Surficial Geologic Map of the Newport and Newport Center Quadrangles, Vermont

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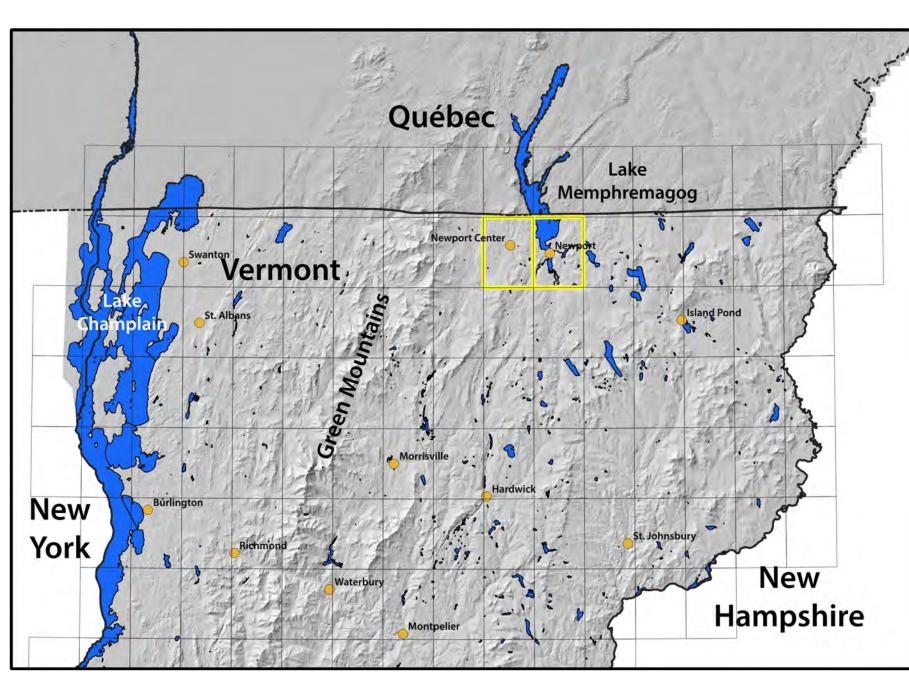


Figure 1: Location of the Newport Center and Newport Quadrangles in northern

Location and Geologic Setting

The Newport and Newport Center Quadrangles lie along Vermont's northern border with Québec (Fig. 1). Most of the area is drained by the north-flowing Black, Barton, and Clyde Rivers, all of which drain into Lake Memphremagog (Figs. 2, 3). The lake extends northward into Québec and drains via Rivière Magog which eventually flows into the St Lawrence River. The north-flowing Missisquoi River drains the western part of the map area.

The bedrock underlying this area ranges in age from late Proterozoic to Devonian and falls into three groups. The first group, present to the west, consists of metasedimentary rocks (schist and phyllite) originally deposited as sediments in the lapetus ocean prior to late-middle Ordovician time (Fig. 3). They were subsequently metamorphosed and deformed during the Taconic Orogeny. A younger group of lower-grade metasedimentary rocks (Silurian/Devonian) were deposited after the Taconic Orogeny and deformed and metamorphosed during the Acadian Orogeny (Fig. 3). Gabbroic to granitic igneous rocks, part of the Northeast Kingdom Batholith, comprise the third group of rocks and were intruded during the Acadian Orogeny (Fig. 3).

Methods

Both traditional field techniques and digital mapping were employed during the 2023/2024 field seasons. Almost 4,000 separate field observations were recorded using the Fulcrum mobile MapApp. Observations included the type(s) of surficial materials and landforms occurring in an area, bedrock outcrops, glacial striations, landslides, and other geologic phenomena pertinent to this study. Field mapping utilized a base map consisting of LiDAR hillshade imagery with LiDAR-derived contours. Field observations were imported into GIS software (QGIS) that was utilized to draw contacts between different surficial mapping units. Cross-sections are based on the surface geology, bedrock outcrops, and water well logs.

Ice Flow History

- Regional ice flow was to the SE when the ice sheet was thick enough to cover the mountains (Fig. 5). Crag and tail structures record this flow direction (Fig. 4).
- During ice retreat, the thinning ice sheet became topographically controlled and generally flowed south, parallel to the region's valleys (Fig. 5).

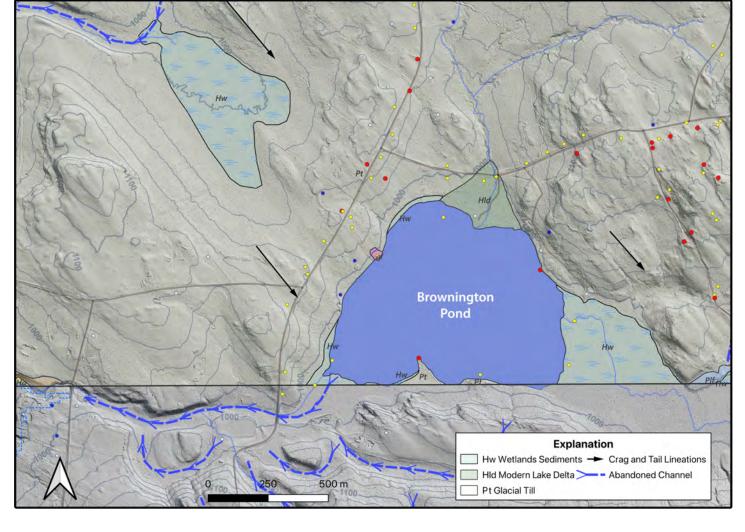


Figure 4: Crag and Tail structures record regional ice flow to the southeast.

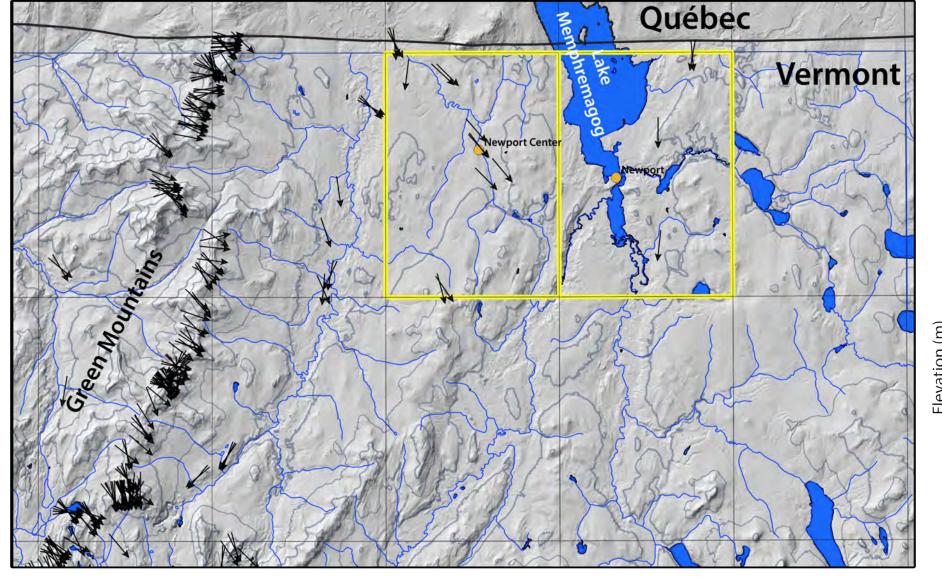
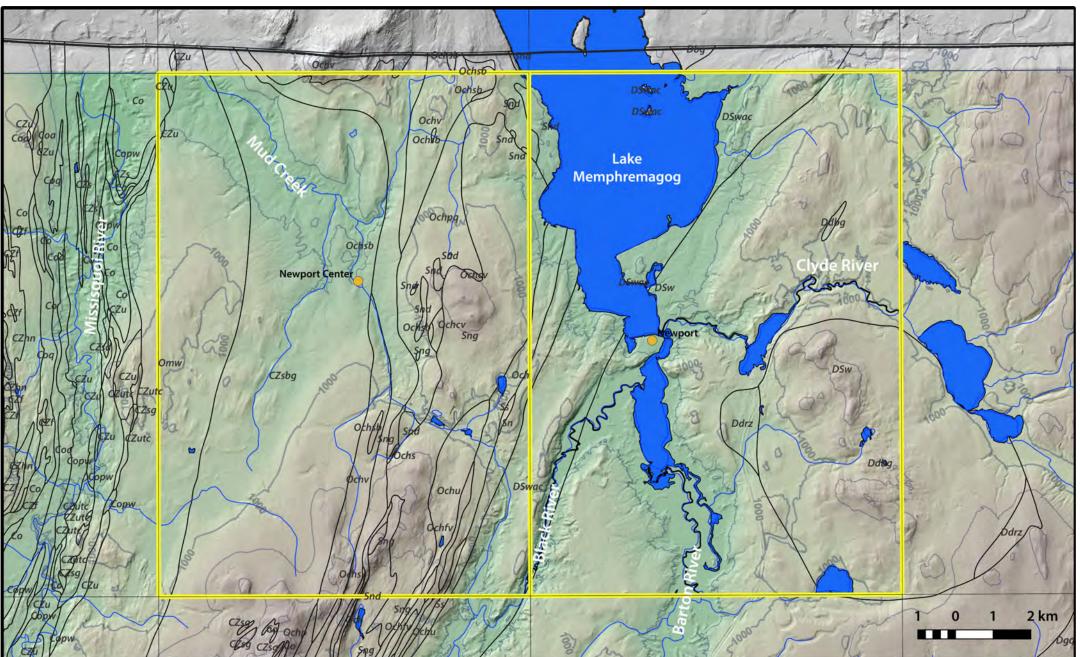
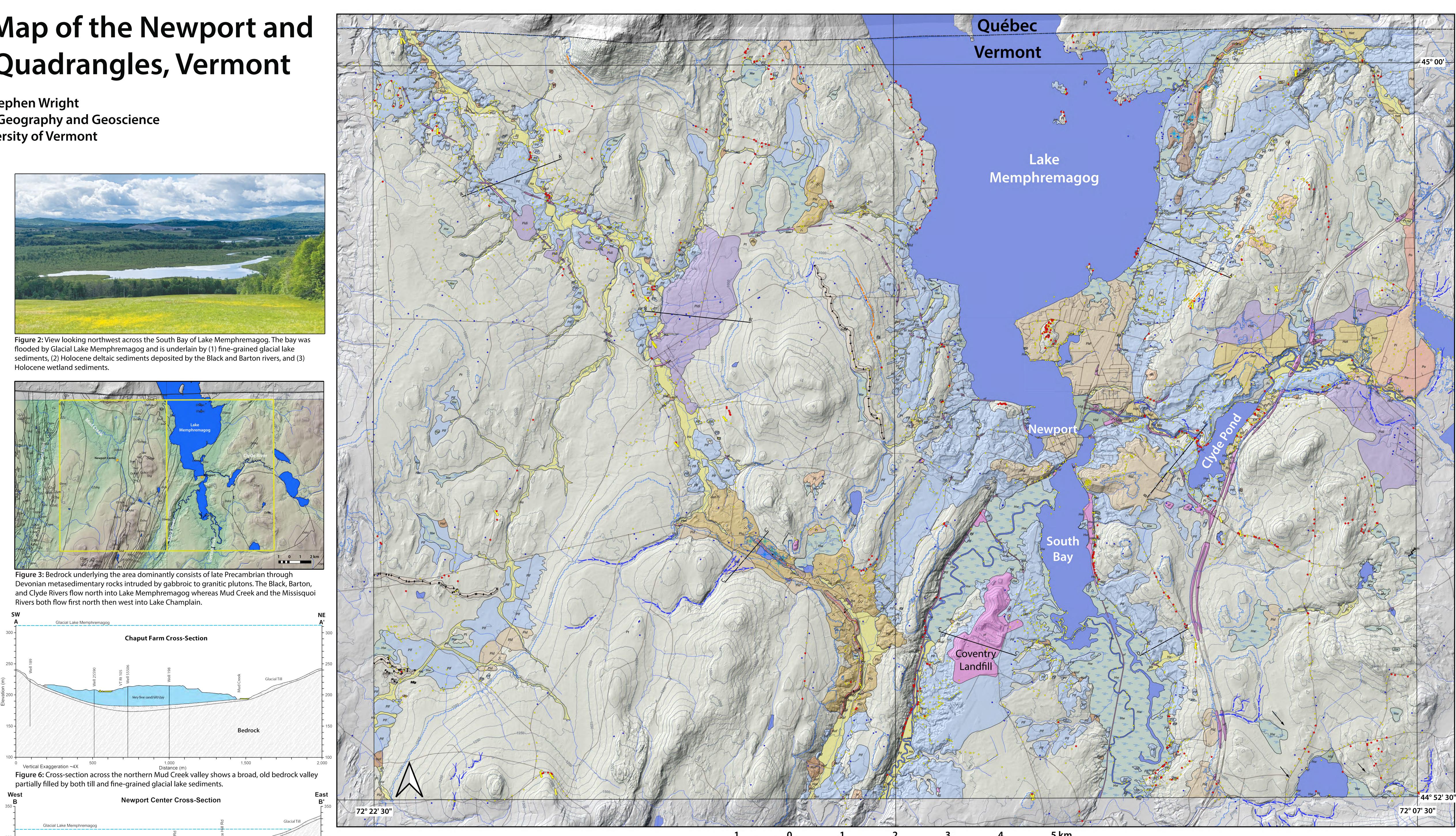
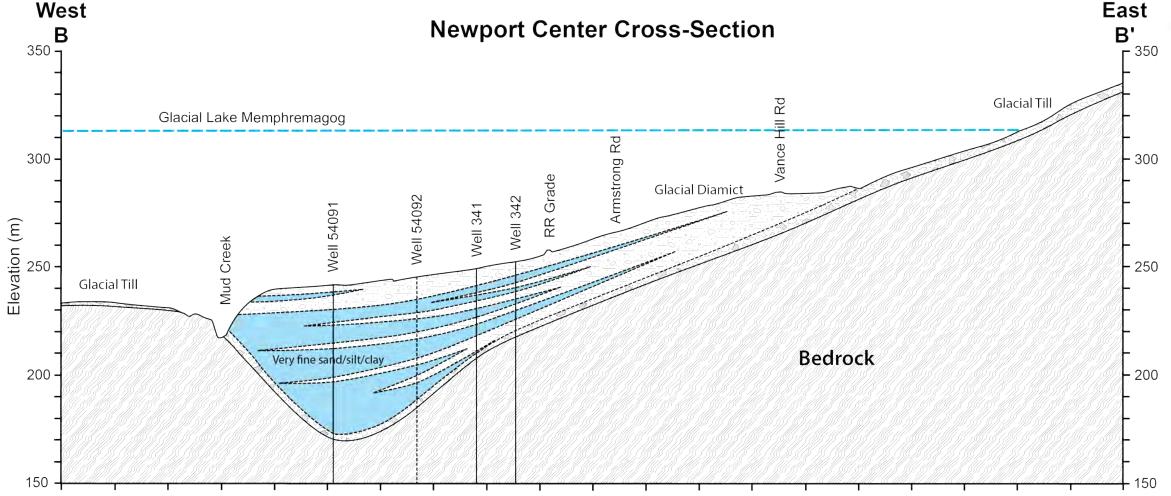


Figure 5: Compilation of glacial striations in northern Vermont indicates regional NW to SE ice flow across the mountains whereas striations in valleys generally mimic the orientation of those valleys.









⁰ Vertical Exaggeration ~4X ⁵⁰⁰ Figure 7: Wells near Newport Center Village outline a deep bedrock valley filled with both lake sediments and landslide debris (diamict), the mapping unit "Stratified Diamict Pldi."

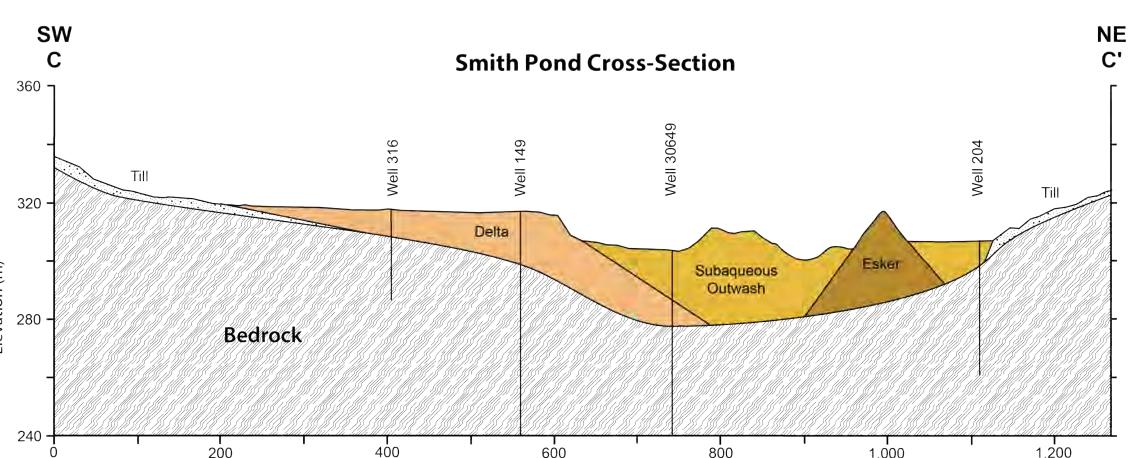


Figure 8: A variety of landforms, all composed of sand and gravel fill the valley. The delta was fed by water flowing along an ice-marginal channel.

Distance (m

Vertical Exaggeration ~3.4X

	Lakes, Ponds	
af	af Artificial Fill: Artificial Fill. Artificially-emplaced material along road beds, embankments and in developed areas. Material varies from natural sand, gravel, or till to various artificial waste materials. Thickness varies.	
Hw	Hw Wetlands Sediments: Accumulations of organic matter and/or clastic sediment in low-lying areas. Includes a wide variety of wetland types. Commonly overlying other deposits such as alluvium, lacustrine sediment, or till. Larger deposits are shown.	
Hld	HId Modern Lake Delta: Well-sorted sand and gravel deposited in a present-day lake at the mouth of a tributary stream.	ŀ
Hls	HIs Modern Lacustrine Shoreline Deposits: Consists of well-sorted sand deposits of present-day lakes and ponds. Includes beach and nearshore deposits from backshore out to shoreface and bars, tomobolos, and spits.	
На	Ha Alluvium: Silt, sand, and gravel deposited by modern streams. Includes stream channel, bar, and floodplain deposits. Wetland deposits are common within these areas and are not distinguished. Thickness is generally equal to the maximum depth of the stream channel.	
Hat	Hat Alluvial Terrace Deposits Silt, sand, and gravel deposited on terraces above the modern floodplains of streams. They are composed of a variety of channel, bar, and floodplain deposits. May include late Pleistocene alluvial sediment deposited onto freshly-drained glacial lake bottoms before the main stream and its tributaries incised down into the lacustrine deposits. Commonly less than 5 meters thick.	
Haf	Haf Alluvial Fan: Boulder, cobble, and pebble gravel, pebbly sand, and diamict deposited at sites where steep, stream gradients are sharply reduced. Holocene alluvial fans (Haf) are common at the mouths of steep tributaries where they meet the main stream. Commonly less than 5 meters thick.	
PI	PI Lacustrine Deposits, Undifferentiated: Coarse- to fine-grained sediment deposited in a glacial lake, generally in an ice- proximal environment. Grain size generally decreases up-section, but marked changes in grain size occur over short distances both laterally and vertically.	F

Explanation

Plf	glacial lake. Commonly laminated.		
Pls	Pls Lacustrine Deposits, Shoreline: Well-sorted fine to coarse beach or nearshore environments.		
PId	Pld Glacial Lake Delta: Well-sorted sand and gravel deposite topset, foreset, and proximal bottomset beds if exposures p		
Pldi	 Pldi Lacustrine Stratified Diamict: Interbedded massive diam Dropstones may be common in the stratified layers. Interpred deposited in an ice-proximal setting. Diamict layers may ext Plo Subaqueous Outwash: Well-sorted sand and gravel depot tunnel mouths. Sediment deposited close to tunnel mouth margin retreats the subaqueous outwash is blanketed with Po Outwash Deposits: Glacial meltwater deposits composed out beyond the glacial margin. Pi Ice Contact Sediments, Undifferentiated: Unsorted to poor with glacial ice. Surface may contain scattered kettle holes to 		
Plo			
Ро			
Pi			
Pie	kame and kettle topography. Pie Esker Sediments: Elongate ridge of ice-contact stratified streams in tunnels within or beneath the glacial ice.		
Ptm	Ptm Moraine Deposits: Composed primarily of till with varial vicinity of an ice margin from both ice advance and the accu		
Pt	Pt Glacial Till: Very dense to loose, unsorted to very poorly so wide range of grain sizes, from clay or silt up to large boulde		
	Surface boulders are generally common. Thickness is highly		

5 km

- Plf Lacustrine Sediments, Fine Grained: Clay, silt, and very-fine to fine sand deposited in quiet-water environments of a
 - rse sand, pebbly sand, pebble gravel, or cobble gravel deposited in
 - ited in a glacial lake at the mouth of a tributary stream. Includes
 - amict layers and sandy layers interlayered with silt-clay layers. preted to represent subaqueous debris flows and turbidity flows extend above shoreline.
 - eposited as subaqueous fans within glacial lakes at and near esker h is coarse-grained, distal sediments finer-grained. As the glacial h finer-grained lacustrine material.
 - ed of stratified sand and gravel deposited in streams in locations
 - oorly-sorted stratified sand, gravel, and silt deposited in contact es formed by melting of buried ice blocks or be a highly complex
 - ed coarse sand and gravel deposited by glacial meltwater
 - riable amounts of stratified sand and gravel. Deposited in the ccumulation of sediment at a stable ice margin.
- v sorted material deposited directly from glacial ice. Contains a ders. Matrix commonly dominated by the silt or sand fraction Surface boulders are generally common. Thickness is highly variable, from less than 3 meters to greater than 30 meters.

Glacial Lakes		<u> </u>	Landslide Scarp
	Glacial Lake Memphemagog	Projection	
Symbols Geologic Field S	Sites	>	Abandoned Channel
۰	Surficial Field Site		Wave Cut Bench
•	Bedrock Outcrop	• • • • • •	Moraine Ridge
Î	Glacial Striations		Grooved Till
Water Wells		_	Esker Ridge Line
•	GPS Location		
		*	Glacial Kettle
0	E911 Address Matched		
		•	NEWSVT Borings and Wells
Х	G	Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program (StateMap), under USGS award number G23AC00462 to the Vermont Geological Survey. The views and conclusior	

Rock Quarry

G23AC00462 to the Vermont Geological Survey. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

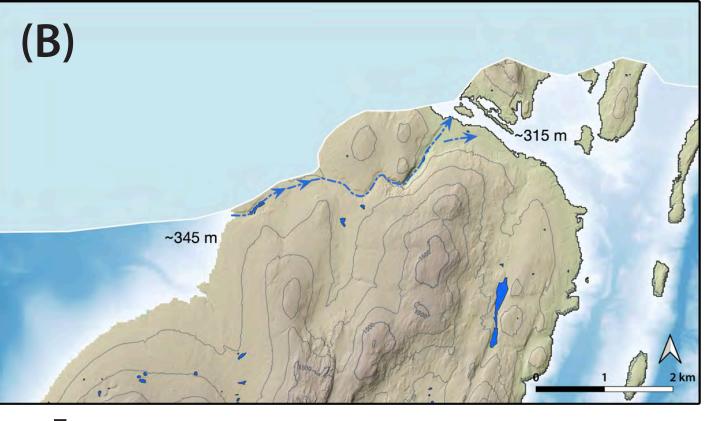
Geologic Cross-Sections University of Vermont students Jared Berlin, Sulemaan Bokhari, Bren Cable, Bryce Doherty, and Mackenzie Patterson assisted with mapping the Newport Quadrangle during the summer of 2023.

Laurentide Ice Sheet Retreat

- The timing of ice sheet retreat across northerr Vermont is poorly constrained, but current dating indicate a timeframe between ~13,600 and 13,200 years ago, several hundred years following the well-dated end of Glacial Lake Winooski at ~13, 800 years ago.
- Ongoing OSL dating will refine this timeframe.
- Moraines are rare in northern Vermont, but sev have been mapped and may have formed during a short-lived standstill or readvance (Younger Dryas?). These moraines are likely younger than the White Mountain Moraine System which formed during the Older Dryas, ~14.0-13.8 cal ka BP (Thompson et al., 2017)

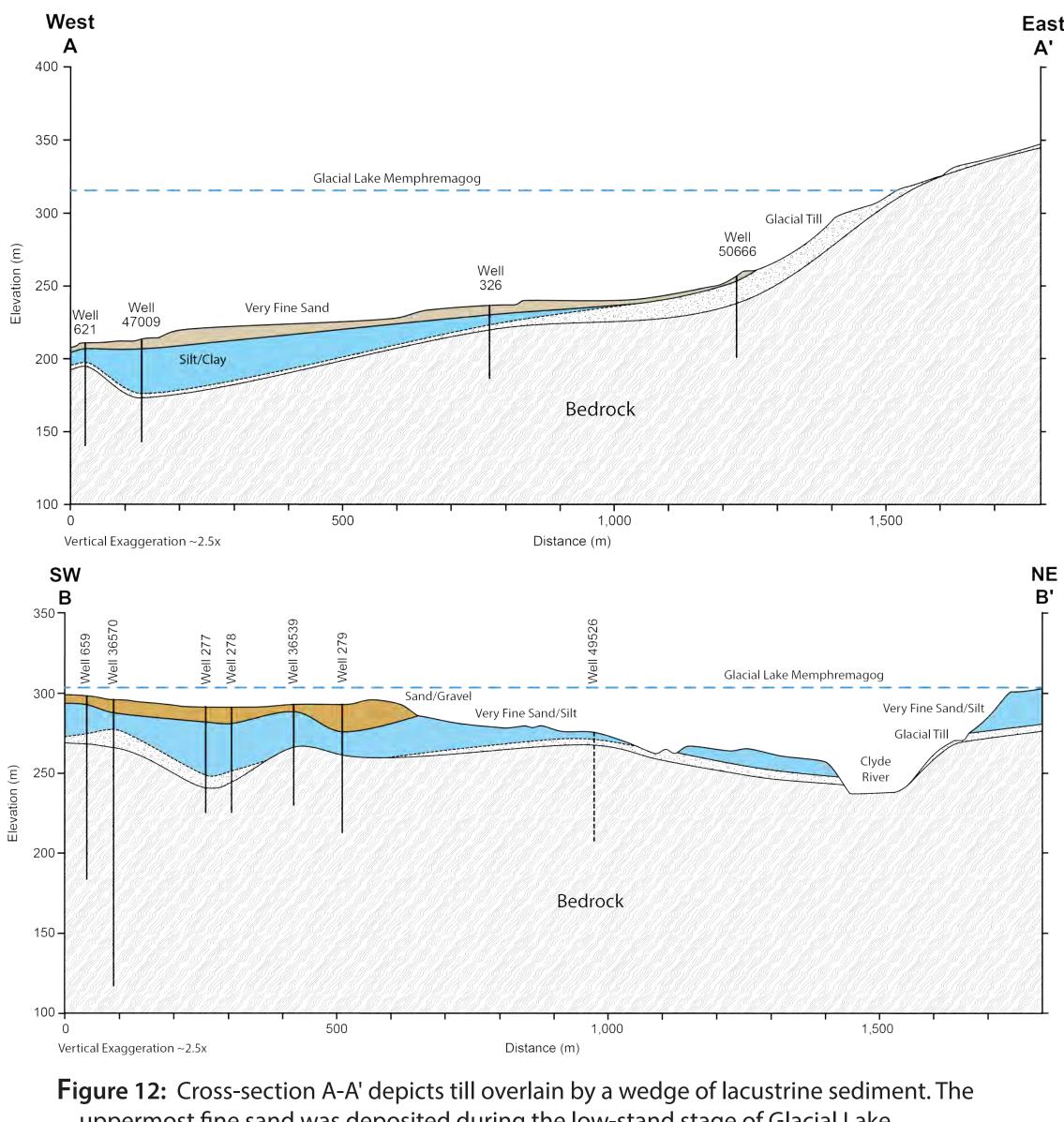
Subglacial Water Flow

- Segments of two eskers occur in the area. These eskers likely extend farther, but are buried beneath younger sediments.
- The eskers are aligned parallel to the valleys they occur in indicating they formed when the thinning ice sheet was topographically controlled, i.e. hydraulic gradients were parallel to those same valleys.



drainage of high-level lakes into lower-level lakes. **Glacial Lake Sediments**

- Glacial lake sediments generally fine upwards reflecting increasing distance from the retreating ice front.
- Areas near eskers are blanketed with subaqueous outwash, i.e. (Figs. 8, 11A).
- Layers of diamict interbedded with "normal" lacustrine sediments are
- While extensive areas are underlain by fine-grained glacial lake North American Varve Chronology (Ridge et al, 2012).



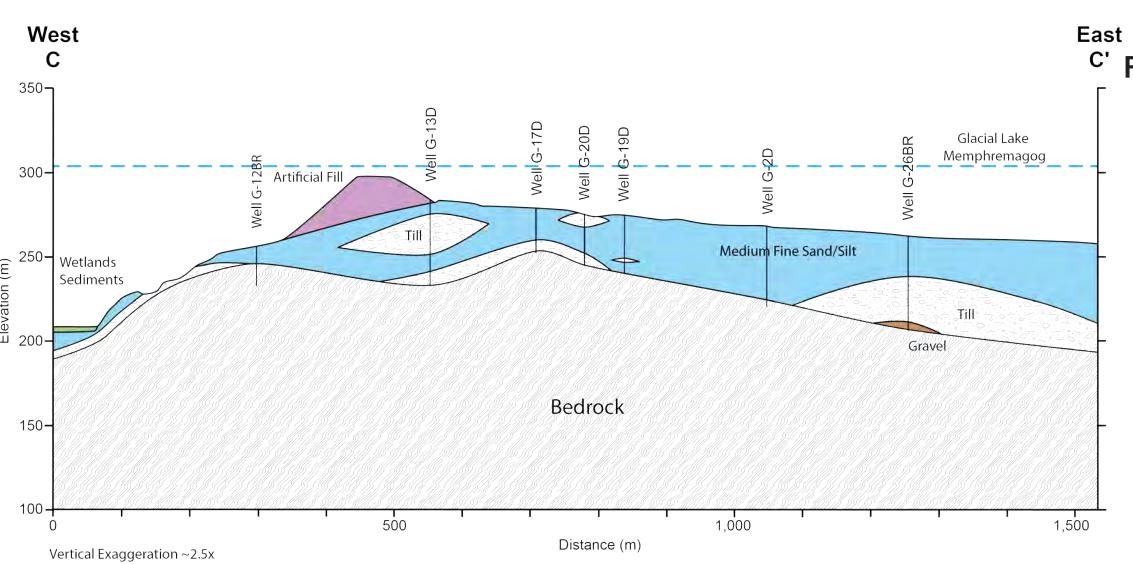


Figure 9: (A) The Missisquoi, Black, and Barton river valleys each hosted glacial lakes. (B & C) Ice marginal channels record the

Evolution of Glacial Lake

tributary valleys during ice retreat.

Many relatively short-lived glacial lakes formed in north-draining

Smaller tributary lakes merged to form Glacial Lake Memphremagog

which grew to a considerable size as the ice sheet retreated into

bandoned ice-marginal channels are abundant and record the

sequential drainage of higher-level lakes into lower-level lakes (Fig. 9).

Memphremagog

Québec (Figs. 9, 10).

sediments deposited in subaqueous fans sourced from esker tunnels

interpreted as landslide deposits composed of remobilized till (Figs. 7

sediments (Figs. 6, 12, 14), no good sections of varved silt/clay were observed preventing correlation of these lake sediments with the



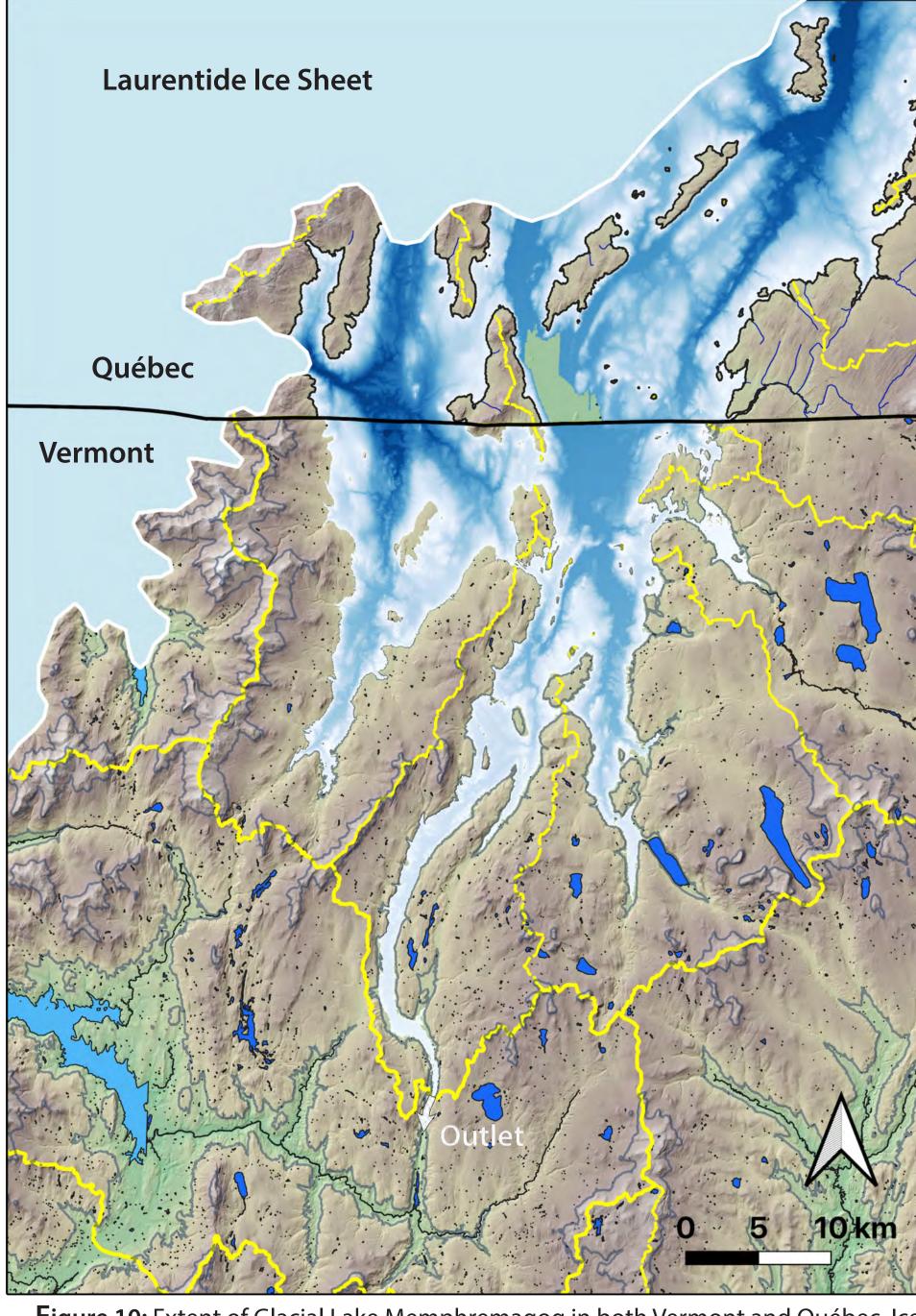
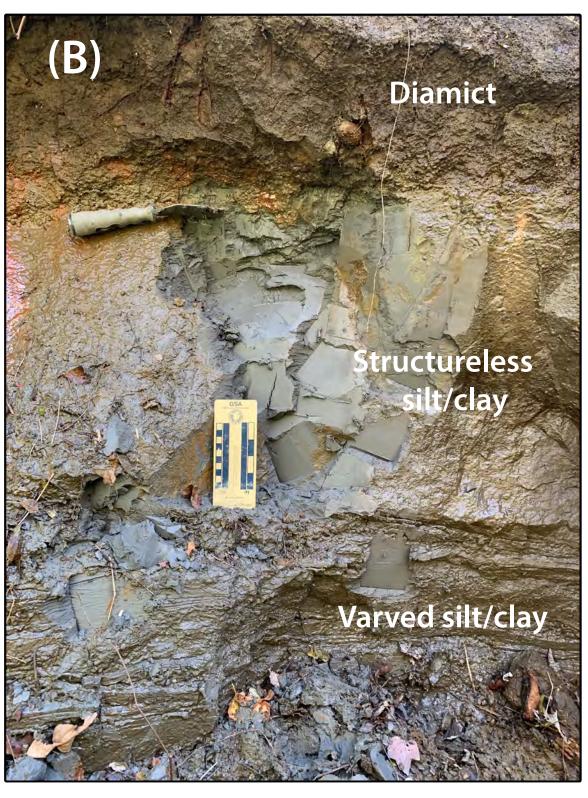


Figure 10: Extent of Glacial Lake Memphremagog in both Vermont and Québec. Ice margin in Québec is from moraines mapped by Parent and Occhietti (1999).

Figure 11: (A) Subaqueou. outwash sediments deposited in Glacial Lake Memphremagog near ar esker. (B) Small section exposed near Mud Creek consists of varved glacia lake sediment overlain by structureless silt overlain by diamict. The silt/diamict is interpreted as a landslide deposit that either flowed into Glacial Lake Memph magog or was deposited on the lake floor shortly after the lake drained.



uppermost fine sand was deposited during the low-stand stage of Glacial Lake Memphremagog. In contrast, Cross-section B-B' extends from the Clyde River delta to the river's modern course where it's eroding into bedrock.

Evolution of South Bay

- Deltaic sediments deposited on either side of South Bay indicate the Clyde River deposited a delta that extended across Glacial Lake Memphremagog where Newport is today (Fig. 14).
- When the retreating ice sheet uncovered a lower outlet in Québec (the Lac Nick outlet) and lake level dropped ~85 m, the delta dammed lake water south of the delta.
- When the delta was breached, a narrow channel eroded through the delta, the channel that now separates South Bay from the main body of Lake Memphremagog.

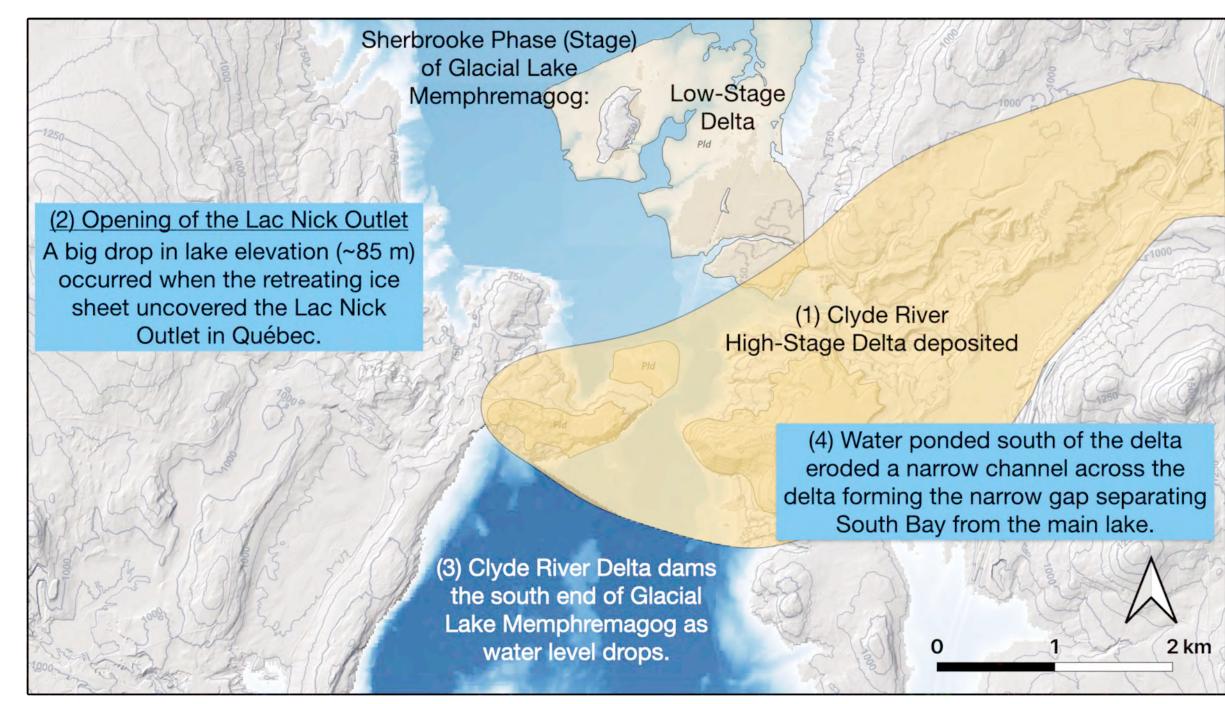


Figure 13: South Bay is separated by a narrow channel from the main body of Lake Memphremagog. The above map hypothesizes that the Clyde River delta in *Glacial* Lake Memphremagog extended completely across the lake basin. When Glacial Lake Memphremagog partially drained when the Lac Nick Outlet was uncovered, water dammed south of the delta eroded a channel through the delta and redeposited that sediment on the low-stage delta.

C' Figure 14: Cross-section C-C' shows the highly variable and discontinuous stratigraphy interpreted from closely spaced borings around the landfill. Deposition may have occurred in shallow water with a grounded ice sheet. In contrast, Crosssection D-D' depicts a uniform stratigraphy of fine-grained glacial lake sediments above the till

