The Lee River Landslide

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<u>Abstract:</u>

Steep hillslopes that lie adjacent to active stream channels are prone to landsliding. Glaciolacustrine material is the dominating surficial sediment in Vermont. Geologic characteristics of eight soil pits, excavated vertically on a 28 degree slope, were examined at the Lee River Landslide in Jericho, VT. As elevation increased, layered sediments gradually increased in grain size and decreased in cohesion. This is characteristic of deltaic sediments. The contact between impermeable lake and fluvial material becomes a plane where subsurface water may flow, and this decreases cohesion between grain particles. Further influx in subsurface flow may eventually seep into the lake sediments and completely undermine the hillside. Vegetation has inherent properties to stabilize a slope by increasing the soil's cohesiveness. The Lee Landslide is generally covered with small leafy plants, but their roots are short and small slides continue to occur which is evident in one of the soil pits by unsorted sand and organic debris.

Introduction:

The landslide studied for this project is located along side of the Lee River, about 300m off of Plains Rd. in Jericho, VT (Fig. 1). The entire landslide is approximately 37m in height and 50m in width. The main slide occurred several years ago, and a number of smaller slides have occurred periodically since (Wright, personal conversation, 2002). The Laurentide Ice Sheet retreated off of this region of Vermont approximately 13 thousand years ago (Wright, Class notes, 2002). When the ice mass ablated, it served as an ice b[illegible]t for fresh water that was flowing north at the time, which resulted in the formation of Glacial Lake Vermont (Chapman, 1937). The Lee River flowed into Lake Vermont and the river deposited deltaic sediments; the post-glacial lake and deltaic sediments remain intact under newly unsorted slide material. Approximately 75% of the landslide surface is covered with minimal to healthy amounts of vegetation and there is evidence to support that there has recently been a small slide on the northwest side of the slope.

Methods:

Eight, one meter deep, soil pits were excavated with a flat head shovel up the Lee River Landslide which was a total of 37 meters in height. A meter tape was used to measure the full distance of the landslide from the top to the bottom. The front side of each section was smoothed so that a cross section of the soil's orientation and structural characteristics of the bedding, sediment grain sized, and cohesiveness of the individual beds could be observed. The cohesive properties of particular beds were measured using a hand held shear vane, cohesion meter.

Results:

The surficial material in the landslide on the Lee River was composed of fine silt to cobble sized sediment. The slope of the landslide is 28 degrees (Wright, personal conversation, 2002). All ripple marks, cross bedding and tilting of the beds through out the landslide were deposited and oriented in the direction of the northeast. The sediment in each of the pits, except for pit 2, increased in grain size as elevation increased. The cohesion of what we thought to be the original sediments decreased as elevation increased (Fig. 2-6)

The cross section of the second pit exposed stratigraphy that was different from the rest of the excavated pits. Pit 2 consisted of unsorted fine to medium grained sand, and within it approximately 2 inch size pockets of gravel intermittent with the surrounding sediment. There also was a sizable amount of organic debris found throughout the pit (Fig. 7).

Discussion:

When the stress on a hill slope exceeds the strength of the sediment, a landslide will occur (Bierman, Class notes, 2003). The sediment that is located along the Lee River is from a glacial delta. This explains why there is a vertical increase of grain size and tilting of the bedding. Where water had run into the lake it formed a delta and deposited sediment beginning with the largest in horizontal beds. Further out, into the actual lake, the sediment began to flow down into the deeper portions of the lake; this created the northeast tilted foreset beds, which were found in the higher excavation sites. Finally, in the deep portions of the lake, very fine clay and silt sediment are able to settle out forming horizontal varves (Fig. 8)(Benn and Evans, 304).

The slope of the Lee River Landslide is 28 degrees. The angle of repose is the angle at which a slope is able to remain stable, in sediments of this nature the angle of repose is approximately 35 degrees (Bloom, 1991). When the slope is saturated in water, the gravitational force, that compresses and holds sediment together, is reduced and frictional resistance between grains is also reduced. Ultimately, subsurface soil saturation dramatically lowers slope stability (Bloom, 1991). Soil saturation seems to be the primary cause for a slope at 28 degrees to fail.

It is not uncommon for deposits of this type to fail and form landslides. Landslides are very common on glaciolacustrine sediments; as is seen next to the Mackenzie Rive in the Northwest Territories of Canada (Duk-Rodkin and Huges, 18). Many different landslides have occurred at this one site. A deposit of the most recent slide can be seen at pit 2. This is the reason that pit 2 is unsorted, fine to medium grained sand, with pockets of gravel and organic sediment mixed throughout. If the sediment was frozen during this most recent landslide it could explain why gravel pockets were found (Fig. 7). The gravel would remain frozen together and compacted during the slide, warmer temperatures would cause the sediment to unfreeze but the sediment would remain consolidated (Wright, personal conversation, 11/24/03). It can be inferred that pit 2 is a small landslide because unsorted sediment is located only a few meters above and below pit 2, but does not extend down to pit 1. The amount of sediment is so small that the landslide also must have been quite small.

Cohesion is a soil's ability to adhere to itself (Beirman, Class notes, 2003). Fine grained, and compacted sediment exhibit more cohesive properties than large grained, loose sediment, presumably because absorption of ions and water by clay minerals creates a binding structure among the particles (Kochel, et al., 1978). Our observations also show more cohesion in the dense, varved silts and less cohesion in larger grained and loose sediments. The cause for small slides on the Lee Landslide to originate is the failure of the loosely packed sandy material located higher up on the slope face. If the lower layers of silty varves were to fail, a large slide could occur. For the silt and clay to fail it must become saturated to the point it starts to have plastic characteristics. The silt and clay will lubricate the surrounding sediments because the absorption of water into the layers will continue until the grains can no longer maintain fixed in a rigid, oriented position (Kochel et al., 1978). The presence of saturated clay and silt is present today at the base of the Lee Landslide (Fig. 9a).

If the roots of the vegetation that surrounds the possible slide zone do not reach the bedrock or fail to anchor the sediment vertically then the soil is only reinforced laterally (Gabet and Dunne, 985-986). There are areas of regrowth on the Lee Landslide, but sporadically in short supply and their lateral roots do not reach bedrock (Fig. 9b). These small plants do however increase the cohesion of upper sediment layers and prevent minor sliding. Larger plant species are needed to reach the bedrock underneath the sediment and completely reinforce the slope from larger slides.

Conclusion:

At each excavated soil pit we observed structural and compositional stratigraphy and cohesiveness of individual layers of bedding. Due to the grain size, orientation of bedding and cohesion data it becomes very likely that these are deposits from Glacial Lake Vermont which existed during the retreat of the Lauentide Ice Sheet during the last glaciation of Vermont. The vegetation on the slope was only able to reinforce the sediment laterally, but there were not any longer roots to reach the bedrock. So as able to help it remain stable in most conditions but when a large amount of water got into the system there could be a landslide, since the angle of the slope was so steep.

References:

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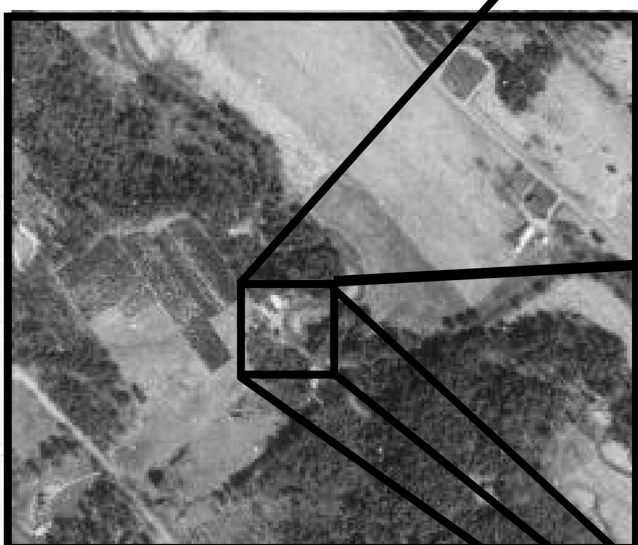
Location Map, Lee River Landslide, Jericho, Vermont

See person for scale

N



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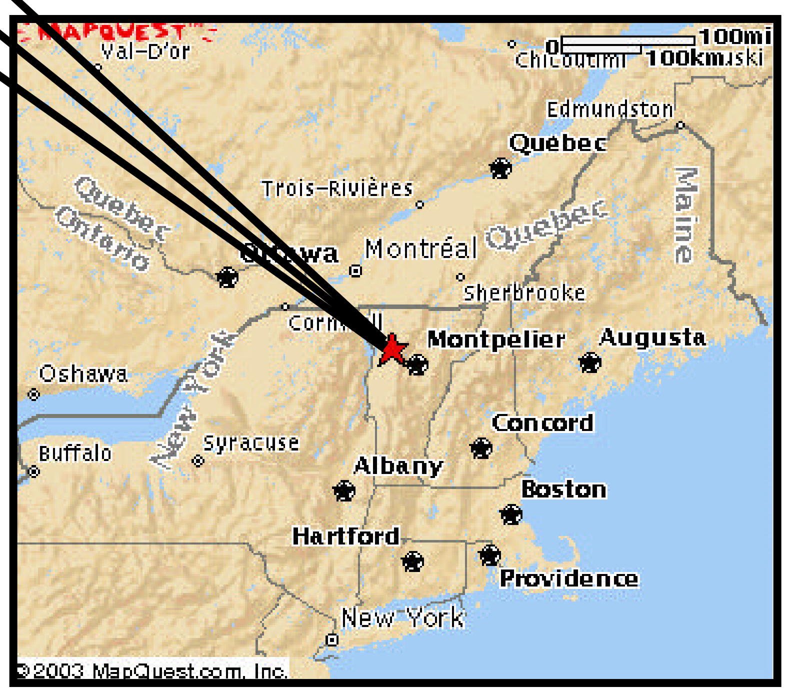

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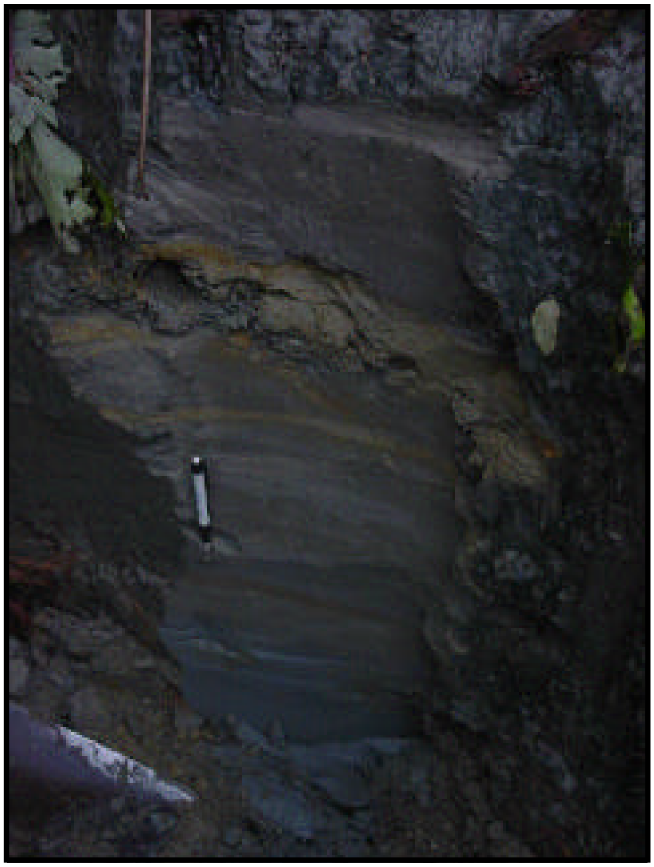
Figure 1:

Location Map of the Lee River landslide located in Jericho, Vermont, USA. Arial Photo (US Dept of the Army Corps of Engineers, 1980). Photo of landslide, 2003.

Pit #1 and Pit #2



See pen for scale.

Figure 2a:
- Pit #1
- 35 meters from top of landslide.
- Varved layers of very fine silt and silt.
- Cohesion value of 0.8 with medium disk.

Figure 2b:
- Pit #2
- 30 meters from top of the landslide.
- Unsorted sediments primarily of medium sand grain size.
- Pockets of gravel.
- Organic depris.
- Cohesion value of 0.1 with the large disk.

See tape measure for scale.

Pit #3 and Pit #4

See pen for scale

Figure 3a:

- Pit #3
- 26.6 meters from the top
- Varved layers of silt and clay.
- Northwest side of pit had characteristics of a past slide with three layers each of very fine, fine and medium grained sand.
- The medium grained sized and layer was very loosely compacted, it would fail when cut away at a high angle.
- Cohesion of 0.5 with the medium disk in the varved sediments.
- Cohesion of 0.1 with the large disk in the sand.

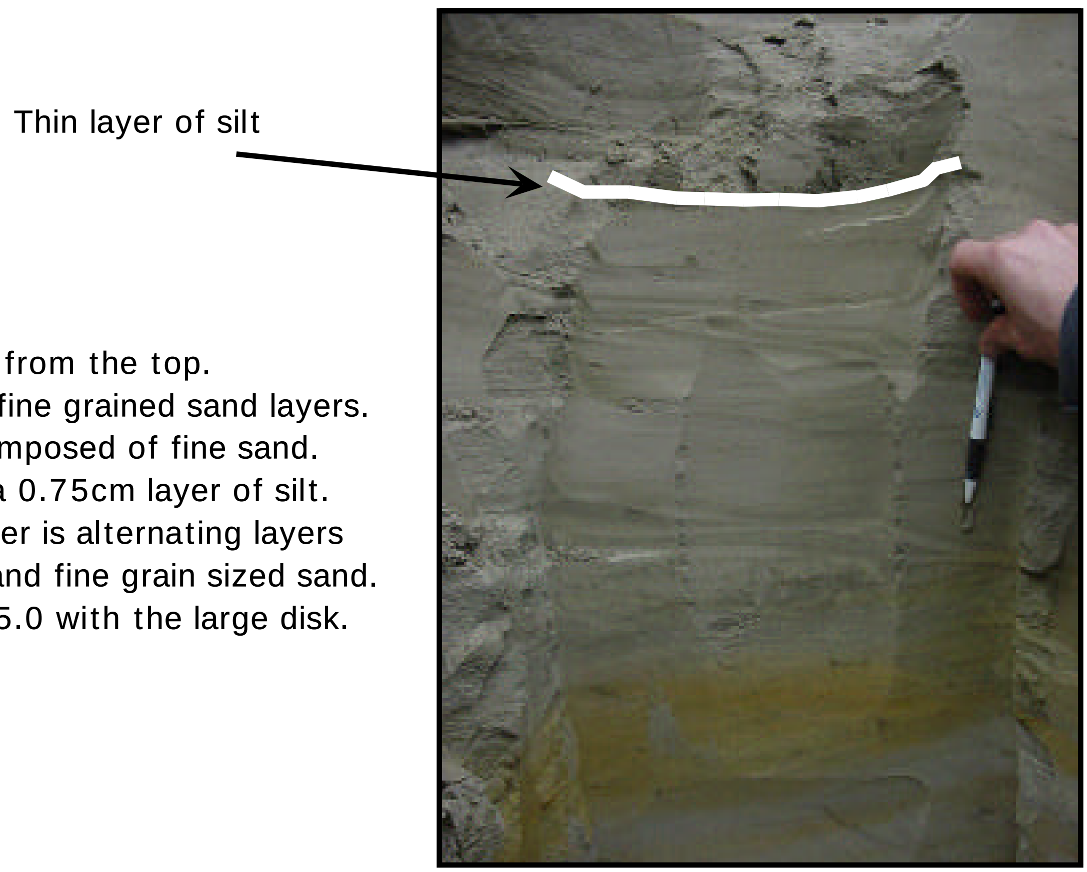


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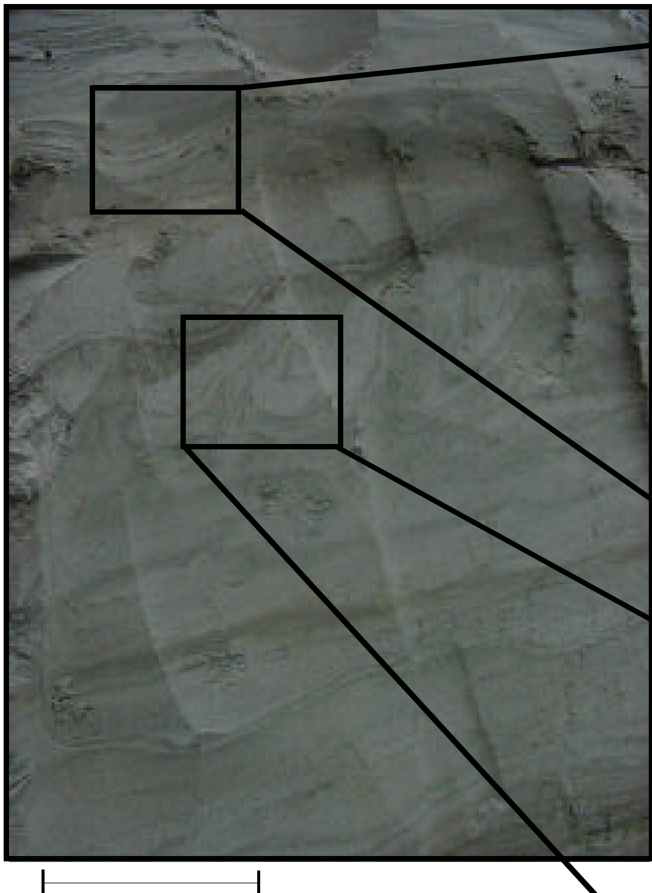
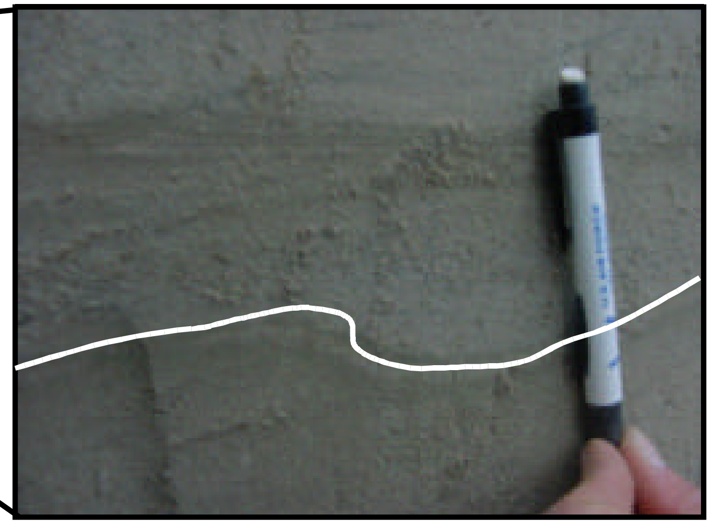
Figure 3b:

- Pit #4
- 23.7 meters from the top.
- Very fine to fine grained sand layers.
- Top 6 cm composed of fine sand.
- Underneath a 0.75cm layer of silt.
- Under silt layer is alternating layers of very fine and fine grain sized sand.
- Cohesion of 5.0 with the large disk.

Pit #5



Ripple



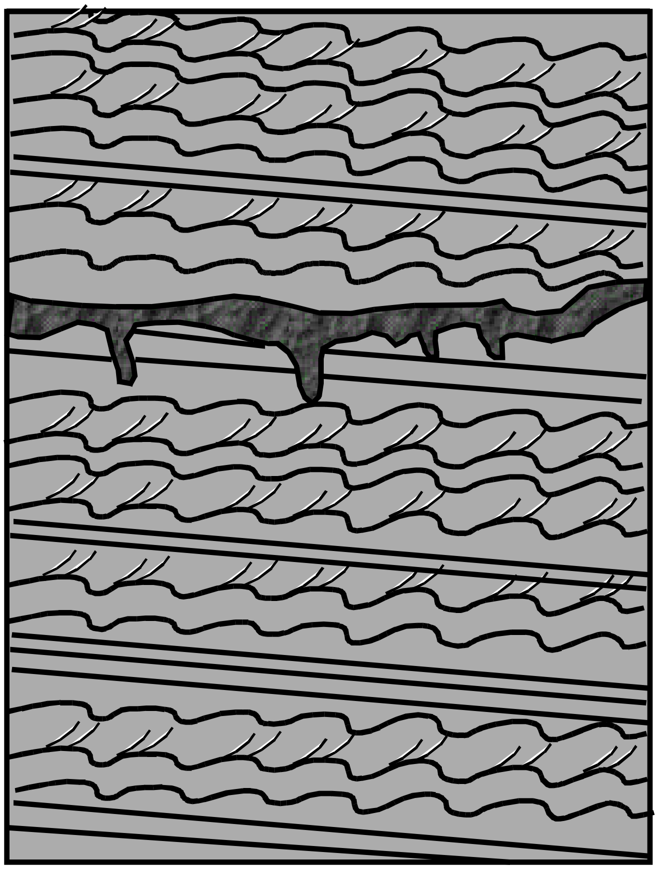
See pen for scale

Period of disruption

See pen for scale

Figure 4:
- 12.5 meters from the top of the landslide.
- Very strong overhangs the sediment located underneath it.
- Fine grained sand layers.
- First pit where ripples, cross bedding and periods of disruption were found.
- Cohesion 6.4 with the large disk.

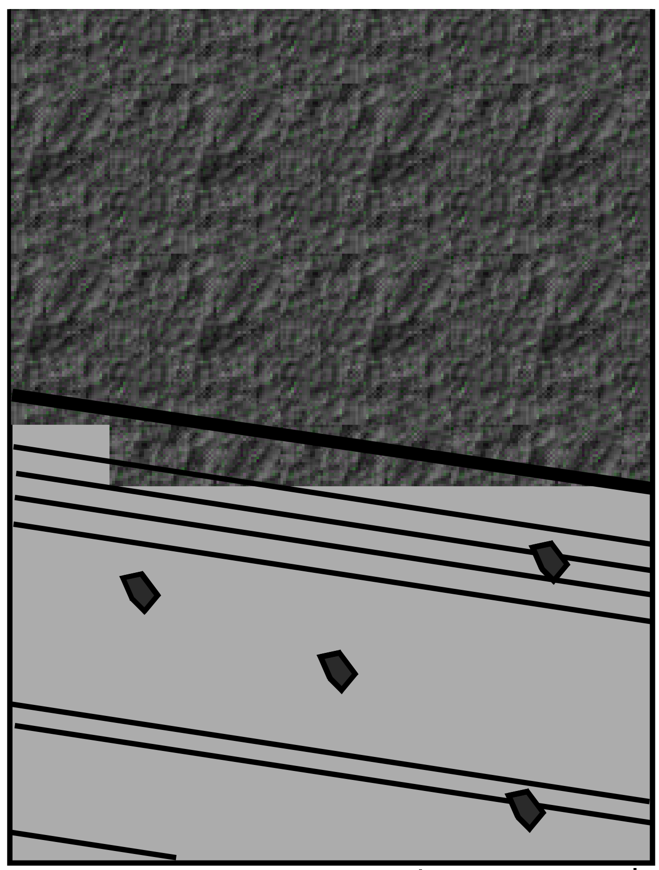
Pit #6 and Pit #7



Scale = 1/4 meter

Figure 5a:
- Pit #6
- 6.8 meters from the top of the slope.
- Top 27 cm of the pit composed of layers of sand and silt, where cross-bedding, ripples, and tilted bedding are present.
- 27 cm down is a 3 cm thick layer of gravel which penetrates the layers under it.
- Bottom 70 cm of the pit is composed of medium grained sand layers where cross-bedding, ripples and tilted bedding could be seen.

Figure 5b:
- Pit #7
- 4.1 meters from the top
- Top half of the pit was composed of unsorted medium and coarse sand.
- Bottom half composed of medium grained sand, some tilted bedding present. pockets of gravel and larger stones found through out.
- Cohesion of the top is 0.8 with the large disk.
- Cohesion of the bottom was 4.5 with the large disk.



Scale = 1/4 meter

Pit #8

See pen for scale

See person for scale

Figure 6:

- Located at the top of the landslide
- Alternating medum to coarse grained sand that were 5 to 10 cm in thickness.
- Brown in color and wet.
- Cohesion value of 2.0 with the large disk in the medium sand.
- Cohesion value of 0.9 with the large disk in the coarse grained sand.

<u>Soil Pit Number Two</u>

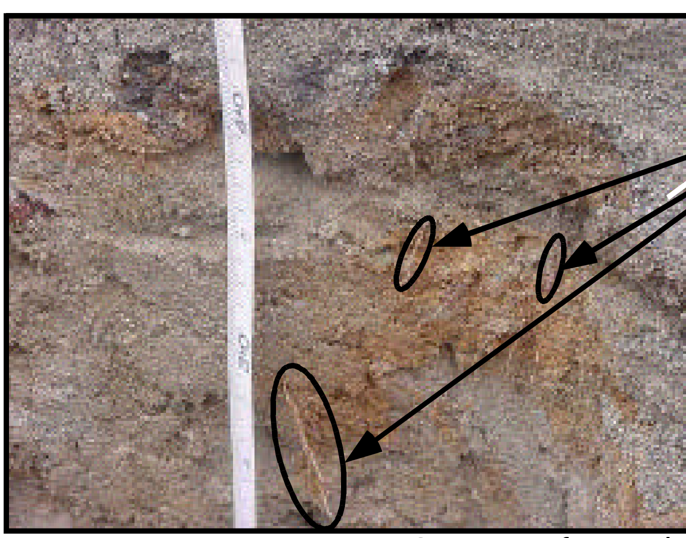
See tape measure for scale

<u>Figure 7a:</u>
The second soil pit. Possible sediment from recent landslide.

<u>Figure 7b:</u>
Pockets of gravel can be found within the pit of unsorted material.

See tape for scale

Organic Material



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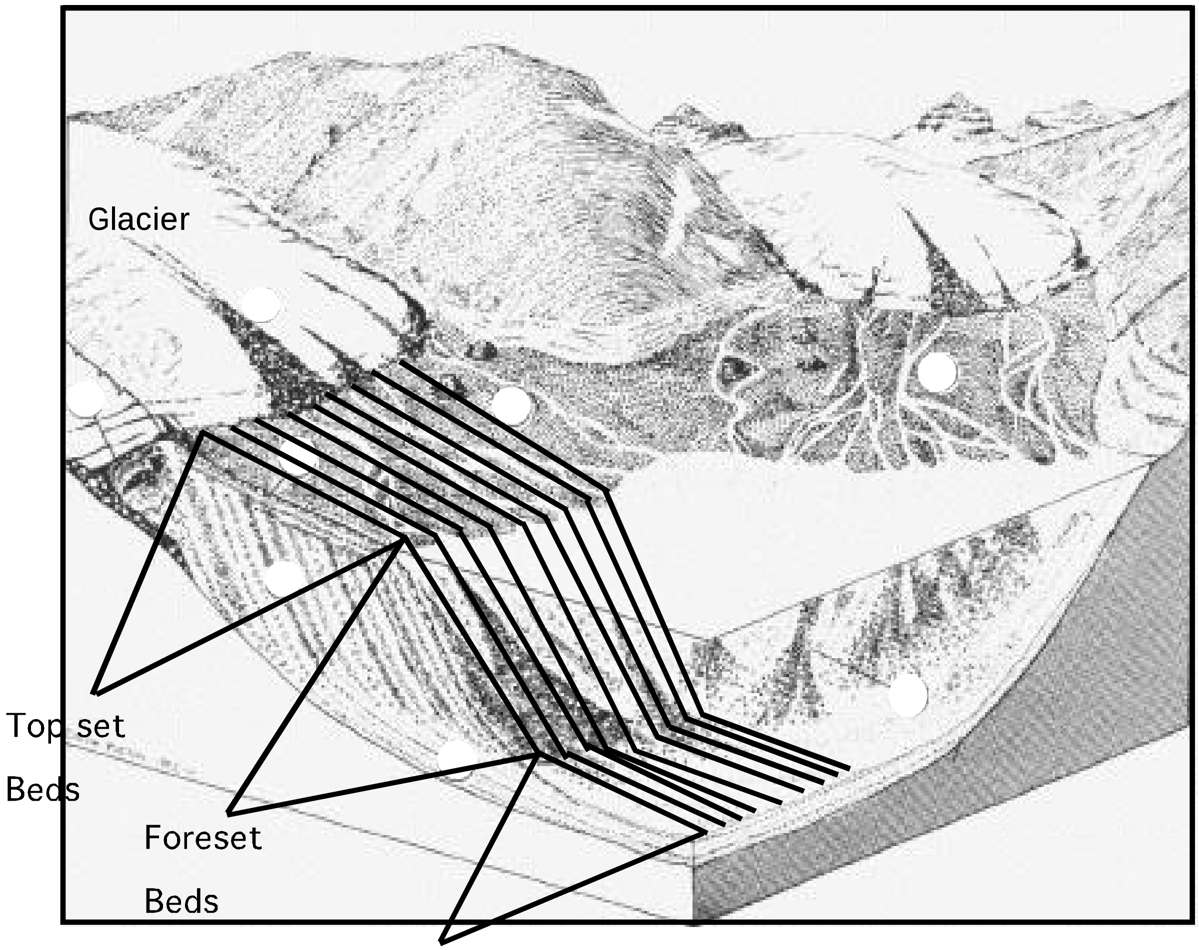
<u>Figure 7c:</u>
Organic material is found through out the soil pit.

<u>Deposition of Glacial Deltaic Sediments</u>



<u>Figure 8:</u> When the Lee River was flowing into Glacial Lake Vermont the most coarse sediment was deposited horizontally closest to the location of the river discharge, on the top set beds. The foreset beds were deposited at an angle, and the bottom set beds were composed of very fine sediment, horizontally, in the deepest part of the lake furthest away from the river discharge (Benn and Evans, 1998). Note: disregard circular blank spots.

Saturated Sediment and Vegetation on the Slope

Scale = 6 in.

Figure 9a:
Water saturated silt and clay is present at the bottom of the landslide. Previous to investigation of the landslide there was a lot of rainfall, that could be the cause of this much saturated sediment.

See person for scale

Figure 9b:
The vegetation located on the landslide did not have roots that were long enough to reach the bedrock and stabilize the slope.