Surficial Geology of the Barre-Montpelier Region

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Introduction

"Surficial Geology" refers to the origin and distribution of the loose, unconsolidated sediments that cover most of earth's surface; "dirt" or "soil" to many of us. These sediments were deposited by streams or glacial ice. Minor amounts may also have accumulated at the base of slopes, in lakes, or in some areas, they may be the remains of the underlying bedrock as it has slowly weathered.

In the Barre-Montpelier region almost all of the surficial materials owe their origin, either directly or indirectly, to the Laurentide ice sheet. The Laurentide ice sheet was the last big continental-scale glacier that covered all of New England. It first formed in the Hudson's Bay region of Canada sometime between 80–100,000 years ago. As the climate slowly cooled the ice sheet grew and advanced slowly towards New England, flowing south and east, up the Lake Champlain Valley and the many tributary valleys, including the Winooski River valley. As the ice sheet advanced and thickened it eventually overwhelmed and completely buried the Green Mountains (as well as the Adirondacks and White Mountains) and, by approximately 23,000 years ago, extended as far south as Long Island. Climate rapidly warmed and the ice sheet responded by thinning and retreating to the north leaving most of Vermont ice-free by approximately 14,000 years ago.

Direction of Ice Sheet Movement in Central Vermont

Several types of observations allow us to conclude that the Laurentide ice sheet was flowing generally from NNW to SSE across north-central Vermont. As the ice moved, blocks of rock entrained within the ice or in the material lying between the bottom of the glacier and the bedrock scraped against the rock leaving striations (scratch marks) or grooves on the rock surface. The effect is very similar to sanding a piece of wood with coarse sand paper. We can measure the orientation of these striations and know that at least the last time the ice moved it was parallel to those striations. The best places to find glacially smoothed and striated surfaces are where the overlying surficial materials (soils) have recently been scraped away from the rock. Where bedrock is exposed to air and water for a long time the minerals comprising the rock either dissolve or change to clay or iron oxide. This process, called *weathering*, roughens the rock surface destroying the polish and striations left by the glacier. Rocky outcrops on mountain tops or in fields have usually weathered extensively and rarely contain good glacial striations, although long, deep grooves may still exist.

Most of the loose rocks within the ice or at the base of the ice sheet have not traveled very far, but a few have been carried long distances and are sometimes quite distinctive of the region where they originated. These "foreign" rocks are called *erratics*. In the Barre-Montpelier region there are erratics from the Worcester Range, the Green Mountains, the Champlain Valley, the St. Lawrence River Valley, and even from the Laurentian Mountains in Québec. This is further evidence that the glacial ice was moving from NNW to SSE.

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Glacial Till

The most common surficial material deposited by the Laurentide ice sheet is an unsorted mixture of clay, sand, gravel, and boulders referred to as *glacial till*. Glacial till can be found almost everywhere, from the valley bottoms to the mountain tops. Most till in the region consists of material that was caught between the glacial ice and the underlying bedrock. This includes both old surficial materials that covered the landscape before the ice advanced (e.g. old stream, lake, and swamp deposits), and new material eroded by the glacier (rocks and boulders broken off from the underlying bedrock [erratics], and the finer sand, silt, and clay size particles resulting from the abrasion of that same bedrock). Because the full thickness of the ice sheet (up to 2 km of ice!) once pressed down on the till, this material is usually very dense and difficult to dig in and is locally known as "hardpan."

Glacial Lake Merwin

As the Laurentide ice sheet advanced, it flowed ESE, up the Winooski River valley from the Champlain Valley, damming the west-flowing Winooski river. With its outlet blocked, a lake formed in the upper Winooski River valley (Glacial Lake Merwin) and its water level rose until it spilled southward through Williamstown Gulf into the Second Branch of the White river, the lowest gap in the drainage system. Typical of most lakes, mud accumulated in the deeper parts of the lake while sand and gravel was carried into the shallower water by streams. As the ice sheet continued to advance up the valley, the lake shrank in size and disappeared entirely when the glacier reached Williamstown Gulf. As the glacier advanced it overrode all of the sediments deposited in the lake. The massive weight of the glacier flowing up the valley deformed the soft lake sediments, folding and faulting (breaking) layers of silt, clay, and fine sand and squeezing out water and air from between the sediment grains. Formerly soft, layered mud on the lake bottom was transformed into dense "till." The broad flat area in Berlin, extending from the State Library past the Hospital and down to the Stevens Branch valley, is underlain by a thick section of deformed, preglacial lake sediments that completely fill an old valley that used to extend from Berlin Pond to the Stevens Branch valley.

Retreat of the Laurentide Ice Sheet

After advancing as far south as Long Island, the climate warmed rapidly and the ice sheet began to shrink and retreat through New England. The margin of the Laurentide ice sheet generally retreated through the region from the SSE to the NNW. During the early stages of retreat the ice was still flowing to the SSE, but was melting back faster than it could flow forward. The ice sheet also thinned rapidly, exposing first the mountain peaks, then the lower flanks and finally thinned until the remaining ice was confined to the valleys. Broad reaches of the glacier became detached from the main glacier and ceased flowing, becoming stagnant blocks of ice that were often buried by younger sediments.

Eskers

Enormous volumes of meltwater were generated as the glacier melted. Some of this water flowed in rivers on the surface or along the margins of the glacier, but most probably flowed down into the glacier through holes called moulins. Once in the glacier, water flowed in tunnels eventually reaching the bottom of the glacier and continued along the base of the glacier to its terminus. Water flowing in these subglacial tunnels carried large volumes of sediment including till eroded from the base of the glacier, debris melting out of the glacial ice, and any material washed onto the glacier by streams flowing down the newly exposed mountains. When the water in the tunnels was flowing fast (during the summer melt season or during rains storms) all except the largest boulders were carried through the tunnel. When water flow in the tunnels was slack (during the cold, dry periods), sediment would accumulate as it does in any stream system and the tunnels would begin to fill with sand, gravel, and cobbles. When the ice melted away, the stream sediments deposited in the tunnel were left standing high and dry. The resulting landform is called an *esker*. An discontinuous esker extends along parts of the Stevens Branch valley from Williamstown to Barre and from there north to East Montpelier. The big gravel pits in the valley are all located on segments of this esker. North of the old Barre landfill, however, the esker lies at the bottom of an old valley, probably the former channel of the Winooski river, and is completely buried and hidden from view by younger sediments.

Glacial Lake Winooski

History repeated itself as the ice margin retreated north, down the Stevens Branch and Winooski River valleys. The glacier still dammed the northwest-flowing Winooski River forming a lake that is referred to as Glacial Lake Winooski. Once more the outlet of that lake was over the drainage divide between the Stevens Branch and Second Branch of the White River, just north of Williamstown Gulf.. As the glacier retreated, the lake grew and extended into all of the tributary valleys of the Winooski River.

The elevation of the surface of Glacial Lake Winooski was probably slightly above the elevation of the outlet south of Williamstown (~915 feet), fluctuating with the seasons as do most lakes. Now, 14,000 years after the lake drained, the shoreline of the lake is tipped up to the NNW rising to 1000 feet along the North Branch near Worchester. The explanation for this is that the land surface was first depressed under the weight of the ice sheet, much the way a boat settles in the water when weight is added to it. Similarly, the boat would tip if more weight was added to the stern than to the bow. Because the ice thickened from SSE to NNW, the land surface was also tipped, areas to the NNW depressed more than areas to the SSE. When the ice melted, the land surface rebounded to its former elevation "tipping" the former shoreline of Glacial Lake Winooski upwards to the NNW, a process referred to as "glacial rebound."

Areas below the elevation of glacial Lake Winooski are often covered by thick sections of mud, fine sand, or gravel that were deposited in this lake. Streams that flowed into the lake abruptly slowed down and deposited the coarse sediment they were carrying, (mostly sand and gravel) creating a delta. Deltas along tributaries to the North Branch confirm the extent and elevation of the lake. Throughout the lake's history the glacier always bounded the lake at some continuously changing position in the river valley, a position that probably migrated several hundred meters down-valley every year. Furthermore, subglacial tunnels in the glacier discharged directly into glacial Lake Winooski, ejecting plumes of sediment onto the lake bottom. The coarsest material accumulated at the bottom of the lake near the mouth of the tunnel forming a subaqueous fan (subaqueous means that it formed underwater and fan refers to the fan-like shape, the apex of which lies at the mouth of the tunnel). Bottom-hugging currents carried fine to very fine sand some distance away from the tunnel mouth where it accumulated rapidly on the lake bottom. The finest sediments, the clay and silt, generally stayed suspended in the water column and clouded the entire lake, giving it a gray cast. During the summer the larger silt particles settled on the lake floor, but the smaller clay size particles needed a very quiet environment to settle on the lake floor. This occurred during the winter months when the lake froze over, preventing the wind from generating currents. Water inputs from streams and the glacier also greatly diminished during the winter months. Seasonal layers of rhythmically bedded silt and clay are referred to as *varves*. Occasionally erratics can be found within the lake clays. These are referred to as *dropstones* and fell to the lake bottom from icebergs that broke off from the glacier and dumped their load of entrained sediment as they slowly melted.

Draining of Lake Winooski and Reformation of Winooski River Drainage System

Glacial Lake Winooski drained when the glacier retreated far enough down the Winooski river valley to uncover lower outlets, first through the Huntington River Valley and later into the Champlain Valley. When that occurred, the rivers in the region began to erode their present channels, cutting through lake sediments, esker sediments, and till that had accumulated and sometimes completely filled the valleys. The modern river sediments, referred to as *alluvium*, form a thin veneer over the older glacial sediments in most of the river valleys and consist almost entirely of recycled glacial sediments. The Stevens Branch and North Branch now flow, for the most part, in their old valleys. The Winooski River, however, never found its old valley between East Montpelier and Barre and instead began flowing west towards Montpelier. The relatively steep gradient and many rock outcrops across the river valley suggest that this channel is relatively new.

Alluvial Fans

While the larger rivers have eroded and deposited material along their valley bottoms, smaller ephemeral streams have also eroded considerable material from some of the steep mountain sides and then deposited those same materials where these streams abruptly change gradient (flatten out) at the valley bottom. These landforms are referred to as *alluvial fans* (again the "fan" refers to the shape of the deposit, the apex of the fan being where the small stream encounters the valley bottom). Alluvial fans contain a wide variety of sediment varying from coarse cobbles and boulders near the apex of the fan to fine mud near the toe of the fan. Most of the sediment in alluvial fans accumulates during large storms when these otherwise quiet streams rage. Fires, extensive land clearing, and other forms of disturbance precipitate deposition on fans. Alluvial fans are particularly common in the Berlin pond area where their arc-like shapes protrude into the Pond.

Conclusions

One can, therefore, find glacial materials almost everywhere in the Barre-Montpelier region. At elevations above the shoreline of Glacial Lake Winooski glacial till is the ubiquitous surficial material, peppered with erratics carried into the region from the NNW. Most of the gravel pits in the valleys are mining gravel that was deposited in tunnels beneath the glacial ice. Rising gradually from approximately 920 feet at Williamstown to 1000 feet in Worchester, the shoreline of Glacial Lake Winooski marks a threshold, below which much of the area is covered with thick sequences of fine sand, clay, and silt, deposited in the quiet waters of that lake or in Glacial Lake Merwin, the lake that existed in the valley during the advance of the ice sheet. The Winooski River and its tributaries have, for the last 13,000 years, been actively eroding these lake sediments and the underlying till and bedrock. In most places streams are reexcavating old channels that existed prior to the last ice sheet advance, but in places they are cutting new channels and elsewhere in the region old channels remain buried, as yet "undiscovered" by the modern drainage system. Currently, all of these eroded materials are being carried to and deposited in Lake Champlain.

Vermont Geological Survey
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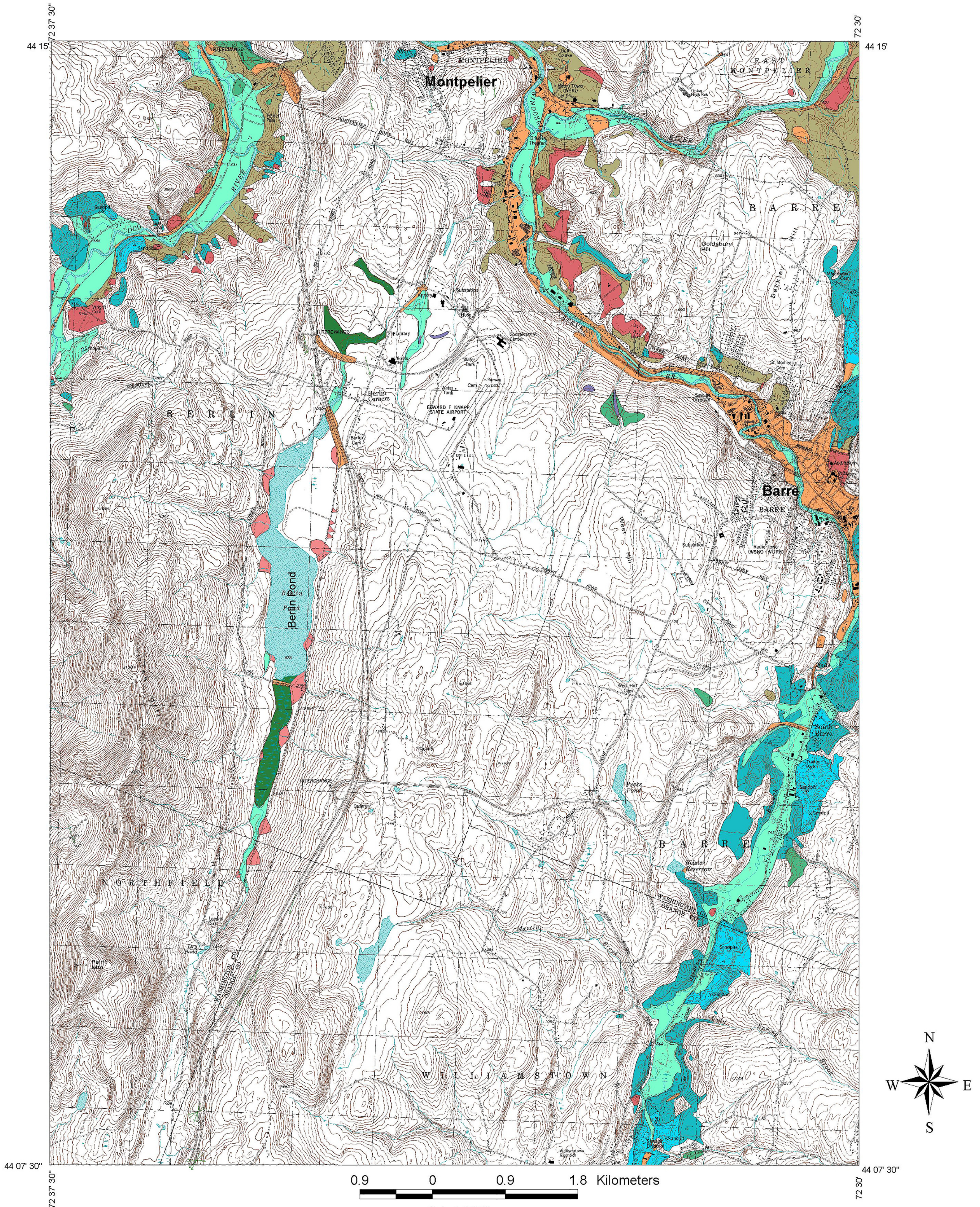

0.9 0 0.9 1.8 Kilometers

Scale- 1: 24,000
Contour Interval = 100'

Surficial Geologic Map of the Barre West Quadrangle, Vermont

Author: Stephen Wright

Digitized by: Jonathan Kim

Map Produced: September 27, 1999

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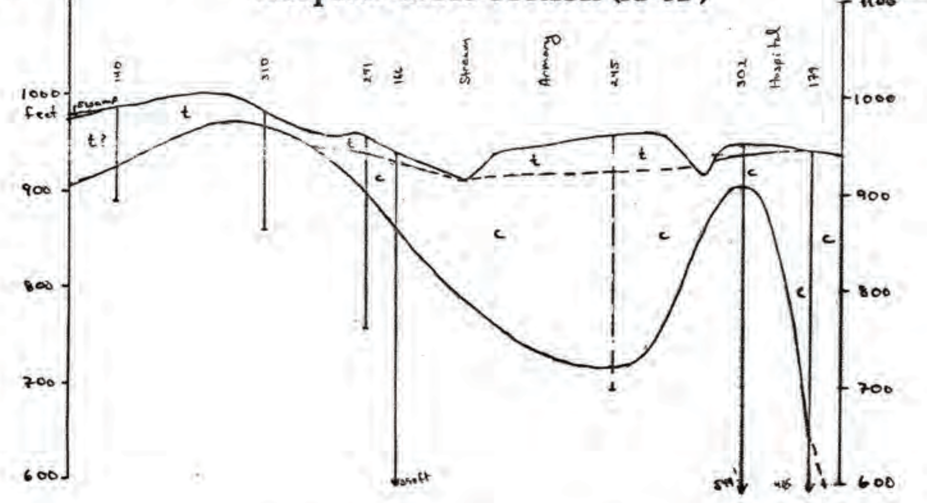
Legend

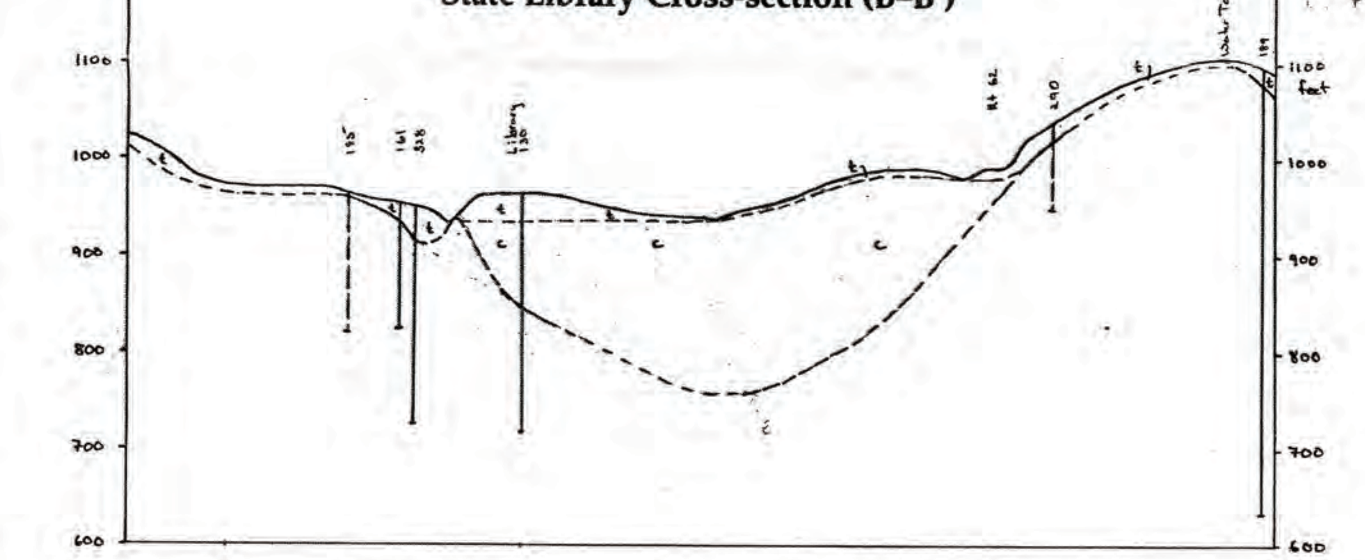
- af- Alluvial Fan: Coarse Gravel to Fine Sand and Silt, usually graded coarse to fine from head to toe.
- al- Recent Alluvium (silt, sand, and gravel) deposited in the flood plain of rivers and streams.
- c- Clay and Silt, varved clay and silt: Lacustrine silt and clay deposited in post-glacial lakes.
- csg- Coarse Sand and Gravel, sometimes with Fine Sand, deposited as topset or foreset beds or deltas formed in Glacial Lake Winooski.
- csgic- Coarse Sand and Gravel deposited in contact with glacial ice. Includes material deposited by streams flowing in subglacial tunnels (eskers), on top of stagnant ice, and along the margins of stagnant ice. Faults are common.
- dc- Deformed Clay: Very dense, deformed clay and silt. Silts and clays deposited in a glacial lake that was overridden by and deformed by the Laurentide Ice Sheet.
- f- Artificial Fill,: Usually beneath roads and railway grades, but also used extensively over alluvium in cities.
- fvfs- Fine and Very Fine Sand: Lacustrine sand deposited in post-glacial lakes.
- oal- Old Alluvium: Fine to Coarse Sand and Gravel comprising terraces lying above the current flood plain.
- sw- Swamp
- t- Till, Basal Till, andAblation Till. Basal till is is dense clay-rich, and contains faceted striated clasts that are often erratic.

Barre West Quadrangle Cross-Sections

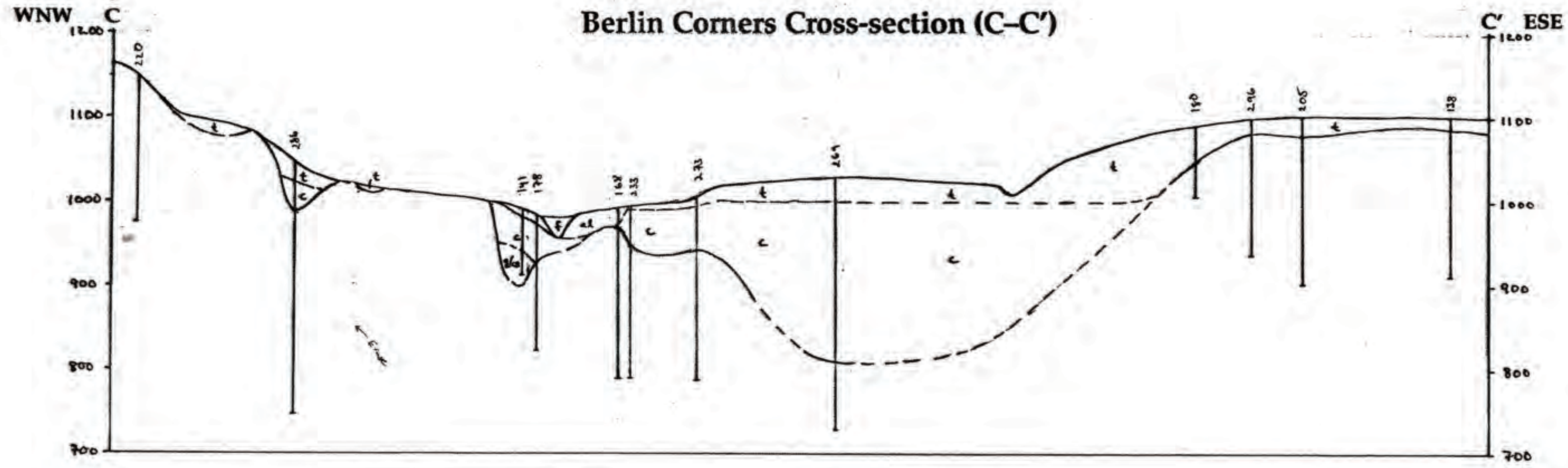
Hospital Cross-section (A–A′)



State Library Cross-section (B–B′)



Berlin Corners Cross-section (C–C′)



EXPLANATION

f	**Artificial Fill: Usually beneath roads and railroad grades, but also used extensively over alluvium in cities, e.g. Barre.**
al	**Recent Alluvium (silt, sand, gravel) deposited in the flood plain of rivers and streams.**
af	**Alluvial Fan: Coarse gravel to fine sand and silt, usually graded coarse to fine from head to toe.**
f–cs/g	**Old Alluvium: Fine to coarse sand and gravel comprising terraces lying above the current flood plain.**
cs/g	**Coarse sand and gravel, sometimes with fine sand, deposited as topset or foreset beds of deltas formed in Glacial Lake Winooski.**
c, vc	**Clay and silt, varved clay and silt: Lacustrine silt and clay deposited in post-glacial lakes.**
fs, vfs	**Fine and very fine sand: Lacustrine sand deposited in post glacial lakes.**
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t, bt, at	**Till, basal till, and ablation till. Basal till is dense, clay-rich, and contains faceted striated clasts that are often erratic.**
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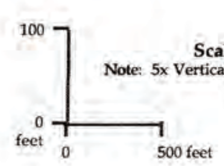
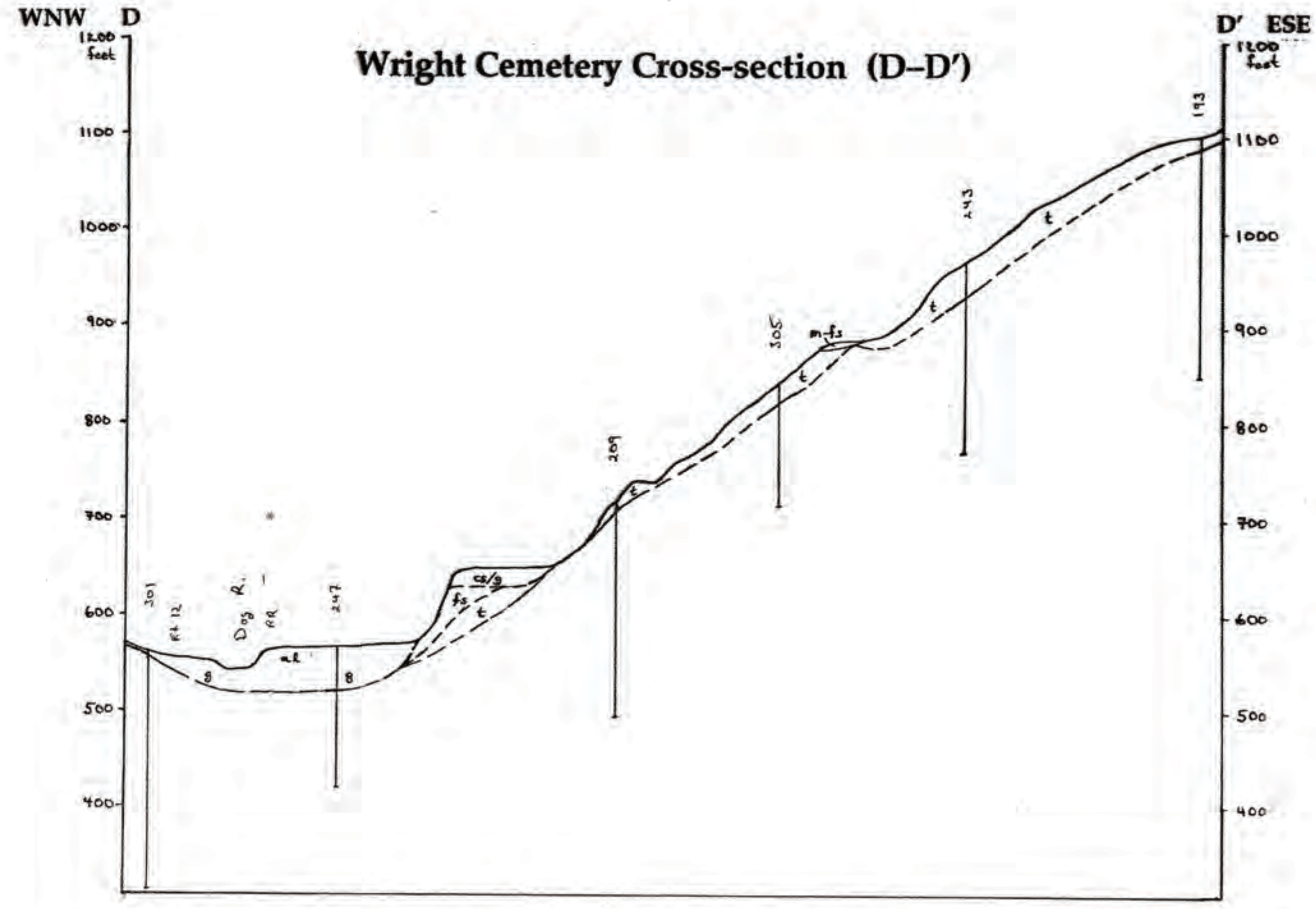


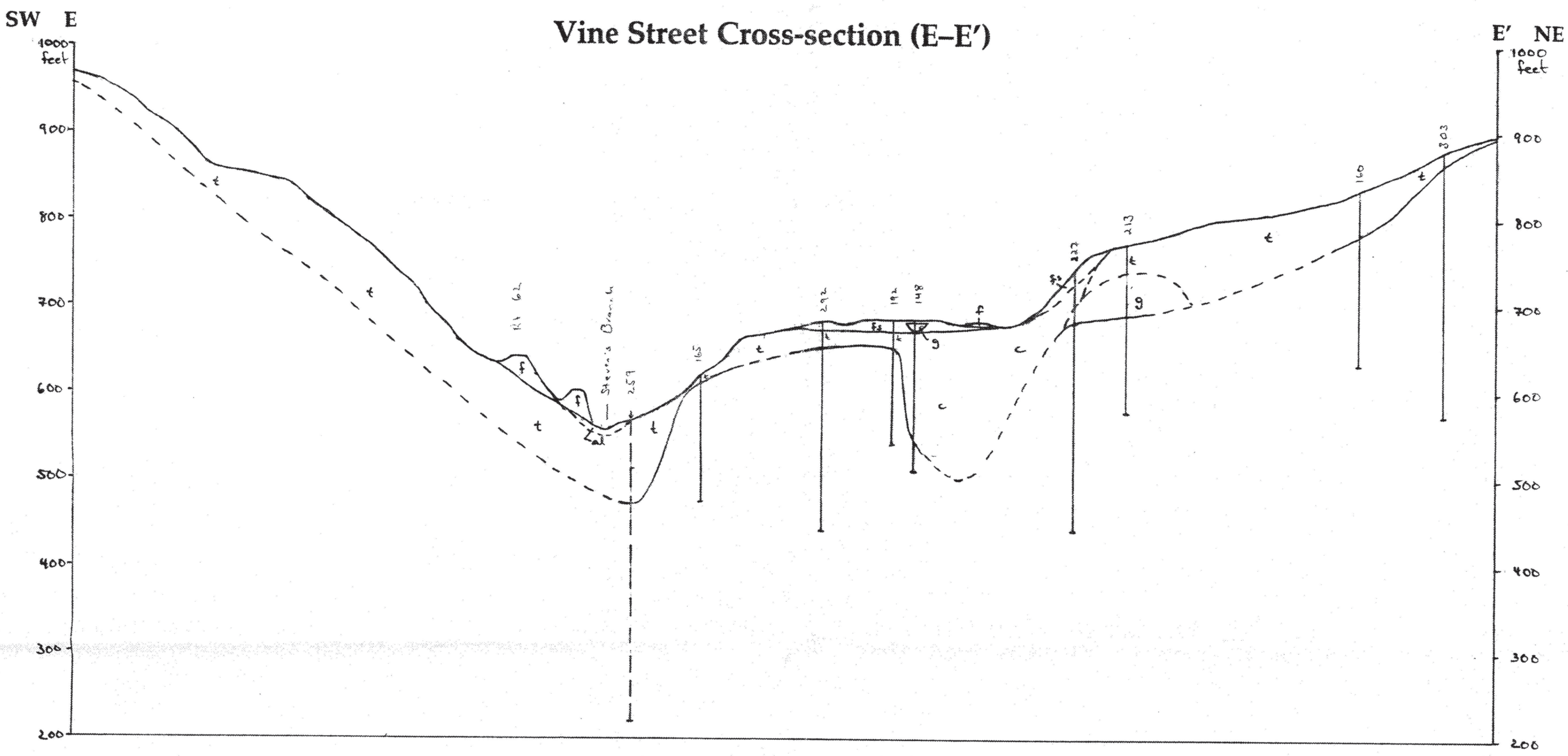
Scale
Note: 5x Vertical Exaggeration

Wright Cemetery Cross-section (D–D′)

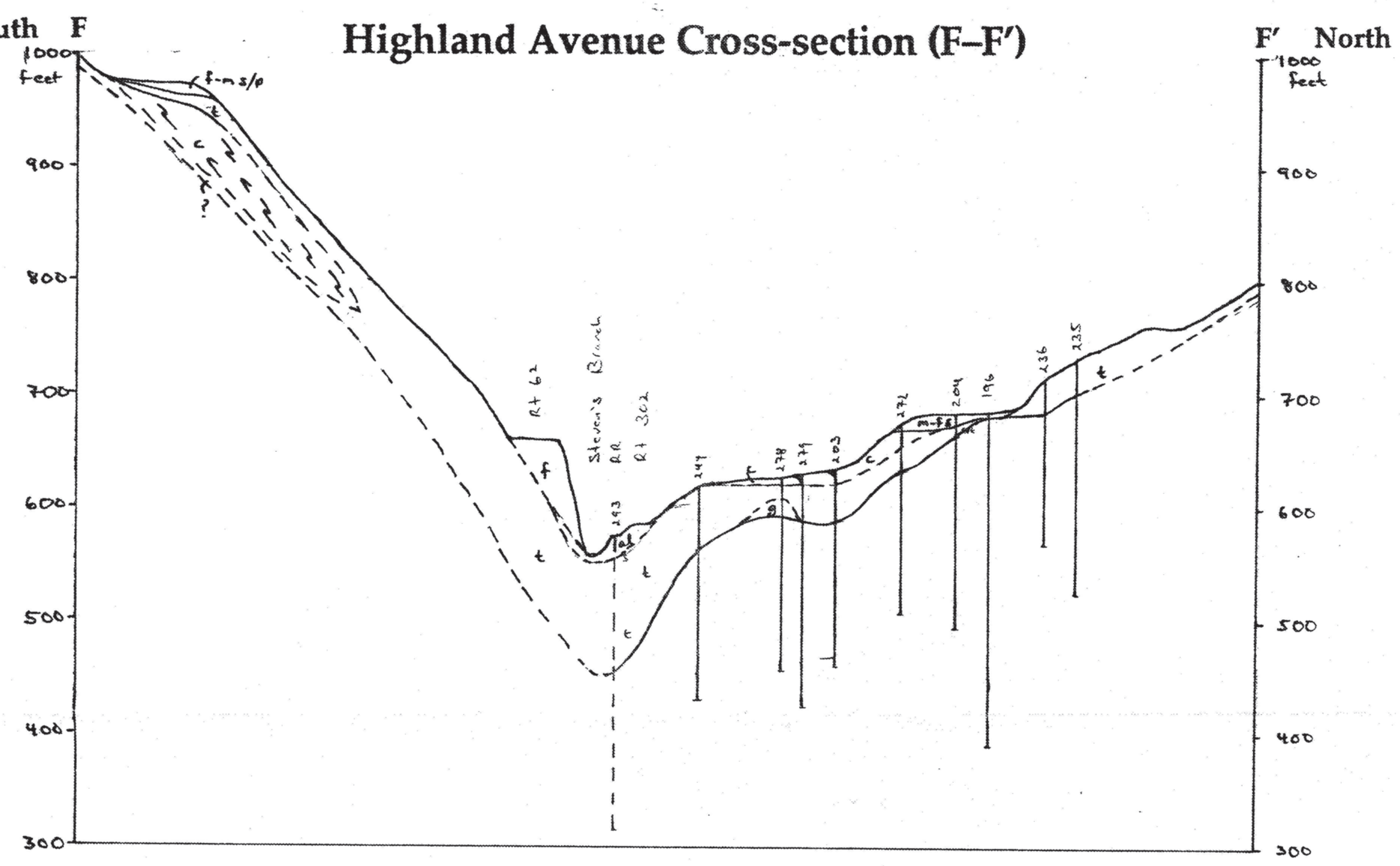


Barre West Quadrangle Cross-Sections

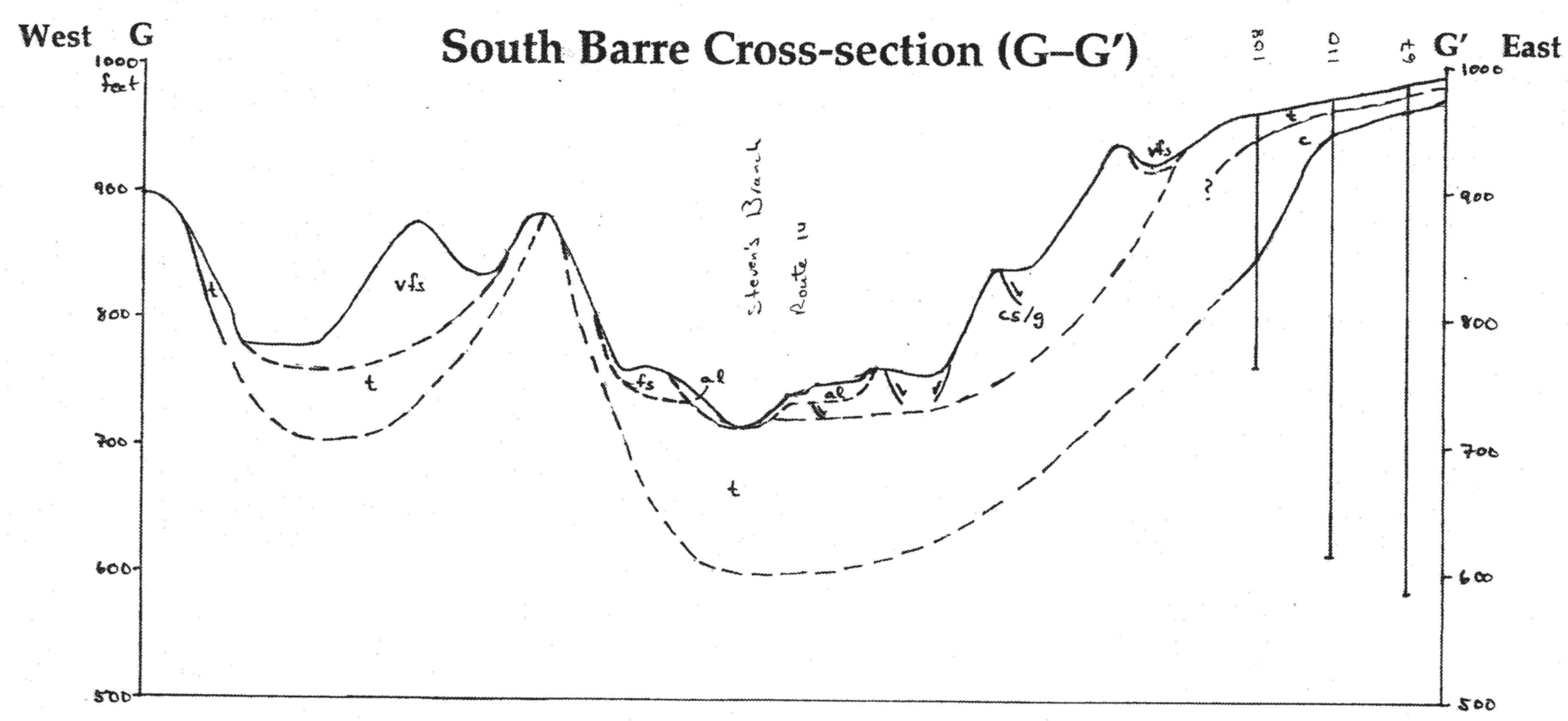
Vine Street Cross-section (E–E′)



Highland Avenue Cross-section (F–F′)



South Barre Cross-section (G–G′)



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Scale
Note: 5x Vertical Exaggeration

100
0 feet
0 500 feet

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Williamstown Cross-section (H–H′)