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Evidence of An Ice-Dammed Lake and Laurentide Readvance Upper Susquehanna Valley, New York State

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Abstract

Landforms and well logs document a system of ice-contact and proglacial lakes in the upper Susquehanna valley during Laurentide Ice Sheet retreat from the Appalachian Plateau, central New York State. Recessional moraines formed dams for all lakes, except a newly revealed “Ancestral Goodyear Lake” retained behind an ephemeral ice dam stranded at Colliersville. A prominent dead-ice sink currently occupies the valley floor at the dam site

Ancestral Goodyear Lake held a stable lake level at 1360 feet as represented by thick lake sediments perched in water well logs on the valley wall above Goodyear Lake. A deltaic terrace at 1250 feet in the same vicinity marks a second, lower lake strand.

In addition, water well logs on the adjacent Portlandville Moraine contain lake sediments bound above and below by ice-contact material deposits thus demonstrating a Laurentide readvance that subsequently dammed the valley to form Glacial Lake Milford as part of the Susquehanna Lake System.

Keywords: Dead ice sink dams, Quaternary, Susquehanna Lake

1. Introduction

1.1 Area of Investigation

Glaciation was the most recent event to modify the incised Susquehanna Valley since headward erosion by the Mohawk River captured its headwaters leaving the maturely dissected Appalachian Plateau with several north-south oriented troughs referred to as “through valleys” (Tarr, 1905). These served as conduits for Laurentide glacial flow and the formation of valley ice tongues between upland reentrants (Fleisher, 1993). Recessional moraines dammed ice-contact lakes that grew headward with progressive retreat, thus forming the lower Susquehanna Lake System between Sidney and Windsor, NY (Heisig, 2012). The combination of well data with glacial landforms were investigated to development the upper-most lakes between Ononta and Milford, including Glacial Lake Otego, Glacial Lake Goodyear and Glacial Lake Milford (Fleisher and Heisig, 2018) illustrated in Figure 1.

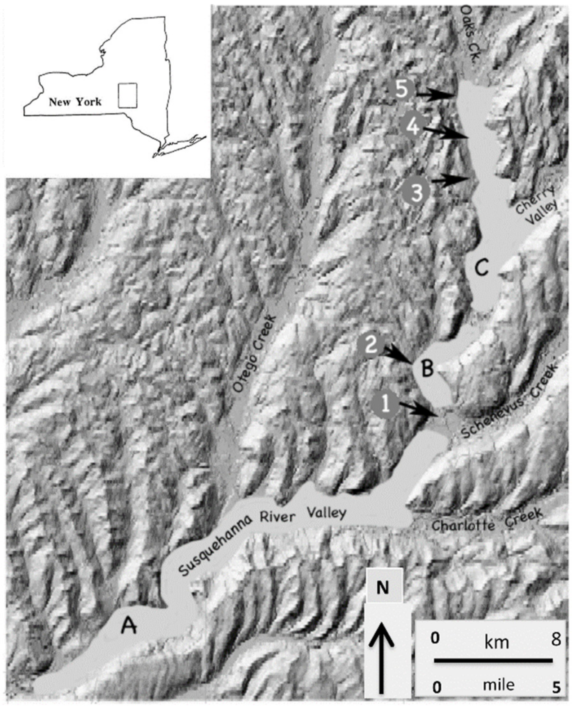

Figure 1. Index Map of upper Susquehanna Ice contact lakes and hamlets / villages in the vicinity of Ancestral Goodyear Lake. Ice-contact lakes are A) Glacial Lake Otego, B) Glacial Lake Goodyear, C) Glacial Lake Milford; 1 is Colliersville, 2 is Milford Center, 3 is Milford, 4 is Hartwick Seminary and 5) is Hyde Park.

1.2 Previous Work

Moss and Ritter (1962) described relatively short, valley ice lobes that extended from the retreating Laurentide ice front. MacNish and Randall (1982) considered flow conditions (active vs. stagnant) and rate of retreat (slow vs. rapid) to establish the association of groundwater aquifers with landforms. Fleisher (1993) related sediment sources and transport mechanisms with environments of deposition leading to the formation of landforms that developed in associated with kilometer long ice-tongues and ice-contact lakes. Remnant landforms associated with these lakes consist of an extensive assemblage of recessional moraines, lacustrine plains, deltaic terraces and hanging deltas. A commonly overlooked landform known as a dead ice sink (DIS) resembles an anomalously broad lacustrine plain confined up-valley and down by valley train outwash terraces, thereby resembling a mega-kettle (Fleisher, 1986b). The term "sink" describes a location of sediment accumulation by subsidence above and adjacent to a mass of buried "dead ice".

Heisig (2012) used well data to relate glacial landforms to groundwater aquifers throughout the lower Susquehanna Valley, whereas Fleisher (1986a) described the lakes that occupied the upper Susquehanna.

A commonly overlooked landform known as a dead ice sink (DIS) resembles an anomalously broad lacustrine plain confined up-valley and down by valley train outwash terraces, thereby resembling a mega-kettle (Fleisher, 1986b). The term "sink" describes a location of sediment accumulation by subsidence above and adjacent to a mass of buried "dead ice".

2. Purpose

This paper serves the dual purpose of presenting evidence for the development and demise of an "Ancestral Lake Goodyear", while presenting evidence that documents a readvance of the Laurentide Ice Sheet into Glacial Lake Goodyear during its retreat from the Appalachian Plateau.

2.1 Subsurface Information - Water Well Logs

Geological information derived from observations within limited regional borrow pits is helpful, but often limited to a two-dimensional perspective that may restrict interpretations to ambiguous generalizations. However, water well logs offer subsurface information that provides a three-dimensional perspective. Confidence and credibility of driller's logs are derived from consistently uniform operating procedures and standard format for recording material encountered.

Well drilling techniques are primarily designed to identify a water-bearing source at depth for domestic use.

Consequently, details related to stratigraphic information, such as bedding characteristics, sedimentary structures and sorting are not included and remain unknown. The driller's main objective is to obtain general insight to subsurface materials and stop drilling when an adequate water source is encountered at depth. Typical materials reported include loam, gravel, pebbles, sand, silt, clay, hardpan and rock. Some logs contain additional details, such as gravel with clay, dirty gravel, or silt with sand. Hardpan uniformly indicates glacial till and bedrock is often identified as either shale or sandstone. Depths at which materials change are normally recorded to the nearest foot. Only occasionally will a log record fractions of feet.

Although limited to general geologic information, water well logs have been successfully used for decades in published literature for the construction of geologic cross sections depicting lateral changes in the subsurface and to identify aquifers and potential recharge areas for groundwater aquifers (MacNish and Randall, 1982; Heisig, 2012). Wells on upland divides differ significantly from those situated within valleys by the common presence of hardpan (typical reference for glacial till) and consistent lack of stratified units. A limited number of upland wells contain gravel and sand interpreted to represent local ponding.

2.2 Anomalously Thick Lake Sediments

The dominant materials encountered in water wells are lacustrine sediments, sand and gravel. They are interpreted to have been deposited in ice-contact and/or proglacial lakes during Laurentide retreat. The thickest is adjacent to Goodyear Lake where OG 1634 penetrates an impressive 547 feet of silt and clay before finishing in 23 feet of rock at a depth of 570 feet. The second deepest well is in the Glacial Lake Otego section of the Susquehanna Valley between Oneonta and Wells Bridge where OG 2392 penetrates 400 feet of clay and clay with gravel before encountering water bearing gravel at 420 feet. Interestingly, both locations are within tight valley meanders, which might be entirely coincidental or taken to imply these valley reaches limited efficient ice flow and erosion, thereby preserving at depth material deposited during earlier glacial events. The vast majority of wells reach water bearing sand and gravel or gravel at depths that preclude deeper drilling, which is borne out by how few wells reach bedrock.

3. Evidence for Ancestral Lake Goodyear

3.1 Development and Elevation

It is proposed that "Ancestral Lake Goodyear", a precursor to Glacial Lake Goodyear, was uniquely confined within a tight valley meander at Milford Center. Unlike other lakes within the Susquehanna Lake System, there is no evidence to indicate Ancestral Lake Goodyear or Glacial Lake Goodyear were dammed by a moraine. No vestige of a moraine exists in the down-valley area of Colliersville, yet a dam for Ancestral Lake Goodyear must have formed here to account for thick lacustrine sediments present in wells OG 2041 and OG 1279 (Figure 2), both perched on the valley wall above Milford Center at 1360 feet and 1340 feet respectively. The OG 2041 well log shows 0 to 100 feet of gray clay above bedrock (shale) and OG 1279 contains 0-20 feet dirty gravel, 20-23 feet sand, 23-183 feet silt, and 183-201 feet clay and gravel on bedrock at 201 feet. These sediments would have settled from turbid glacial meltwater and required a significant amount of time to accumulate, thus portraying a perched ice-contact lake.

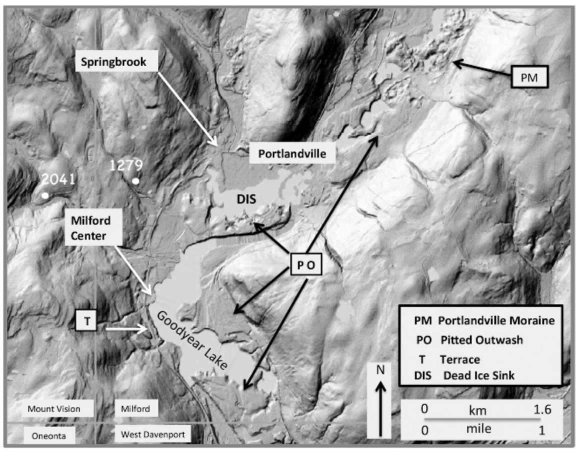

Figure 2. Goodyear Lake area. Illustrated are the locations of Portlandville Moraine, a pitted outwash surrounding Goodyear Lake and a 1250 foot terrace immediately south of Milford Center. The locations of wells OG 2041 and OG 1279 containing thick sections of lake sediments above Milford Center are also identified. A small dead-ice sink (DIS) is part of the pitted outwash area.

Complementing this at a lower elevation of 1250 feet is a deltaic terrace deposited by a meltwater stream that flowed above the western shore of Goodyear Lake at Milford Center. Similarly, strandline sediments in well log OG 673, also at 1250 feet indicate the elevation of the lake at this time coincided with an embayment into the mouth of a tributary valley (Springbrook Creek) between Milford Center and Portlandville (see Figure 2), where silt, clay and sand accumulated as indicated by well OG 770. These sediments represent the lower stand of Ancestral Goodyear Lake~~.~~

3.2 Strandline Soils

A search for soils formed within parent materials common to a lacustrine shoreline was undertaken in an attempt to attempt to confirm abandoned strandlines on the slopes above Milford Center.

In order to determine if soils maps actually contain such evidence, the soils maps of slopes above the documented lacustrine plain of Glacial Lake Otego (Fleisher, 1986a) were examined at an elevation indicated by hanging deltas. Although the specific elevation of such a shoreline is known, soils maps failed to contain information that would indicate soils in strandline parent materials exist.

The same procedure was applied on the slopes above Milford Center to determine if an earlier lake elevation could be recognized, as suggested by well driller's logs. Consistent with soil map analysis in the vicinity of Glacial Lake Otego, abandoned strandlines representing Ancestral Lake Goodyear are simply lacking.

3.3 Glacial Lake Goodyear – a vestige of Ancestral Lake Goodyear

As may be anticipated for an ice-contact lake at a calving ice front such as Glacial Lake Goodyear, icebergs and grounded ice remnants would have been common. Isolated bathymetric lows describe a lake floor with irregularities interpreted to be the result of melting buried ice remnants (Figure 3). The pitted nature of the entire outwash surface bordering Goodyear Lake (Figure 2) indicates icebergs were commonly included in aggrading outwash. The Stump Lot segment of the lake (Figure 3) is evidence of an exceptionally large ice block that was enclosed by segments of the pitted outwash surface. The entire Goodyear Lake basin (currently occupied by Goodyear Lake enlarged by a hydroelectric dam) appears to be the remnant of a huge ice block stranded within the incised valley meander.

The configuration of the lake floor and its elevation may be interpreted from the elevation of the outwash/lake sediment contact between 1125 feet to 1175 feet as indicated by multiple well logs variously locations on the pitted outwash. (OG 1632, OG 1784, OG 2498, OG 915 OG 1557, OG 2208, OG 974, OG 1668 OG 1836 and OG 2287).

The pitted outwash plain that extends down-valley from the Portlandville Moraine decreases in elevation as it grades into the dissected valley train surrounding the dead ice sink at Colliersville**.**

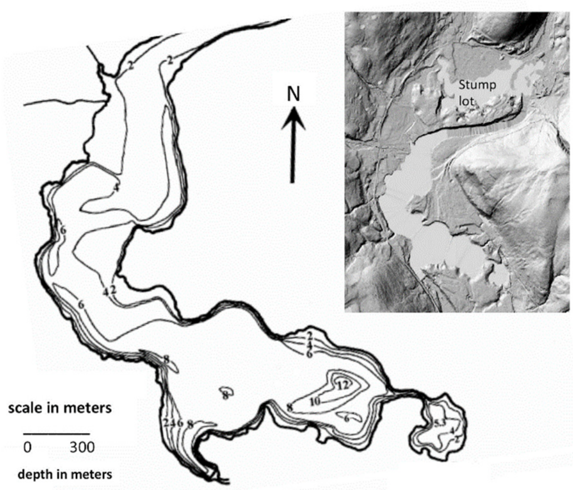

Figure 3. Bathymetric Map of Goodyear Lake. Irregularities on the lake floor suggest vestiges of icebergs trapped in Glacial Lake Goodyear

All of the features listed below (1-6) are consistent with an origin related to the incorporation of large blocks of ice separated from a retreating ice front and ice bergs trapped in the aggrading environment of an ice-contact lake.

1) Shoreline curvatures and cuspate bays of various sizes are similar in shape and scale to kettles commonly found in outwash terraces and valley trains

2) Bathymetric contours indicate the presence of three, arched-shaped closures (6 m and 8 m deep) parallel to the western shore 1.3 to 2.1 km (0.8 to 1.3 miles) south of Milford Center. Well logs located on shore and adjacent to these bathymetric lows (OG758 and OG 818) contain alternating units of clay-rich gravel of relatively uniform thickness, unlike units of sand and gravel typical of outwash or silt and clay of lake sediments

3) The flat center of the lake is interrupted by an isolate 8 m basin similar to an irregularly shaped basin at the southern end of lake that reaches a depth greater than 12 m adjacent to a smaller irregularly shaped 6-8 m depression

4) Contributing to the lake's irregular shape, Silliman Cove, a small asymmetric, steep-sided embayment at the southernmost end of the lake, is separated by a narrow 2 m deep inlet that reaches a maximum depth of 5.3 m. The cove is very similar in size and shape to the kettles found on the adjacent pitted outwash

5) A large irregularly shaped, shallow basin less than 1 m deep referred to as "Stump lot" on the bathymetric map is confined by outwash thereby separated from the deeper segments of the lake, which fits the description of a dead-ice sink. This shallow basin is partially filled with alluvium (OG 2392) from Springbrook Creek.

6) Steep slopes extend with depth along the entire lake shoreline, thus defining a shape unique to conventional lakes.

4. Discussion

4.1 Ancestral Goodyear Lake Dammed by a Dead Ice Sink

The water body referred to here as "*Ancestral Goodyear Lake"* eluded earlier recognition because depositional evidence in the form of lake sediments perched on the valley wall above Milford Center (OG1279, OG 2041) were not known to exist until well data became available (U.S. Geological Survey National Water Information System and well completion reports from the NYS DEC well permit program). Furthermore, the absence of a moraine down-valley precluded the expectation of a lake here.

In lieu of a moraine, it is proposed that a massive ice block abandoned by the retreating Laurentide formed the dam for Ancestral Goodyear Lake. The dam location is represented by an exceedingly large dead ice sink (Figure 4) expressed as an anomalously broad floodplain at the confluence of Schenevus Creek and the Susquehanna River. Here the floodplain is bound, up-valley and down by dissected valley train terraces, beneath which well data indicate (OG 83, OG 2378 and OG 90) a variety of discontinuous, non-correlative stratigraphic units, thus satisfying the definition of a dead ice sink (Fleisher, 1986b).

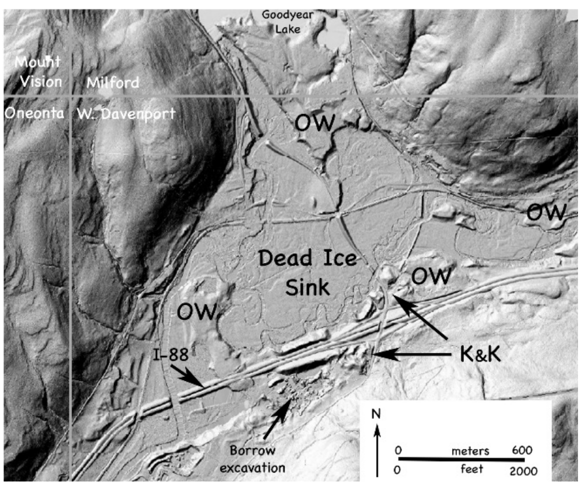

Figure 4. Dead-Ice Sink. The dam for Ancestral Goodyear Lake is represented in the current landscape by a Dead-Ice Sink and associated outwash remnants (OW). Kame and kettle topography (K&K) appears on southern edge of the dead-ice sink. Also shown are Interstate Highway I-88 and an active borrow excavation.

4.2 The Ice Dam Location

Retreat conditions are interpreted to have favored dead ice sink development, beginning with the abandonment of a massive ice block (Mullholdand, 1982). The ice block had horizontal dimension sufficient to fill the entire valley width (Fleisher, 2019) and sufficient heights to form a dam that reduced down-valley meltwater flow, which temporarily impounded an ephemeral lake. Progressive leakage through and around the ice dam led to two stable lake stands, one at 1360 feet and another at 1250 feet.

Surface ice ablation, combined with downwasting, eventually led to the development of local basins in which heterogeneous fine sediment accumulated. Outwash sand and gravel accumulated along ice block margins and ponded silt and clay interbedded with fluvial sand and gravel filled growing basins. Thus, the term “sink” describes a location for sediment accumulation above and adjacent to a mass of buried “dead ice”. Well logs OG 2228, OG 83, OG 2378, and OG 90 indicate ongoing intermittent subsidence, which resulted in truncation and offset of silt interbedded with fluvial sand and gravel. Sediment accumulation due to seepage of meltwater in such a low-energy environment would preclude any significant accumulation of coarse sediment.

Ultimately, subsidence ceased with the complete melting of all buried ice. If down-valley meltwater flow were to have continued the “sink” would have filled to the level of the adjacent valley train and all topographic expression of the abandoned ice block would vanish. Therefore, preservation of the dead ice sink as a landform requires cessation of deposition from continued meltwater flow, which occurred here when retreat of the Laurentide ice sheet from the Susquehanna system caused meltwater diversion into the Mohawk Valley (Fleisher 1993) to the north, followed by limited meteoric discharge, which lead to floodplain aggradation within the dead ice sink.

A hummocky kame and kettle area dominates the southern flank of the DIS at the base of the adjacent valley wall (Figure 4). Although limited in extent, it indicates a portion of the remnant ice associated with the DIS was covered by colluvium and outwash (most likely from Schenevus Creek) while finer sediment accumulation persisted within the dead ice sink. Here, a terrace crosses the kame field at 1240 feet, thus establishing a threshold for drainage of the lower phase of Ancestral Lake Goodyear.

The final topographic expression is an anomalously broad floodplain resembling a lacustrine plain that is confined up-valley and down by valley train outwash terraces. Furthermore, Goodyear Lake bathymetry, well logs and existing landforms indicate that ice also lingered within the lakes throughout the transition from Ancestral Goodyear Lake to Glacial Lake Goodyear, ending in Goodyear Lake.

Glacial Lake Goodyear came to an end when the kame and kettle dam associated with the Colliersville dead-ice sink was breached and the Glacial Lake Goodyear emptied into Glacial Lake Otego, which was the next lake down-valley, thus leaving the Portlandville pitted outwash high and dry.

4.3 An Alternative Hypothesis

To account for the occurrence of thick lake sediments perched on the valley wall above Milford Center without involving a down-valley dam would require the existence of a standing body of water (i.e. a melt pond) flanking ice within the valley. Such an alternative would also assume significant sediment accumulation in the melt pond as the ice retreated. However, published literature fails to document sediment accumulation in melt ponds (Cook and Quincey, 2015), which is consistent with a surface meltwater source that would be relatively sediment-free, thus leading to negligible accumulation. Furthermore, melt ponds tend to be short-lived, which would preclude significant accumulation of sediment. Therefore, the possibility for a melt pond on the valley wall to accumulate 100 feet of clay (OG 2041) and 160 feet of silt (OG 1279) respectively is deemed very unlikely.

4.4 Evidence of a Laurentide Readvance

A moraine at Portlandville spans the full width of the valley except where it is breached at the base of the western valley wall (Figure 2). It stands 60 feet above the Glacial Lake Milford / Hyde Park lacustrine plan to the north and grades down-valley into the extensive pitted outwash that surrounds Goodyear Lake and continues as part of the valley train surrounding the dead ice sink at Colliersville. Local relief on the moraine is 60-80 feet, which is like other moraines in the Susquehanna Lake system.

The topographic expression of the moraine clearly represents the gradational transition from a kame and kettle expression into a pitted outwash as represented by two large kettle ponds at the head of an extensive pitted outwash surface that surrounds Goodyear Lake. Two wells on the moraine crest (OG 1477 and OG1502) contain 177 feet of lake sediments bound above and below by ice-contact material thereby demonstrating a Laurentide readvance into an aggrading ice-contact lake. The absence of lake sediments on the moraine indicates that the elevation of the moraine exceeded the surface elevation of the ice-contact lake.

4.5 Interpretation of Goodyear Lake Bathymetry

Goodyear Lake occupies a deeply incised valley meander (Fig 2) that had the capacity to retard normal glacial flow sufficiently to permit a zone of local stagnation to develop (Fleisher, 2019) in conjunction with separation of a large ice block in Colliersville 1.6 km (1.0 miles) down-valley. Lake sediments recorded in well logs from the adjacent valley slope (OG 1279, OG 2041) indicate Ancestral Goodyear Lake occupied temporary strandlines, initially at 1360 feet, thus permitting thick lake sediments to accumulate on the valley floor followed by lower terrace development at 1250 feet. Remnants of sub-lacustrine ice, as well as ice bergs remained trapped within ongoing sediment accumulation. The shape of Goodyear Lake's arched shorelines and isolated bathymetric lows suggest an origin related to progressive melting of trapped sub-bottom ice and subsidence. The largest ice mass appears to have occupied the basin that currently holds Goodyear Lake. A similar, but smaller ice mass occupied the shallow ponded area (i.e. Stump lot), which has the topographic expression of a small dead ice sink.

Three, small arched-shaped bathymetric closures are situated along the western shoreline, where well logs OG 1861, OG 758 and OG 818, OG 673, OG 770 and OG 916 report alternate accumulation of discrete units of gravel, dirty gravel, clay with sand, and clay-rich gravel consistent with deltaic accumulation associated with the adjacent onshore 1250 foot deltaic terrace. Evidence of additional subsidence above decaying sub-bottom ice is represented by several bathymetric lows reaching depths of 8 and 12m in the southern end of Goodyear Lake, as well as 8 m at the lake outlet above the current hydroelectric dam and 6 m in Silliman Cove. Further evidence of subsidence over deteriorating sub-bottom ice beneath the main body of Goodyear Lake is represented by closely space bathymetric contours representing unconsolidated material along the eastern and western shorelines. The final Pleistocene event occurred in front of the Portlandville Moraine where outwash incorporated the last vestiges of ice bergs and remnant ice, thus leading to the formation of the extensive pitted outwash that encloses Goodyear Lake.

4.6 Significance of Hard Clays and Hard Gravel

All wells that penetrate the lacustrine plain of glacial lakes encountered thick units of silt and clay. However, OG 1693 on the lacustrine plain of Glacial Lake Milford / Hyde Park contains "0-3 ft. gravel, 3-12 ft. sand. and gravel, 12-165 ft. clay, 165-180 ft." hard clay", 180-232 ft. "cemented gravel", 232-265 ft. "hard clay", 265-269 ft. "cemented gravel"., and rock at 269 feet. Additionally, two well logs (OG 2208, and OG 2498) beneath the pitted outwash of Goodyear Lake also make reference to "hard clay", "cemented gravel" and "hard gravel", plus "hard packed gravel in a clay matrix". Four additional well logs in the same vicinity (OG 973, OG 2283, OG 2287) contain similar materials at comparable depths. This suggests a degree of compaction not encountered elsewhere. Furthermore, these wells are in the vicinity of the thickest sediments in the entire valley. Although cemented gravel has been reported in open borrow pits within valleys that originate in limestone terrain (Fleisher, 1993), the same process of consolidation does not apply to hard clay, which is too fine-grained to facilitate infiltration of a cementing agent. This indicates the hard clays originated by a different process. Although all local depositional glacial landforms are interpreted to be the product of the most recent Laurentide event (Moss and Ritter, 1962; MacNish and Randall, 1982; Fleisher, Mullins and Yuretich, 1992, Fleisher, 1993), elsewhere in New York State earlier glacial events have been reported (Kozlowski, et al., 2016; Young and Burr, 2006: Young, 2012). This suggests ice may have advanced across this region multiple times. Based on this information, the hard clays encountered in well log OG 1693 is interpreted to represent the result of compression by the overriding Portlandville readvance, whereas similar material reported south of the moraine in well logs beneath the pitted outwash were compressed beneath earlier advances.

5. Conclusions

Recently acquired water well logs documents recognition of "Ancestral Lake Goodyear", retained behind an ephemeral ice dam in a location represented now by a prominent dead ice sink at the confluence of Schenevus Creek and the Susquehanna River in Colliersville. This is the only ice dam known to have existed within the entire Susquehanna Lake System.

Ancestral Lake Goodyear occupied two stable elevations; one at 1360 feet represented by thick sections of lake sediments recorded within well logs on the valley wall above Milford Center and a lower deltaic terrace at 1250 feet, supplemented by a variety of adjacent shoreline features. A still lower version of this lake stabilized to form Glacial Lake Goodyear into which the Laurentide readvance formed the Portlandville Moraine, an event not previously recognition. Two wells on the moraine contain lake sediments confined by ice-contact material, thus establishing a Laurentide readvance

This ice-contact lake environment, replete with multiple remnant ice blocks is well represented by an extensive pitted outwash surface the currently surrounds Goodyear Lake. The elevation of the contact separating underlying gravel from lake sediments undulates in a manner consistent with bathymetric irregularities present in modern lakes choked with iceberg and buried remnant ice. The pitted outwash elevation decreases down-valley where it grades into the dissected valley train that confines the Colliersville Dead Ice Sink.

Subsequent retreat from the Portlandville Moraine led to the formation of the dam behind which Glacial Lake Milford formed.

Hard clay at depth in multiple wells beneath the floor of Lake Milford and the pitted outwash adjacent to Goodyear Lake is interpreted to represent compaction beneath an earlier overriding glacial event for which there is no geomorphic evidence.

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