Landslides and Ground Water Permeability with Respect to the Contact Point of Glacial Lake Vermont and the Champlain Sea Sediments at Town Line Brook, Winooski, VT

Michala Peabody
Lara Vowles

Abstract:

This paper discusses the permeability differences between the sediments of Glacial Lake Vermont and of the Champlain Sea exposed at Town Line Brook in Winooski, Vermont. The contact between these sediments distinguishes the stability of the slope with respect to ground, rain, and melt water and the correlation to the current landslides. Observations of the contact reveal that coarser grained sediments of the Champlain Sea overlie the fine grained clay varves of Glacial Lake Vermont. Water is able to infiltrate more easily through the Champlain Sea sediments than the Lake Vermont sediments causing a thin saturated layer directly at the contact. We suspect that at this contact point there is a zone of weakness permitting the initiation of local landslides along the slope.

Introduction:

Approximately 13,000 years ago, the Laurentide Ice Sheet retreated out of Vermont and Glacial Lake Vermont developed from the melt water in the Champlain Valley (Benn & Evans, 1998). During this period, silt and clay sediments settled out of the water to form varves, thin alternating silt and clay layers that represent seasonal changes between summer and winter. Sedimentation in Lake Vermont occurred between 13,000 and 12,000 years ago, ending with the invasion of seawater from the St Lawrence Seaway (Freeman-Lynde, 1980). During glaciation, the extensive weight of the ice depressed the ground causing the Champlain Valley elevation to drop below sea level. When the Laurentide Ice Sheet finally retreated beyond the St Lawrence Seaway, the difference in elevations caused the seawater to flow into the Champlain Valley and form the Champlain Sea. The sediments deposited below the Champlain Sea consist of layers of fine sand and silt. The contact between the Champlain Sea and the Glacial Lake Vermont sediments can be found at Town Line Brook in Winooski, Vermont.

Throughout the valley of Town Line Brook, several different morphologies of landslides are visible. The erosion that occurs from rivers, glaciers, or ocean waves on steep slopes tends to form landslides (USGS, 2003). Such steep slopes are weakened through the saturation by snowmelt or heavy rains (USGS, 2003). Due to the differences in texture between the Champlain Sea and the underlying Glacial Lake Vermont sediments, ground, rain, and melt water will most likely travel differently through each. The water should not penetrate very far into the hard packed Glacial Lake Vermont varves but should filter easily through the larger sand and silt grains left by the Champlain Sea.

Site Description:

Town Line Brook is a small stream running southwest along the town line between Colchester and Winooski, Vermont (Figure 1). Town Line Brook flows into the Winooski River upstream of its entrance into Lake Champlain. The brook forms a v-shaped valley cutting through sediments deposited first by Glacial Lake Vermont and then by the Champlain Sea. In the first half of the twentieth century a landfill occupied the northern slope of the valley. This landfill can be seen in an aerial photograph from 1962 (Figure 2a). The landfill has since been covered over as seen in recent 1999 aerial photographs (Figure 3). In comparing the aerial photographs of the series of years, there was an expansion of the walls of the brook valley caused by landslides (Figure 2b). Throughout the small valley there is evidence for both old and new landslides. Landslides represent weaknesses that have occurred within the sediments. We suggest that the weakness will most likely occur at the contact between the Champlain Sea sands and the Glacial Lake Vermont clays because of the differences between sediments.

Methods:

To support our hypothesis, we located the contact between the two types of sediments. We did this using a shovel to dig away the overlying and slumping sediments and found the point where sand and silt meet within alternating layers of clay. To find the contact we created a series of four holes with the bottommost hole containing the contact. Once this point was found, the permeability was measured. A pocket vane tester was used to determine the shear strength of the sediments, quantifying the tendency of material to be sheared by a differential force (Weisstein, 2003). A level and rod were used to create a cross section of the site we analyzed, which was approximately twenty meters from the Winooski River.

Results:

Finding the exact contact point between the Champlain Sea and the Lake Vermont took time and involved a few very muddy articles of clothing. A cross section was created to provide a general overview of the area studied and to further understand the landslides present, noting where our holes were dug in the slope (Figure 4). Photographs of these holes providing a general stratigraphic column are provided in Figure 5.

Once uncovered, the contact continuously created small-scale landslides. The Champlain Sea sediments, visible in all four holes, mostly consisted of heavy wet layers of silt. A layer of saturated silt and clay, approximately 1-2 centimeters thick, was mixed together with a large amount of water at the contact between the Champlain Sea and Lake Vermont. The Lake Vermont sediments, located directly below this point, were very dry and hard packed layers of gray and maroon colored clay (Figure 6). The clay layers were tightly packed and prevented the water from the saturated contact layer to penetrate through causing the water to run off the side of the slope.

Using the pocket shear vane tester we determined the shear strength of the sediments from the top to the bottom of the section studied by testing the different sediment types in each of the holes (Table 1). The results from the pocket tester showed a gradual increase in shear strength until the contact. The contact point revealed very weak shear in comparison to the rest of the material. With respect to grain size, the results from the pocket vane shear test suggest a decrease in strength with an increase in grain size from clay to sand.

After several days of rain, the studied area became saturated and produced a mini-landslide that eventually caused the material above the contact point to slide. The surrounding slides around our mini-landslide appear to have formed in the same manor as the mini slide. It appears as though the slides have moved as large blocks shifting down the slope in one piece and are then eroded by the stream. The erosion of the stream prevents us from viewing further evidence of the slides.

Analysis:

The observations of the contact reveal drastic differences between the permeability of the Champlain Sea and Lake Vermont sediments. The Sea sediments were very wet and the Lake sediments were very dry. This observation suggests the clay sediments of Lake Vermont are not nearly as permeable as the sand and silt sediments of the Champlain Sea. The saturated layer at the contact point suggests an area where the groundwater is escaping through the slope because it cannot penetrate down any father through the clay. As water saturates pores, the pore spaces expand and contract which further reduces resisting force, and results in a slide (Iverson, et al, 2000). Additional weight added to a slope such as rain, snow, or waste piles cause weak slope to fail and produce landslides (USGS, 2003). This statement follows observations of small slides throughout the area as well as observations at the contact. The slide produced at the contact was most likely produced by the additional weight of the loose sediments due to excess rain.

Observations from the pocket vane measurements showed a gradual increase in shear strength from top to bottom until the contact point and clearly depict a zone of weakness on the slope. As noted earlier, landslides tend to slide on such zones of weakness. The balance between shear strength of slope material and the "down slope component of the gravitational force imposed by the weight of slope material above a potential slip surface" determines whether a given slope produces a slide (Keefer, et al., 1987). The contact represents zone of weakness that initially causes the slide to occur. This zone of weakness is most likely caused by the differences in porosities between the Champlain Sea and Lake Vermont. The different porosities cause the water to infiltrate down through the Sea sediments to the groundwater table at the contact. The Lake Vermont sediments are so tightly packed that the water cannot infiltrate through and the water begins to seep out at the contact point and over time produces landslides. When rain falls on soil, the pore pressure increases as the water table rises, which causes the soil to become saturated and heavy and gravity eventually causes it to slide over the clay sediments to produce landslides along slopes (Soils May Signal Imminent Landslide, 1988).

Conclusions and Discussion:

The sandy sediments of the Champlain Sea are more permeable to the groundwater than the varved clay sediments of the Glacial Lake Vermont as evidence by saturated silt and sand layers of the Champlain Sea and very dry, hard-packed sediments of the underlying Glacial Lake Vermont. From these observations, we conclude that the contact between the Champlain Sea and Glacial Lake Vermont is a zone of weakness that causes landslides along steep slopes.

"In landslides, as in life, it's the little things that count."

~ S.P. "Slump or Slide, Density Decides"

Location Map of Town Line Brook

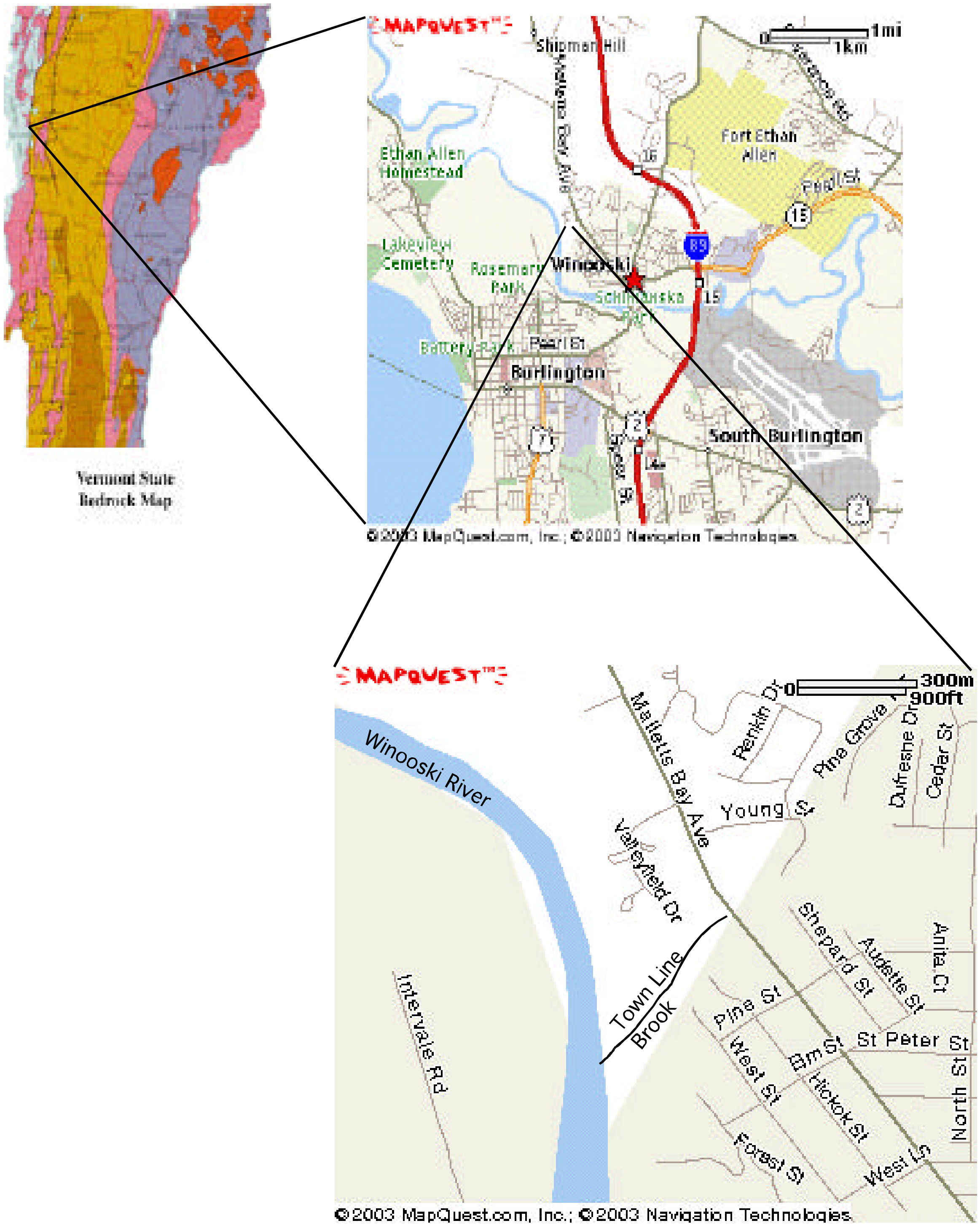

Figure 1: Location map of Town Line Brook in Winooski, Vermont.

Landfill Photograph

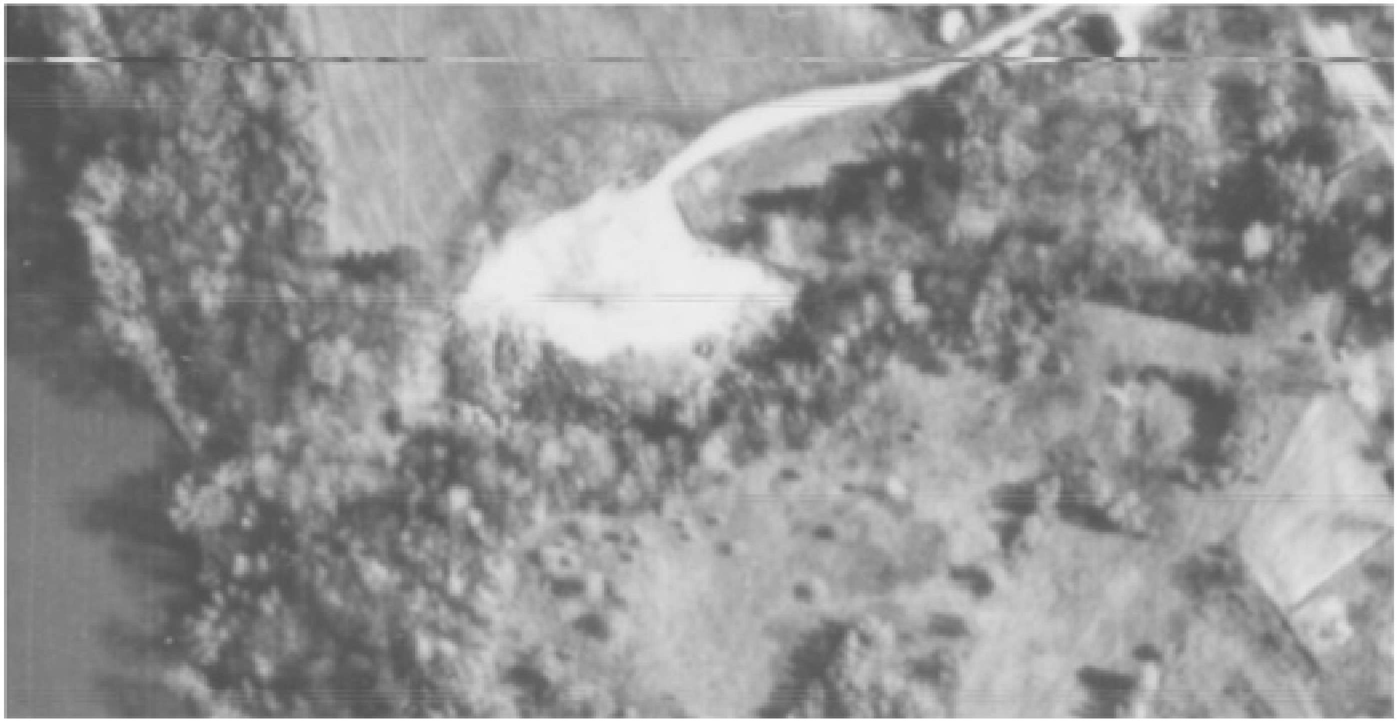

Figure 2: This photograph depicts the landfill located at Town Line Brook in Winooski, Vermont taken on May 9th, 1962.

Landfill Photograph

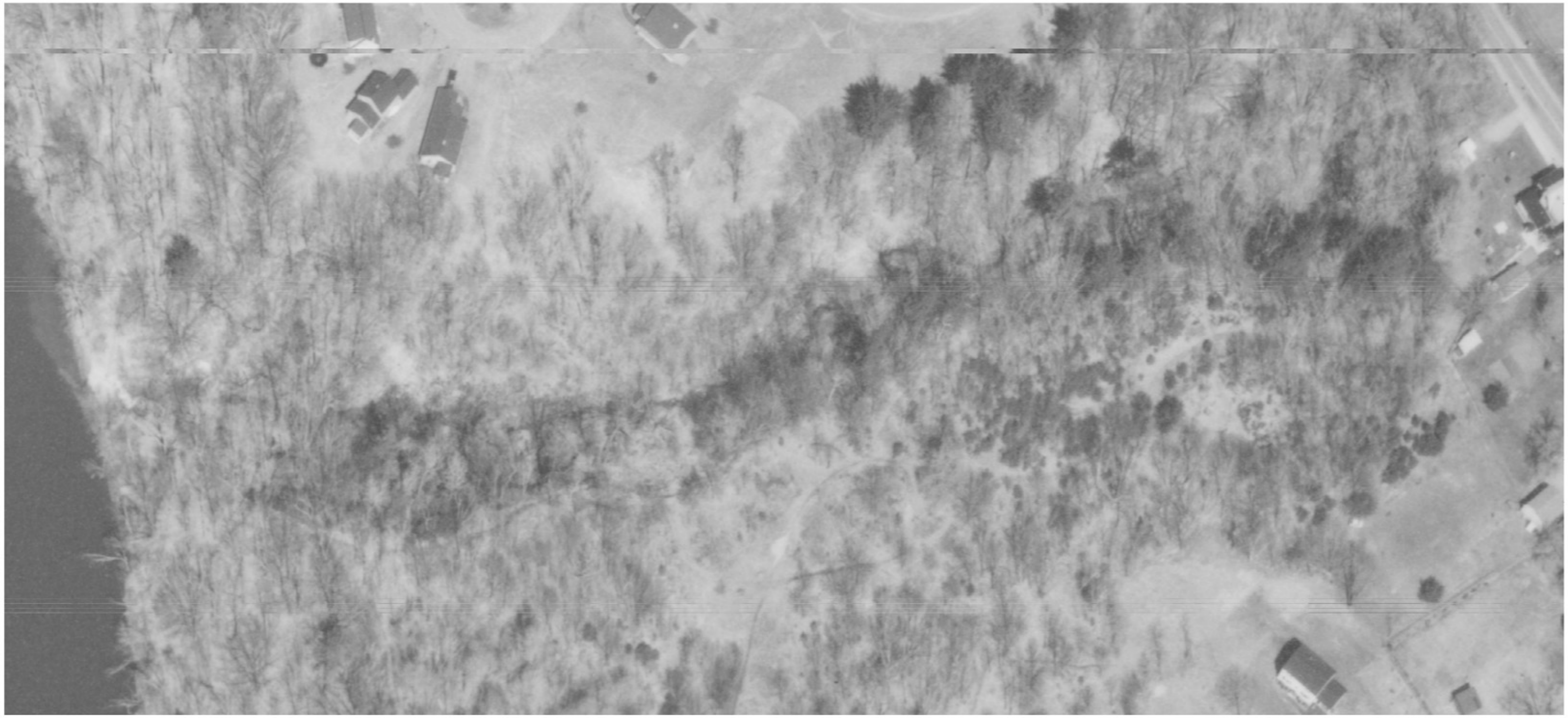

Figure 2b: This photograph depicts the Town Line Brook located in Winooski, Vermont taken in 1988.

Town Line Brook Photograph

Figure 3: This photograph depicts a present day aerial view of Town Line Brook taken in 1999.

Cross Section of Town Line Brook

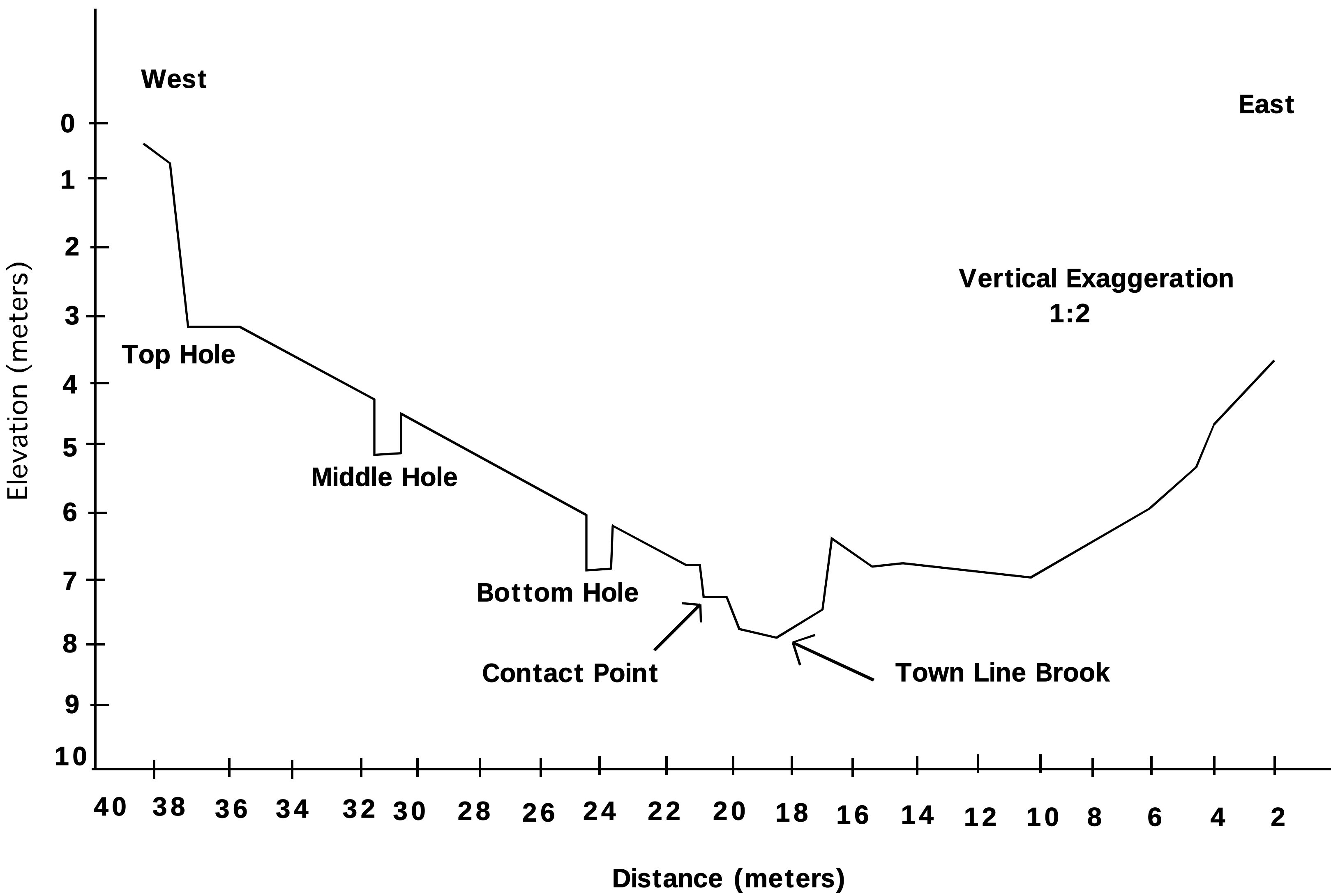

Figure 4: This figure depicts the Cross Section of Town Line Brook located in Winooski, Vermont. The holes dug in the slope are labled as top, middle, and bottom holes.

	Top Hole				Middle Hole	Bottom Hole		Contact	
	Sand	Silt	Silt	Sand	Silt	Sand	Silt	Above	Below(Glacial sediments)
	2.125	4.5	5	1.5	4.5	7	3.875	1.5	2.25
	1.625	4	4.25	2	5	5.875	6	3	2.5
	2.5	3.75	3.5	1.63	4.875	6.75	6	3.5	2.125
	2.625	4.5	3	2	3.5	5.75	5	4	3
Average	2.2	4.19	3.94	1.78	4.47	6.34	5.22	3	2.47

Table 1. Shear strength measurement conducted at each layer within each hole.
Four measurements were made at each and an average was taken for comparison.


Top Hole


Middle Hole


Bottom Hole


Contact

Figure 5: These photographs show the four different holes uncovered along the slope at Town Line Brook located in Winooski, Vermont. They depict a general stratigraphic column showing the differences in sediment layers and grain size. The contact also shows the mini-landslide created from our digging and excess rain.

References:

Benn, D. I., Evans D.J.A. "Glaciers and Glaciation." Oxford University Press, New York, 1998.

Freeman-Lynde, R. et el. "The Origin and Distribution of Subbottom Sediments in Southern Lake Champlain." Quaternary Research, 1980, v14 p224-239.

Iverson, R.M. et al. "Acute Sensitivity of Landslide rates to Initial Soil Porosity." Science, October 20, 2000, v290 i5491, p513.

Keefer, David et al. "Real-Time Landslide Warning During Heavy Rainfall." Science, Nov 13, 1987, v238 n4829 p921-926.

Monastersky, Richard. "When Mountains Fall." Science News, August 29, 1992, v142 n9 p136-139.

S.P. "A Slump or a Slide? Density Decides." Science News, October 28, 2000, v158 i18, p287.

"Soil May Signal Imminent Landslide." Science News, November 12, 1988, v134 n20 p318.

http://www.landslides.usgs.gov November 15, 2003

Weiczorek, Gerald et al. "Landslide Hazards in Glacial Lake Clays – Tully Valley, New York." April 1998, http://pubs.usgs.gov/fs/fs13-98/

Weisstein, Eric W. "Shear Stress" November 20, 2003. http://scienceworld.wolfram.com/physics/ShearStress.html