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

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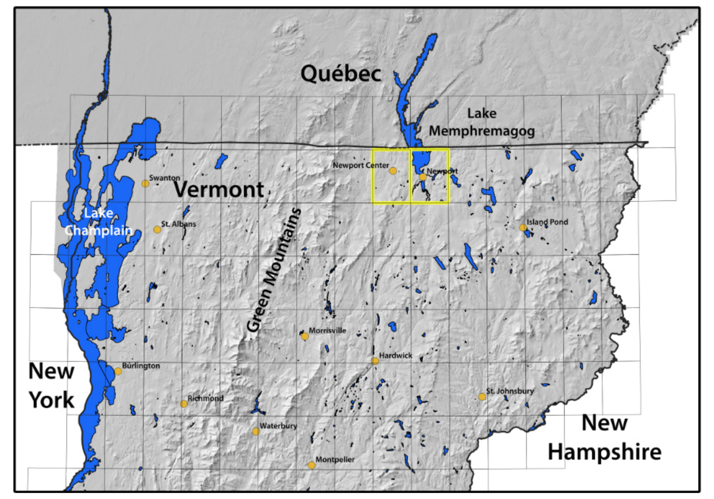


Figure 1: Location of the Newport Center and Newport Quadrangles in northern Vermont.

Figure 2: View looking northwest across the South Bay of Lake Memphremagog. The bay was flooded by Glacial Lake Memphremagog and is underlain by (1) fine-grained glacial lake sediments, (2) Holocene deltaic sediments deposited by the Black and Barton rivers, and (3) Holocene wetland sediments.

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 Iapetus 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).

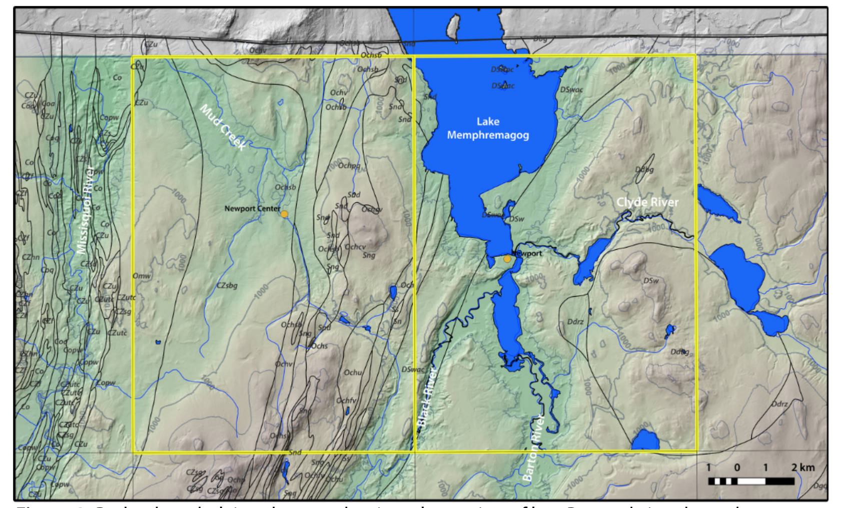


Figure 3: Bedrock underlying the area dominantly consists of late Precambrian through Devonian metasedimentary rocks intruded by gabbroic to granitic plutons. The Black, Barton, and Clyde Rivers flow north into Lake Memphremagog whereas Mud Creek and the Missisquoi Rivers both flow first north then west into Lake Champlain.

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.

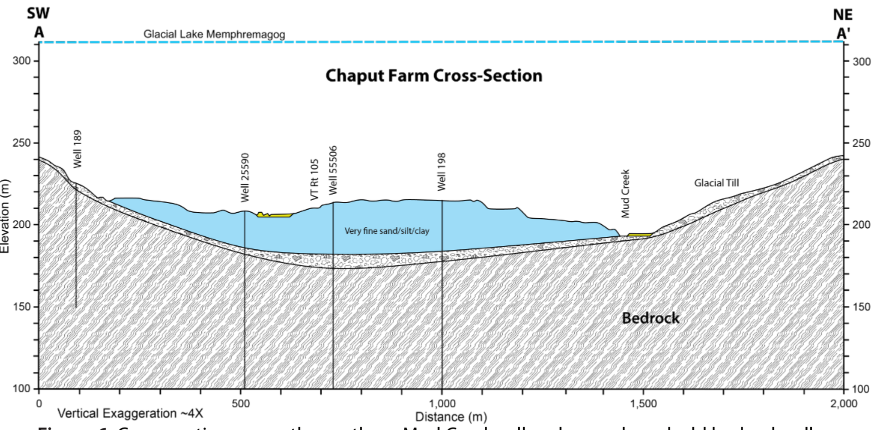


Figure 6: Cross-section across the northern Mud Creek valley shows a broad, old bedrock valley partially filled by both till and fine-grained glacial lake sediments.

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).

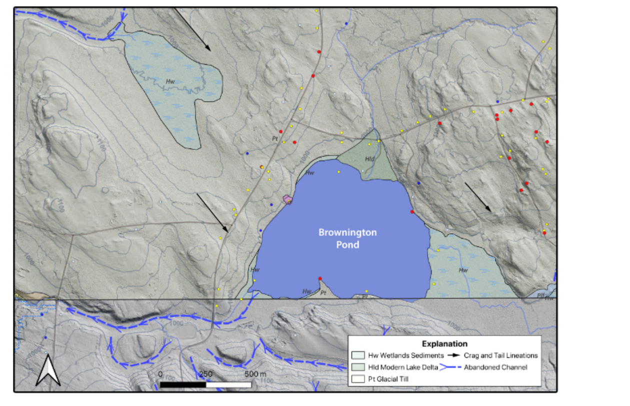


Figure 4: Crag and Tail structures record regional ice flow to the southeast.

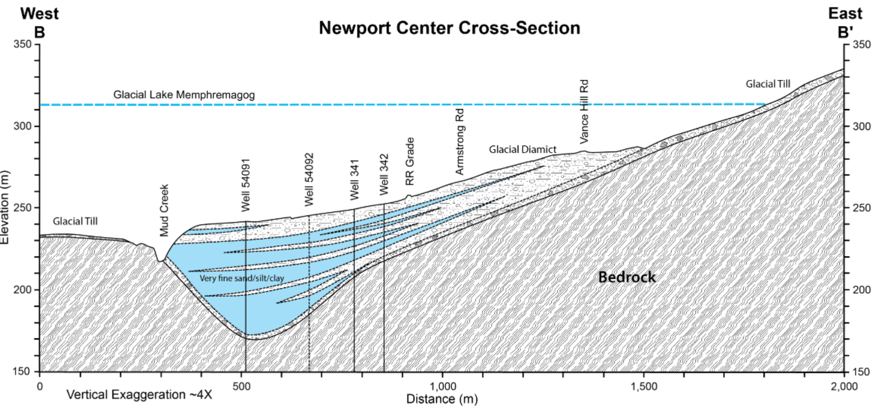


Figure 7: Wells near Newport Center Village outline a deep bedrock valley filled with both lake sediments and landslide debris (diamict), the mapping unit *"Stratified Diamict Pldi."*

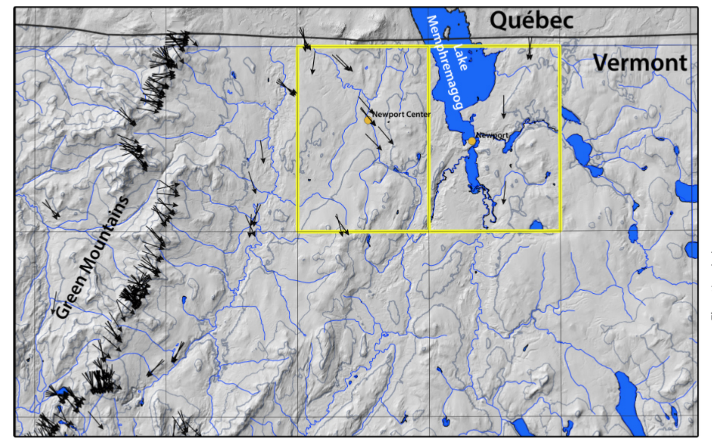


Figure 5: Compilation of glacial striations in northern Vermont indicates regional NW to SE ice flow across the mountains whereas striations in valleys generally mimic the orientation of those valleys.

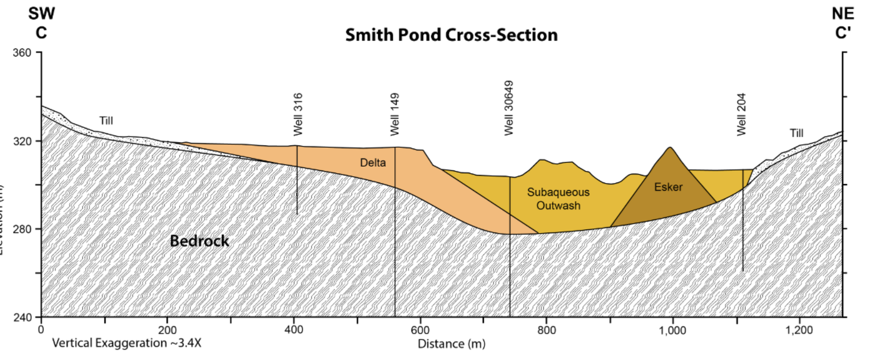
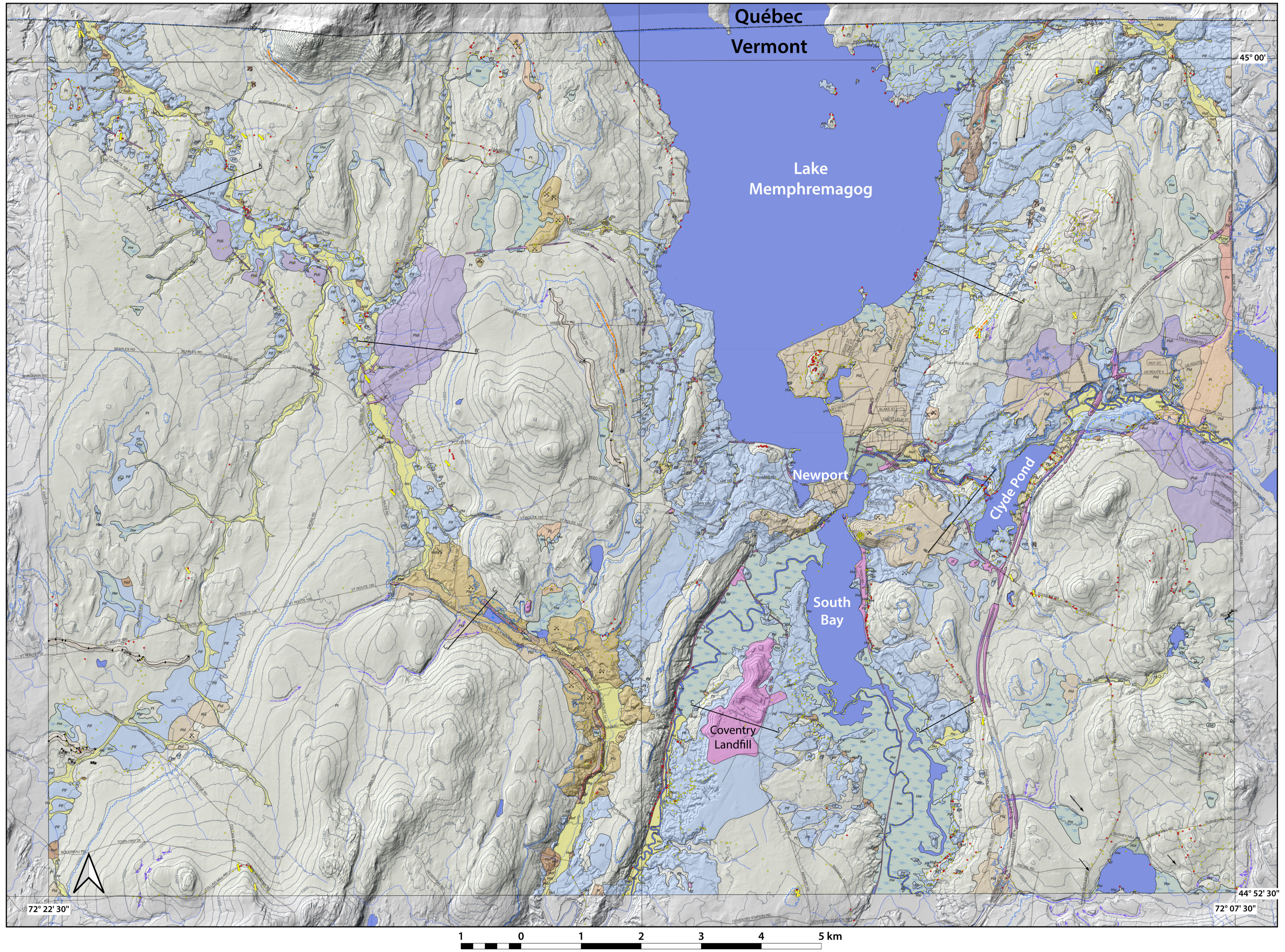


Figure 8: A variety of landforms, all composed of sand and gravel fill the valley. The delta was fed by water flowing along an ice-marginal channel.



Explanation

	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	Hld Modern Lake Delta: Well-sorted sand and gravel deposited in a present-day lake at the mouth of a tributary stream.
Hls	Hls 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.
Ha	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.
Pl	Pl 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.
Plf	Plf Lacustrine Sediments, Fine Grained: Clay, silt, and very-fine to fine sand deposited in quiet-water environments of a glacial lake. Commonly laminated.
Pls	Pls Lacustrine Deposits, Shoreline: Well-sorted fine to coarse sand, pebbly sand, pebble gravel, or cobble gravel deposited in beach or nearshore environments.
Pld	Pld Glacial Lake Delta: Well-sorted sand and gravel deposited in a glacial lake at the mouth of a tributary stream. Includes topset, foreset, and proximal bottomset beds if exposures permit.
Pldi	Pldi Lacustrine Stratified Diamict: Interbedded massive diamict layers and sandy layers interlayered with silt-clay layers. Dropstones may be common in the stratified layers. Interpreted to represent subaqueous debris flows and turbidity flows deposited in an ice-proximal setting. Diamict layers may extend above shoreline.
Plo	Plo Subaqueous Outwash: Well-sorted sand and gravel deposited as subaqueous fans within glacial lakes at and near esker tunnel mouths. Sediment deposited close to tunnel mouth is coarse-grained, distal sediments finer-grained. As the glacial margin retreats the subaqueous outwash is blanketed with finer-grained lacustrine material.
Po	Po Outwash Deposits: Glacial meltwater deposits composed of stratified sand and gravel deposited in streams in locations out beyond the glacial margin.
Pi	Pi Ice Contact Sediments, Undifferentiated: Unsorted to poorly-sorted stratified sand, gravel, and silt deposited in contact with glacial ice. Surface may contain scattered kettle holes formed by melting of buried ice blocks or be a highly complex kame and kettle topography.
Pie	Pie Esker Sediments: Elongate ridge of ice-contact stratified coarse sand and gravel deposited by glacial meltwater streams in tunnels within or beneath the glacial ice.
Ptm	Ptm Moraine Deposits: Composed primarily of till with variable amounts of stratified sand and gravel. Deposited in the vicinity of an ice margin from both ice advance and the accumulation of sediment at a stable ice margin.
Pt	Pt Glacial Till: Very dense to loose, unsorted to very poorly sorted material deposited directly from glacial ice. Contains a wide range of grain sizes, from clay or silt up to large boulders. 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

- Glacial Lake Memphemagog Projection

Symbols

Geologic Field Sites

- Surficial Field Site
- Bedrock Outcrop
- Glacial Striations

Water Wells

- GPS Location
- E911 Address Matched
- Gravel Pit
- Rock Quarry
- Geologic Cross-Sections
- Landslide Scarp
- Abandoned Channel
- Wave Cut Bench
- Moraine Ridge
- Grooved Till
- Esker Ridge Line
- Glacial Kettle
- NEWSVT Borings and Wells

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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 northern 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 several 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.

Evolution of Glacial Lake Memphremagog

- Many relatively short-lived glacial lakes formed in north-draining tributary valleys during ice retreat.
- Smaller tributary lakes merged to form **Glacial Lake Memphremagog** which grew to a considerable size as the ice sheet retreated into Québec (Figs. 9, 10).
- Abandoned **ice-marginal channels** are abundant and record the sequential drainage of higher-level lakes into lower-level lakes (Fig. 9).

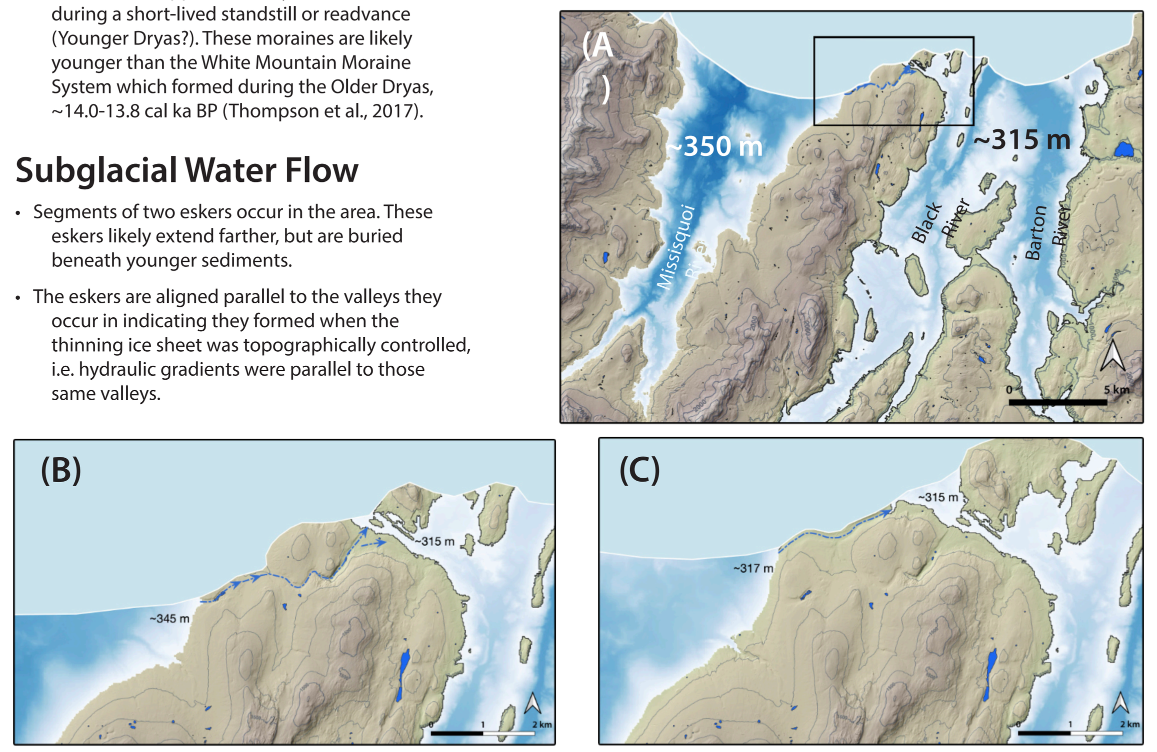


Figure 9: (A) The Missisquoi, Black, and Barton river valleys each hosted glacial lakes. (B & C) Ice marginal channels record the drainage of high-level lakes into lower-level lakes.

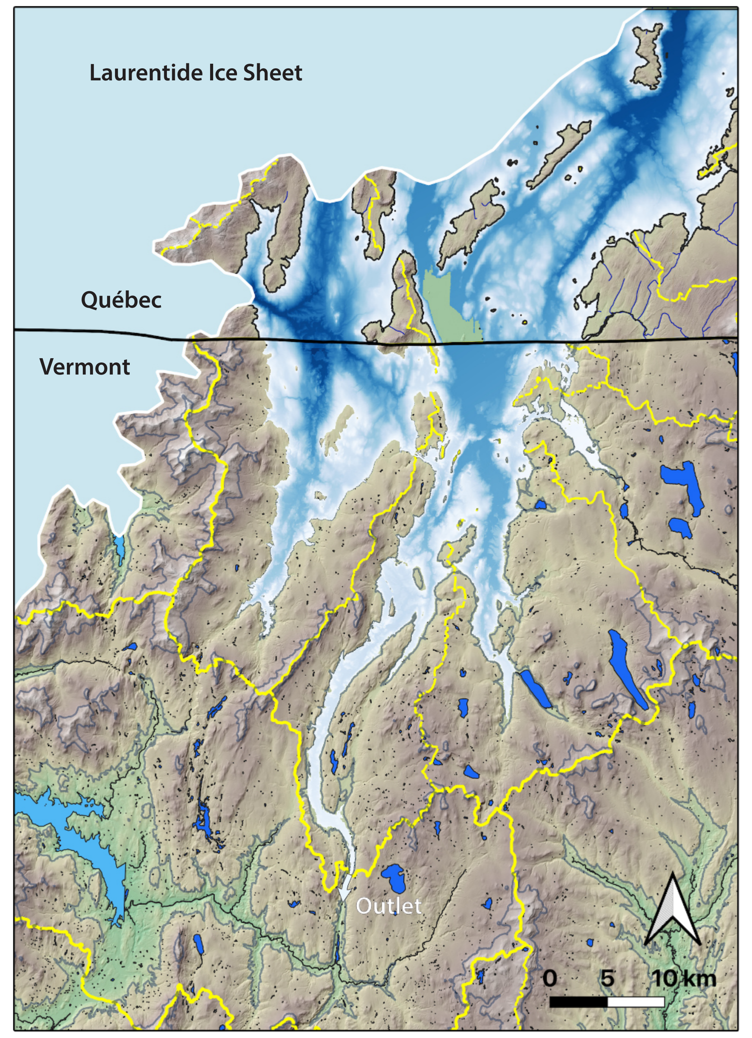
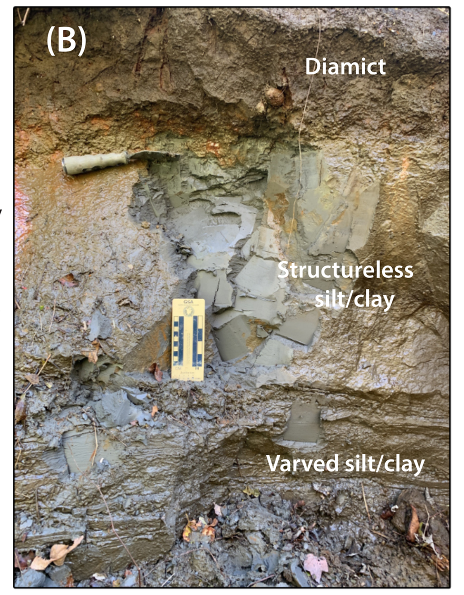


Figure 10: Extent of Glacial Lake Memphremagog in both Vermont and Québec. Ice margin in Québec is from moraines mapped by Parent and Occhietti (1999).

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. sediments deposited in subaqueous fans sourced from esker tunnels (Figs. 8, 11A).
- Layers of diamict interbedded with "normal" lacustrine sediments are interpreted as landslide deposits composed of remobilized till (Figs. 7, 11B).
- While extensive areas are underlain by fine-grained glacial lake sediments (Figs. 6, 12, 14), no good sections of varved silt/clay were observed preventing correlation of these lake sediments with the North American Varve Chronology (Ridge et al, 2012).

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



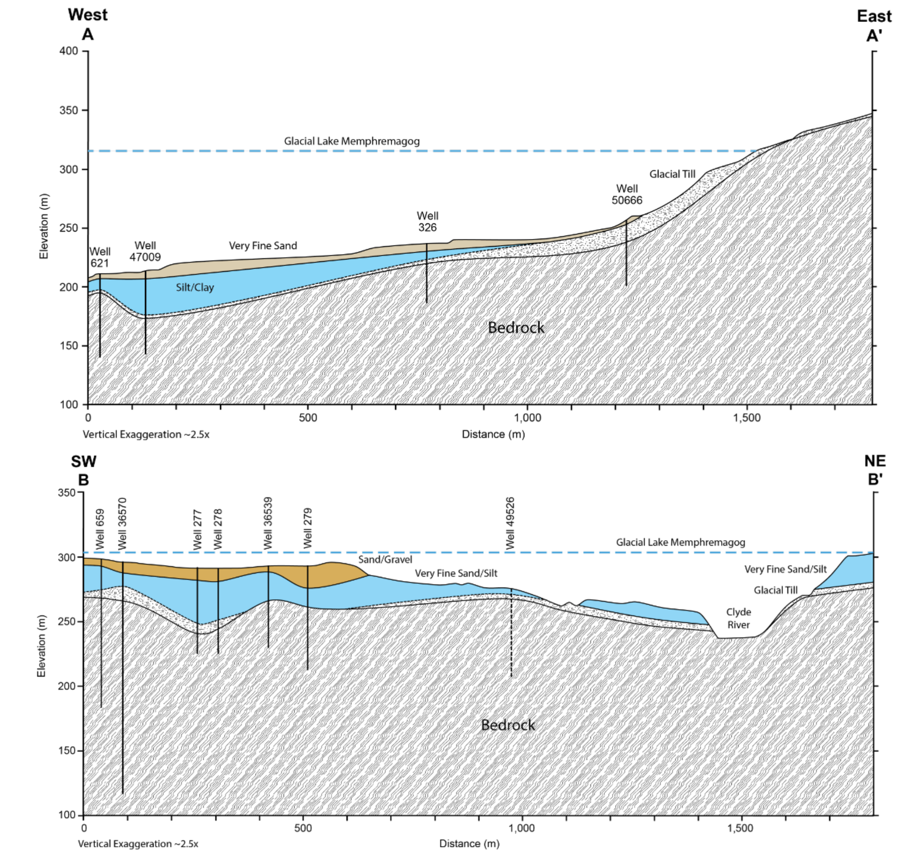


Figure 12: Cross-section A-A' depicts till overlain by a wedge of lacustrine sediment. The uppermost fine sand was deposited during the low-stand stage of Glacial Lake Memphremagog. In contrast, Cross-section B-B' extends from the Clyde River delta to the river's modern course where it's eroding into 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.

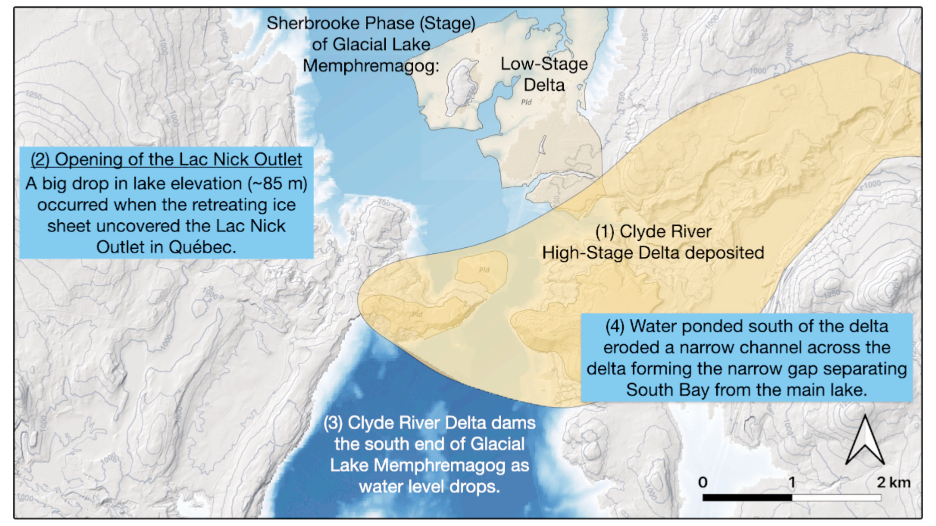


Figure 13: South Bay is separated by a narrow channel from the main body of Lake Memphremagog. The above map hypothesizes that the Clyde River delta in *Glacial* Lake Memphremagog extended completely across the lake basin. When Glacial Lake Memphremagog partially drained when the Lac Nick Outlet was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

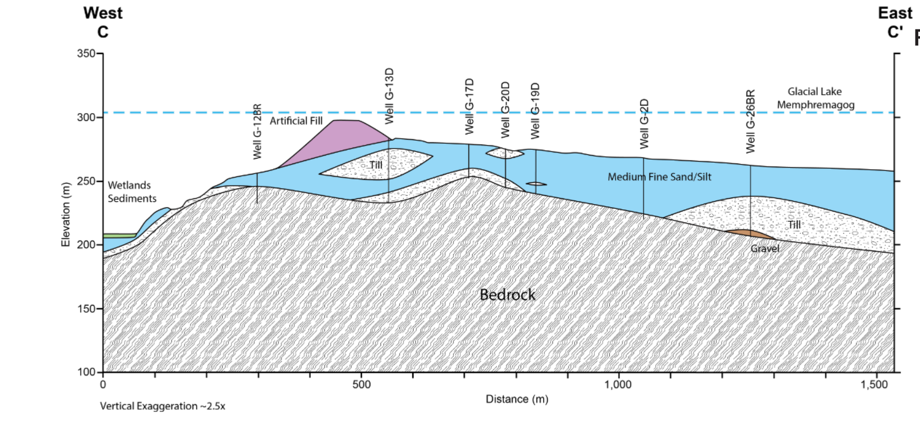


Figure 14: Cross-section C-C' shows the highly variable and discontinuous stratigraphy interpreted from closely spaced borings around the landfill. Deposition may have occurred in shallow water with a grounded ice sheet. In contrast, Cross-section D-D' depicts a uniform stratigraphy of fine-grained glacial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