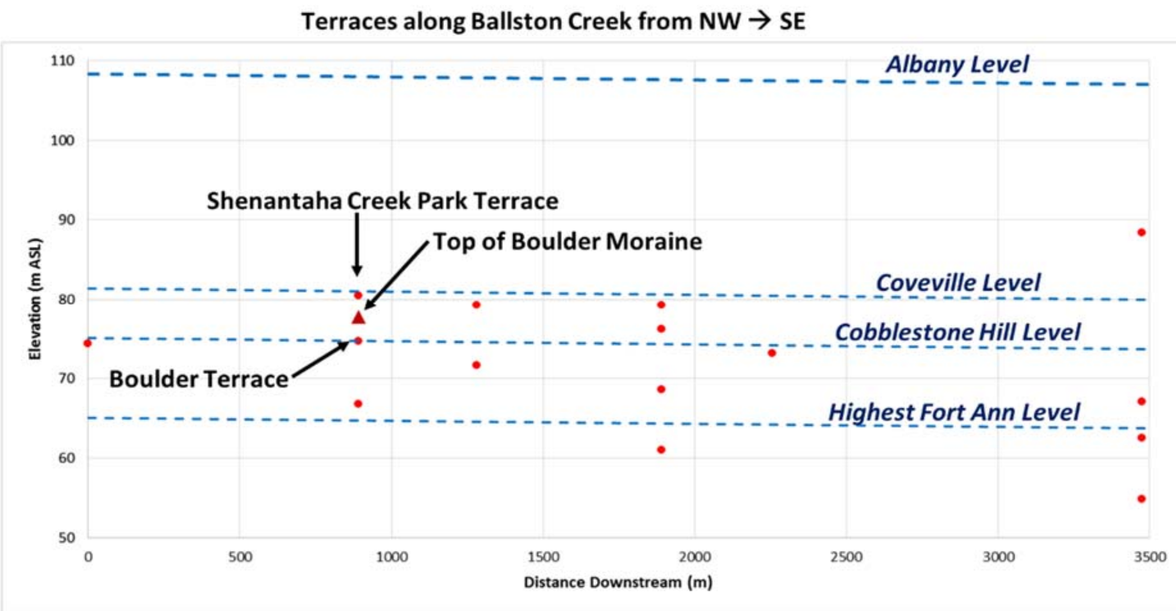


Figure 15. Altimeter determined elevations of terraces and the top of a moraine in the Ballston Creek channel compared with glacial lake levels in the Hudson Valley.

**ACKNOWLEDGEMENTS**

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**REFERENCES**

Antevs, E., 1922: The recession of the last ice sheet in New England. American Geographical Society Research Series 11, 120 pp.

Antevs, E., 1928: The last glaciation, with special reference to the ice sheet in northeastern North America. American Geographical Society Research Series 17, 292 pp.

Baldwin, S.P., 1894. Pleistocene History of the Champlain Valley. Am. Geol. 13: 170-184.

Barclay, D.J., 2018. Deglacial Ice Margins in the Finger Lakes Region of Central New York. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-311170.

Brill, M., Leverone, T., Loehr, C., Pinkey-Drobnis, A. D., and Frappier, A. 2012. Varve chronology from Glacial Lake Warrensburg: A preliminary study of a forgotten glacial lake near Warrensburg, NY. Geological Society of America Abstracts with Programs, Vol. 44, No. 2, p. 99, Abstract 41-4.

Bruehl, D. H., 1969. Bedrock topography of the Albany to Lake George area, New York: NY State Department of Transportation, open file 1:62,500 maps.

Chapman, D.H., 1932. Late Glacial and Post-glacial History of the Champlain Valley. American Journal of Science. 34: 89-124.

Connolly. G.G., and Sirkin, L.A., 1969. Deglacial history of the Lake Champlain-Lake George lowland: NYSGA Guidebook, 41st annual meeting, Trip I, 20p.

Cronin, T.M., Manley, P., Brachfield, S., Manley, T., Willard, D.A., Guilbualt, J-P., Rayburn, J.A., Thunell, R., Berke, M., 2008. Impacts of post-glacial lake drainage events and revised chronology of the Champlain Sea episode 13-9 ka. Palaeogeography, Palaeoclimatology, Palaeoecology, 262, 46-60.

Dahl, J., 1978. Surficial geologic map of the northern half of the Schaghticoke, NY, 1:24,000 quadrangle: NY State Geological Survey, open file map 2gk1296.1 .

DeSimone, D. J., 1977. Glacial geology of the Schuylerville quadrangle, NY: Rensselaer Polytechnic Institute, Master's thesis with 1:24,000 map.

DeSimone, D. J., 1985. The Late Woodfordian history of southern Washington County, NY: Rensselaer Polytechnic Institute, Doctoral dissertation with maps.

De Simone, D.J., 2006. Strandline features in the Hudson-Champlain region reveal water planes which tilt at 4.0 ft/mi: GSA Abstracts with programs, NE sectional meeting, March 2006.

DeSimone, D.J., 2015a. Bedrock Geologic Map of Saratoga National Historical Park and Vicinity, New York: National Park Service publication, map & text.

DeSimone, D.J., 2015b. Surficial Geologic Map of Saratoga National Historical Park and Vicinity, New York: National Park Service publication, map & text.

DeSimone, D.J., 2016. Surficial & Bedrock Maps of the Saratoga National Historical Park Generated for Archaeological & Educational Purposes: NE-GSA Abstracts with Programs, Mt. Washington, NH.

De Simone, D.J., and La Fleur, R.G., 1985. Glacial geology and history of the northern Hudson basin, NY and VT: NYSGA guidebook to field trips, trip A-10, p. 82-116.

DeSimone, D. J., and LaFleur, R. G., 2008. Deglacial history of the upper Hudson region: NY State Geological Association, Guidebook to Field Trips, 80th annual meeting, Trip 4, p. 35-56.

De Simone, D.J, Wall, G.R., Miller, N.G., Rayburn, J.A., Kozlowski, A.L., 2008. Glacial geology of the northern Hudson through southern Champlain lowlands: Friends of the Pleistocene, Guidebook to field Trips, 71st annual meeting.

Dineen, R. J., and Hanson, E. L., 1983. Bedrock topography and glacial deposits of the Colonie Channel between Saratoga Lake and Coeymans, NY: NY State Museum, Map & Chart Series #37, 1:62,500 maps.

Fairchild, H.L., 1917. Post-glacial features of the upper Hudson Valley. NYS Mus. Bull. 195, 22p.

Fisher, D. W., et al, 1970. Geologic map of New York, Hudson-Mohawk sheet: NY State Museum, Map & Chart Series #15, 1:250,000 map.

Franzi, D.A., Ridge, J.C., Pair, D.L., DeSimone, D.J., Rayburn, J.A., Barclay, D.J., 2016. Post Valley-Heads deglaciation of the Adirondack Mountains and adjacent lowlands. Adirondack Journal of Environmental Studies 21, 119-146.

Gonda, N.J., Rayburn, J.A., 2018. Cross-correlation of Glacial Lake Vermont Varve Sections in New York and Vermont. In: Program with Abstracts, Geological Society of America Northeastern Section Meeting, 2018.

Hanson, E.L., 1977a. Late Woodfordian drainage history in the lower Mohawk Valley: RPI MS thesis.

Hanson, E. L., 1977b, Surficial geologic map of the Round Lake, NY, 1:24,000 quadrangle: NY State Geological Survey, open file map 2100.384.

Hanson, E. L., 1980. Surficial geologic map of the Quaker Springs, NY, 1:24,000 quadrangle: NY State Geological Survey, open file map 2gk881.

Hanson, E. L., 1977, and Dahl, J., 1978. Surficial geologic map of the Mechanicville, NY, 1:24,000 quadrangle: NY State Geological Survey, open file map 2gk680.

Khan, T., Thieringer, P., Outterson, A., Bullis, C., Lovejoy, C., Mccully, E., Nitkin, E., Carames, J., Sidor, L., Kilgore, M., Ng-Yow, R., and Frappier, A. B. 2016. A continued analysis of the Glacial Lake Warrensburg varve chronology. Poster presentation 39-6. NEGSA Annual Meeting, 21-23 March, 2016, Albany, NY. Geological Society of America Abstracts with Programs. Vol. 48, No. 2. DOI: 10.1130/abs/2016NE-272619.

Kidd, W. S. F., Plesch, A., Vollmer, F. W., 1995. Lithofacies & structure of the Taconic flysch, melange & allochthon in the NY Capital District: NY State Geological Association, Guidebook to Field Trips, 67th annual meeting, p. 57-80.

La Fleur, R.G., 1979. Deglacial events in the eastern Mohawk-northern Hudson lowland: NYSGA Guidebook to field trips, 51st annual meeting, p.326-350.

La Fleur, R.G., 1965. Glacial geology of the Troy, NY, quadrangle: NYS Museum and Science Service, Map and Chart series #7.

Landing, E., et al, 2003. Tectonic setting of outer trench slope volcanism: pillow basalt and limestone in the Ordovician Taconian orogen of eastern New York: Canadian Journal of Earth Sciences, vol. 40, p. 1173-1187.

Miller, W.J., 1911. Preglacial course of the upper Hudson River. Bul. of the Geol. Soc. of Am. 22:185-186.

Miller, W.J., 1914. Geology of the North Creek Quadrangle, New York. NYS Mus. Bul. 170: 69-73.

Miller, W.J., 1925. Remarkable Adirondack glacial lake. GSA Bulletin 36: 513-520.

Nolan, K., Cristiano, J. Mundi, C., Casarella, D., Wall, B., Hudziak, S.X., Deutsch, E., Janigian, L., Frappier, A., 2018. Expanding the varve chronology: More preliminary results from Glacial Lake Warrensburg, Hudson Valley, NY. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-311170.

Peet, C.E., 1904. Glacial and Post-glacial Histories of the Hudson and Champlain Valleys. Jour. Geol. 12:415-469, 617-660.

Peteet, D., Rayburn, J.A., Menking, K., Robinson, G., Stone, B., 2009. Deglaciation in the southeastern Laurentide sector and the Hudson Valley – 15,000 years of vegetational and climate history - Trip 4; ; In: NYSGA Annual Meeting Guidebook, 2009, p. 4.1 - 4.18.

Rayburn, J.A., 2004. Deglaciation of the Lake Champlain Valley New York and Vermont and Its possible effects on North Atlantic climate change. Ph.D. Dissertation, Binghamton University, 158 p.

Rayburn, J. A., Cronin, T. M., Franzi, D. A., Knuepfer, P. L. K., & Willard, D. A. 2011. Timing and duration of North American glacial lake discharges and the Younger Dryas climate reversal. Quaternary Research, 75(3): 541–551.

Rayburn, J. A., Franzi, D. A., & Knuepfer, P. L. K. 2007. Evidence from the Lake Champlain Valley for a later onset of the Champlain Sea and implications for late glacial meltwater routing to the North Atlantic. Palaeogeography, Palaeoclimatology, Palaeoecology, 246(1): 62–74.

Rayburn, J. A., Knuepfer, P. L. K., & Franzi, D. A. 2005. A series of large, Late Wisconsinan meltwater floods through the Champlain and Hudson Valleys, New York State, USA. Quaternary Science Reviews, 24(22): 2410–2419.

Ruedemann, R., unknown date. Bedrock geologic map of the Schuylerville, NY, 1:62,500 quadrangle: NY State Geological Survey, open file map 1g1372.

Rickard, L. V., unknown date. Bedrock geologic map of the Schuylerville, NY, 1:62,500 quadrangle: NY State Geological Survey, open file map 1g1645.1 .

Schock, R. N., 1963. Geology of the Pleistocene sediments, Troy North quadrangle: RPI MS thesis.

Stanford, S. D. 2009. Onshore record of Hudson River drainage to the continental shelf from the late Miocene through the late Wisconsinan deglaciation, USA: synthesis and revision. Boreas, 39(1): 1–17.

Stoller, J.H., 1911. Glacial geology of the Schenectady quadrangle: NYS Museum Bulletin 154.

Stoller, J.H., 1916. Glacial geology of the Saratoga quadrangle: NYS Museum Bulletin 183.

Stoller, J.H., 1918. Glacial geology of the Cohoes quadrangle: NYS Museum Bulletin 215.

Stoller, J.H., 1922. Late Pleistocene history of the lower Mohawk and middle Hudson region: GSA Bulletin, vol. 33, p. 515-526.

Taylor, F.B., 1903. The correlation and reconstruction of recessional ice borders in Berkshire County, Massachusetts: Journal of Geology, vol. 11, p323-364.

Upham, W., 1889. Glaciation of the Mountains in New England and New York. Am. Geol. 4:165-174, 205-216.

Wall, G. R., 1995. Postglacial drainage in the Mohawk River Valley with emphasis on paleodischarge and paleochannel development: Doctoral dissertation, Rensselaer Polytechnic Institute, Troy, New York, 352p.

Woodworth, J.B., 1905. Ancient water levels of the Champlain and Hudson valleys: NYS Museum Bulletin #84, 265p.