Clyde River Landslide

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Abstract:

This paper investigates a landslide on the Clyde River in Newport, Vermont. The landslide is located below the Citizens Utility Dam. The history of the slide dates back to at least 1957. The slide is 25.3m wide and 11.5m high. Landsliding can occur as a result of undercutting, increased pore pressure due to heavy precipitation and or snowmelt, and seismic shaking.

The Clyde River landslide is interesting because there are unstable fluvial deposits above less cohesive sand and silt rythmites. Both these layers are above a relatively cohesive clay and silt layer. Undercutting initialized the slide by removing the clay and silt layer. After the initial slide the slope became very prone to small slides because of the lack of cohesiveness of the sand and silt layers, preventing slope stabilization by vegetation over time. Vegetation and a visible soil horizon helped us determine times of stability. Slope calculations show that stability occurs at an angle between 32 and 42 degrees.

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Introduction:

The Clyde River is located in the town of Newport, in the Northeast Kingdom of Vermont (see figure 1). The landslide of interest is located in between the Citizens Utility Dam and the USGS gauging station on the south side of the Clyde River (see figure 2). This particular section of the river is prone to landsliding and has two distinct sections. The upper portion located near the dam has been remediated against landsliding (see figure 5). The lower section, where the investigated landslide is located, has been termed the "jungle" by the locals because it is densely vegetated compared to the remediated, less vegetated upper section. The jungle has not been remediated, therefore it has remained in its natural state. By talking to locals and viewing orthophotos we determined that the landslide we investigated has been active since at least 1957. The landslide is about 25 meters long and consists of several different sediment layers.

In our investigation of the landslide, we hypothesize that initial failure was due to high water flows that undercut the bank of the slope. We also believe that more recent landsliding has occurred from failure in the fine sand and silt layer near the top of the slope. The frequency of slope failure is high on the Clyde River landslide. The data and discussion sections of the paper will provide evidence for our hypotheses.

Methods:

It was important to first distinguish the slide from an area of erosion on the left side of the landslide. We concluded that a slide occurred, and was later eroded by the river causing an area of vertical exposure (see figure 6). This area had been part of the original slide. Then, tape measurements were taken of the entire slide (see figure 17).

Tape measurements were the primary source for determining the size of the slide, stadia rod and bubble level measurements could not be used widely because of the heavy vegetation and the steep topography. Stadia rod and bubble level measurements were taken to determine the slope of the slide and to measure the depth of material that failed on the slope. Strength test measurements were taken of the clay and silt rythmite layers using a Torvane soil test. Photographs were taken of the entire slide and specific points of interest were later investigated. Flow data was collected from the USGS homepage and an attempt to correlate high-water events and slope failure was made. Airphotos from 1963, 1975, 1987, and 1999 were collected so that the history and frequency of the slide could be determined. The stratigraphy was examined and determined for the landslide.

Data:

The volume of material that has failed was calculated using the tape and stadia rod and bubble level measurements, 350m^3 of material slid and slumped. The slope of the lower sub-vertical section of the slide was roughly 42 degrees. Strike and dip were taken of a soil layer found between the fine sand and silt layer and a layer of failed material, its slope is 32 degrees (see figure 11). The stratigraphy of the landslide consisted of four primary layers (see figure 16), on the bottom a 1m clay and silt rythmite layer (see figures 7 and 8), then a 5m layer of till deposits consisting of sands, pebbles, and cobbles (see figure 9). On top of that layer is a 3 meter layer of fine sand and silt rythmites (see figure 10), with a 2 meter layer of fluvial deposits with boulders up to 1.5 meters wide deposited above (see figures 12 and 13). A small topsoil layer is present at the top of the slide. Airphotos helped to determine the history of the slide. The 1963 and 1975 paper orthophotos showed that sliding had been taking place in the past (see figures 3 and 4). The 1987 printed photograph again revealed evidence of slope failure in the area of the slide studied. In the 1999 orthophotos the sliding was visible as well (see figure 2). Animal burrows were photographed (see figure 15), along with vegetation on the slide (see figure 14). Other observations include landslide scars next to the slide studied, along with river flow along the cut bank and the presence of undercutting. We also noted the stability of the layers. The clay and silt rythmites were broken into two sections the upper redder section that yielded a strength around 1 and the lower grayer section yielded a strength around 2. The sand and silt rythmites were visibly the weakest layer but could not be measured. Large cracks were visible that were easily pulled off the slide. Deposits on the sand and silt layer in the form of mud drippings down the 5 meter till deposit layer were visible. Also observed was the failed material forming an island in the middle of the Clyde River at the base of the landslide that helped to form a dam consisting of large woody debris (see figure 6).

Discussion:

The initiation of landsliding was due to undercutting by the Clyde River. At the base of the slide the river has a higher velocity because the bank is on an outside bend. The erosion of the clay and silt layer prompted the gravel and sand layers to fail creating the landslide. Significant evidence for undercutting is directly related to the location of the landslide being on a cut bank. Flow data for the Clyde River for each month of the year from 1909 to 2000 was used to determine that undercutting most likely occurs in the spring, when flow is greatest (USGS web page, 2001). For the months of March, April, and May the average discharge was 490 ft3/s, which is about 2.7 times higher than the average flow recorded for the other months of the year (181 ft3/s).

This landslide has been active for many years. Evidence for landslide activity was taken from old orthophotos, as well as through personal communications with local residents. A soil horizon in the slide also reveals that the slide has remained active because unsorted sands and silts have been deposited on top of the horizon from a previous slide. Times of stability are evident through plant growth, limited to smaller grasses, and the presence of animal burrows. The slope of this soil horizon is 32 degrees and the slope of the landslide is 41.85 degrees. The angle of repose for dry sand is 35 degrees (Bloom). Thus, we can conclude that since the slope angle is steeper than the angle of repose required for sand to fail, the slope will slide again.

The layer that is most responsible for current sliding is the sand and silt layer. The loose sands and silts are easily carried away by water (rain). They are very fine grained and it does not take much energy to move them. Evidence for the erosion of the sand layer (via water) are the mud droplets. These droplets are small mud deposits (muddy water droplets that trickled down) on the till below. This is evidence that the sand and silt layer is the most susceptible layer to erosion. Also, the sand and silt rythmite layer at the top of the slide is approaching an angle of 90 degrees. This top layer of sand and silt rythmites is highly unstable due to the lack of cohesiveness of the sands. When the sand and silt layer is disturbed gravity pulls the sands away from the wall causing the layer to fail. The material then falls onto the slope, increasing the angle, and the potential for further failure. Boulders and sediments above the sand and silt layer also fall because the material below it fails. The weight of the boulders can not be supported by the weak, less cohesive sandy matrix. The failure of boulders in the top layer of fluvial deposits theoretically could cause enough seismic disturbance to cause further failure to the slope. Gravity is the main cause for loss of material in the upper layers.

The section of the landslide next to the debris dam, which has been removed due to erosion, is an extreme case of the instability of the sediments within the slope (see figure 9). This section of total failure was due to the damming of the left side of the river channel. The dam caused the water to flow around it causing heavy erosion of the slide. This left section had the clay and silt rythmite section removed causing the layers above to fail (see figure 7). The failed material was completely removed except for large boulders and cobbles that could not be transported by the river.

Summary:

The landslide on the Clyde River was most likely initiated by bank undercutting. This process removed the stable, cohesive silt and clay layers leaving the upper, less cohesive sands and gravels unsupported. Then gravity caused the gravel till to collapse, which in turn caused the layer of sands and silts to slide. Although the landslide is temporarily stable, there is strong evidence that sliding will reoccur. This prediction is based on the relative weakness of the less cohesive sand and silt layers, which are at an angle of about 90° as well as supporting heavy fluvial deposits above. These factors cause this layer to fail easily under the force of gravity and erosion. This failure is initiated by disturbances such as; rain, tumbling rocks from the fluvial layer above, or falling trees.

References:

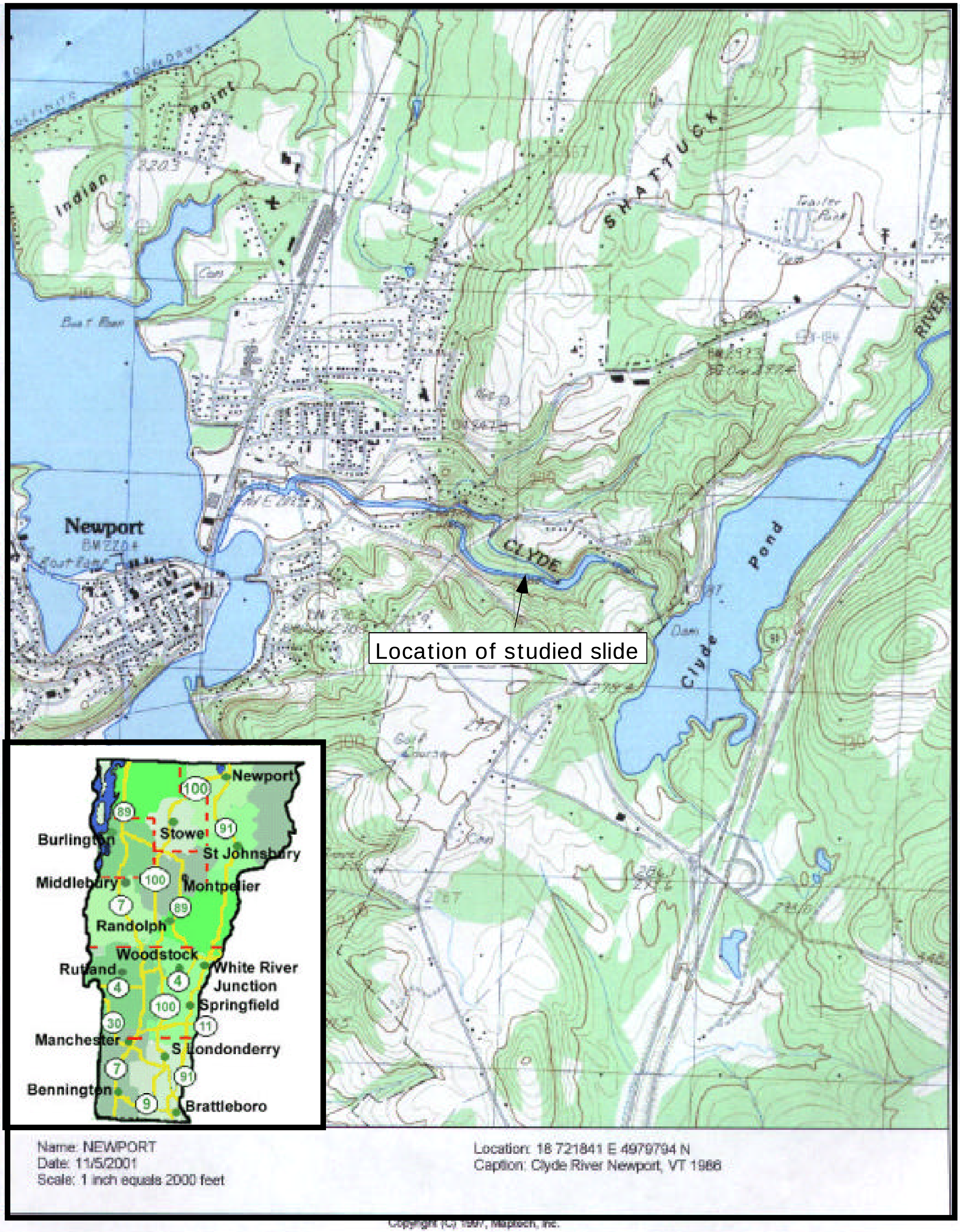
Bloom, Arthur L. (1991). Geomorphology: A Systematic Analysis of Late Cenozoic Landforms. Prentice-Hall Inc., New Jersey. Pp. 175-180

Nichols, et al. (2001). Long Run-Out Mass Movements in Glacially Conditioned Landscapes. Department of Geology, University of Vermont, Vermont.

USGS, http://water.usgs.gov/nwis/monthly?siteno=0429500&agencycd+USGS&format-html. [accessed via web, Oct. 2001]

Wayne, The Antenna Man. Personal Communication, 16 Nov. 2001.

Wright, Stephen. Personal Communication, 19 Nov. 2001.



Name: NEWPORT
Date: 11/5/2001
Scale: 1 inch equals 2000 feet

Location: 18 721841 E 4979794 N
Caption: Clyde River Newport, VT 1986

Figure 1: The studied slide is located on the Clyde River in Newport, Vermont.

Figure 2: This aerial photograph was taken in 1999.

Figure 3: This aerial photograph was taken in 1975. The area within the black box represents the studied landslide. This aerial photagraphs are important in studied the history and growth of the landsliding.

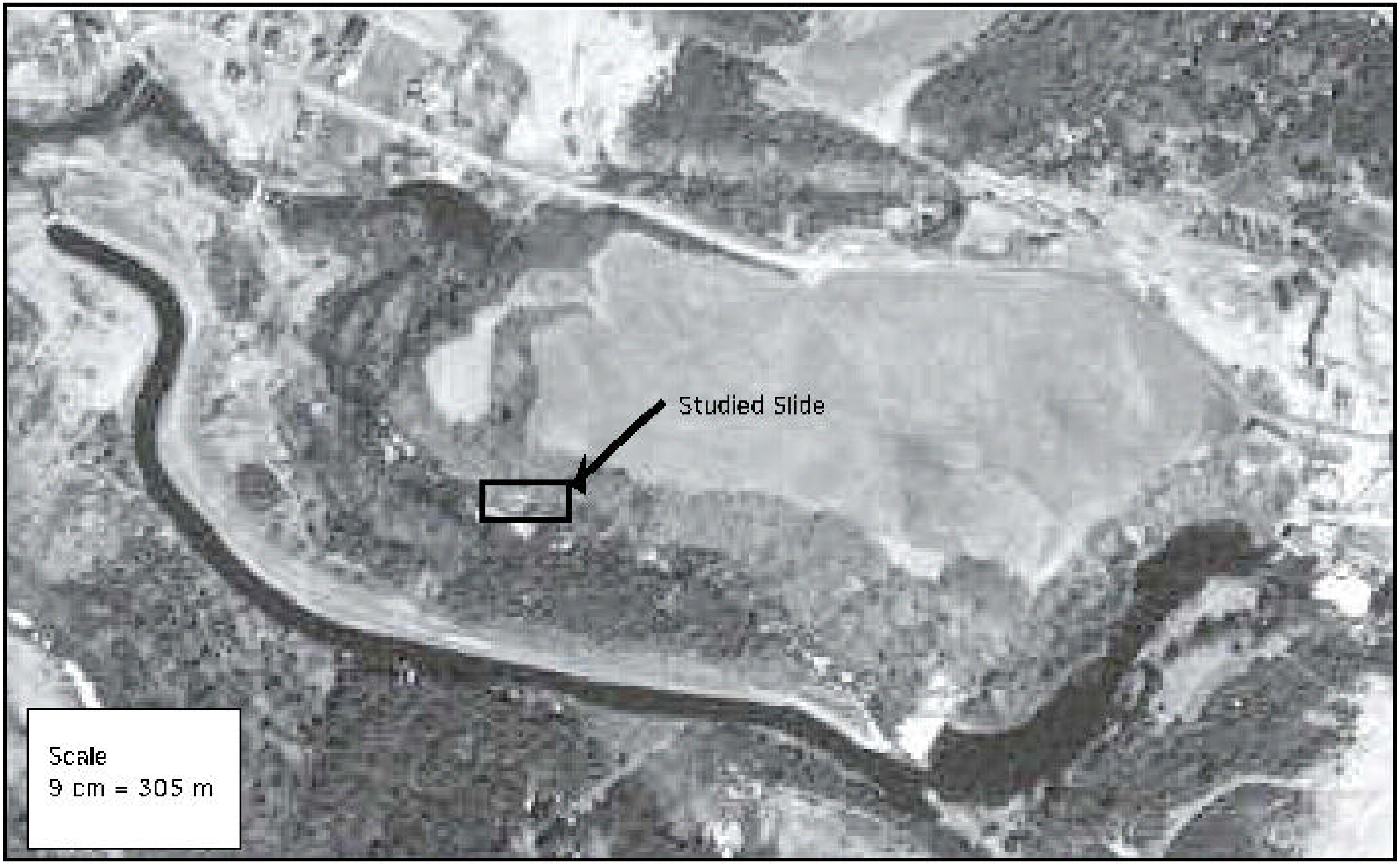


Figure 4: This aerial photograph was taken in 1963. The box highlights the studied landslide. From this photograph we can trace the history of the slide. From this data it can be concluded that the slide has existed since at least 1963.

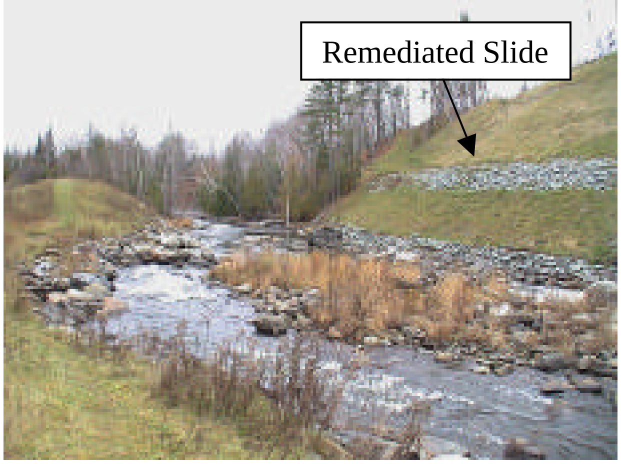


Figure 5

This is a view looking down the Clyde River above the slide. On the right is a remediated slide.

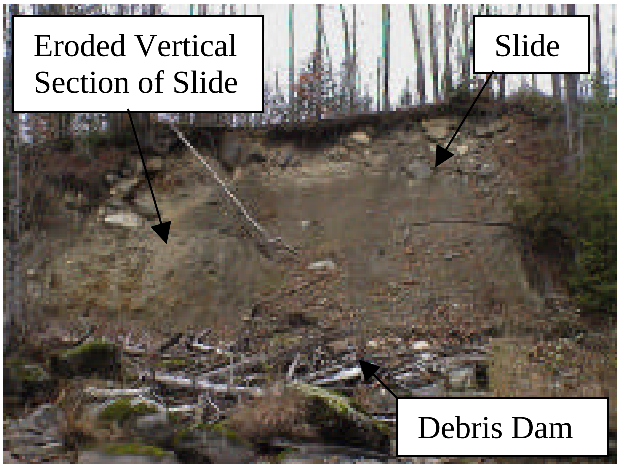


Figure 6

This is a view of the slide from across the river. The debris damn is visible in the foreground. The left side of the slide is the area of increased erosion with the exposed vertical stratigraphy.

Figure 7

Clay and silt rythmites deposited by a glacial lake. This layer was undercut by the river. This removal initiated the first slide

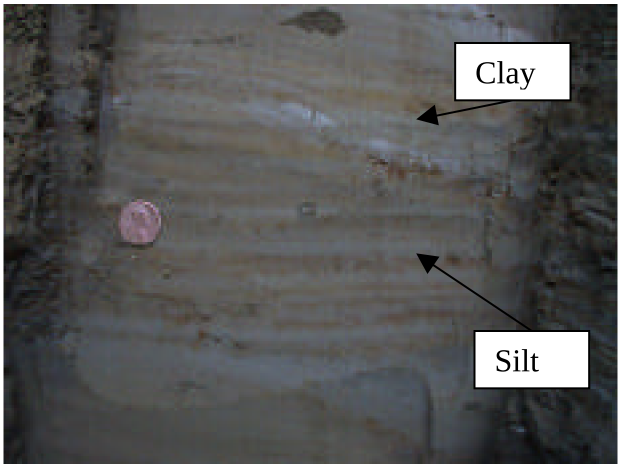


Figure 8

The redder clay and silt rythmites above the grayer clay and silts.

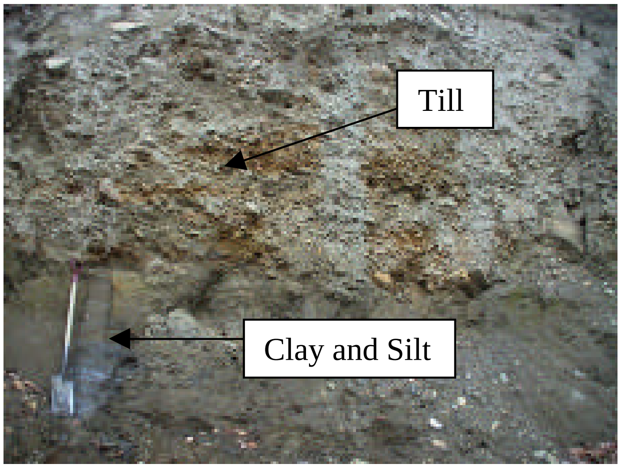


Figure 9

This is the exposed vertical section of the slide due to heavy erosion. The clay and silt rythmites with till deposits above (sands, pebbles, and cobbles). This till is a result of the re-advancement of glaciers.

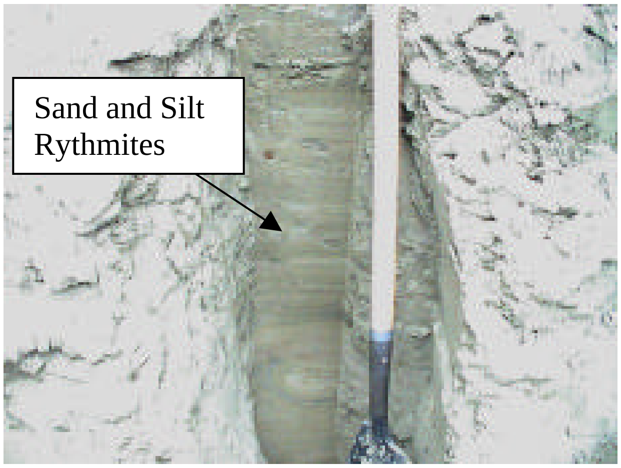


Figure 10

Fine sand and silt beds above the till deposits. This layer is responsible for the continual failure of the slope. It is very dry and cracks are visible across the entire layer.

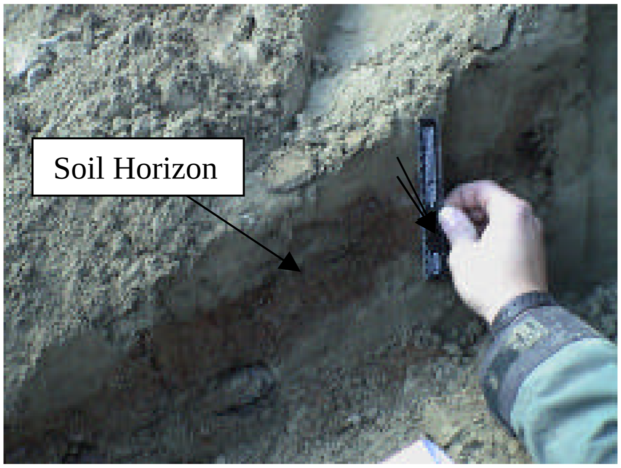


Figure 11

A soil horizon between the fine sands and silts. The soil represents a period of stability, the sands and silts failed again burring the soil. The soil is at an angle of 32° and the slope is at an angle of 42°. Stability lies somewhere in between.

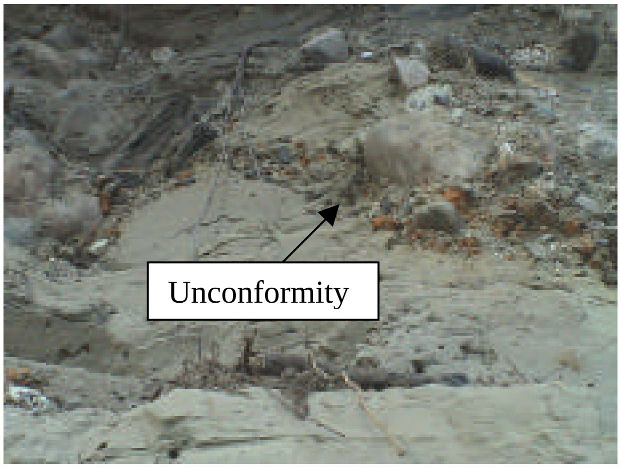


Figure 12

An unconformity exists between the fine sands and silts and the large till deposit. The unconformity is a layer of sand and pebbles.

Figure 13

Greg standing at the top of the slide with large boulders deposited by high energy fluvial deposits..

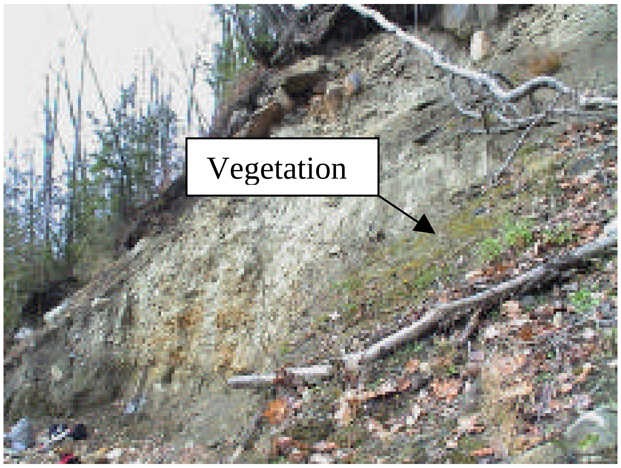


Figure 14

Vegetation is visible on the slide. This is useful for dating the slide. The young vegetation represents the short period of time for vegetation to grow between slide events.

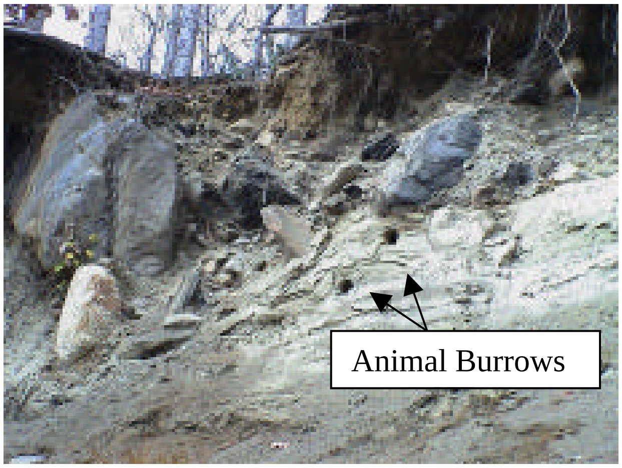
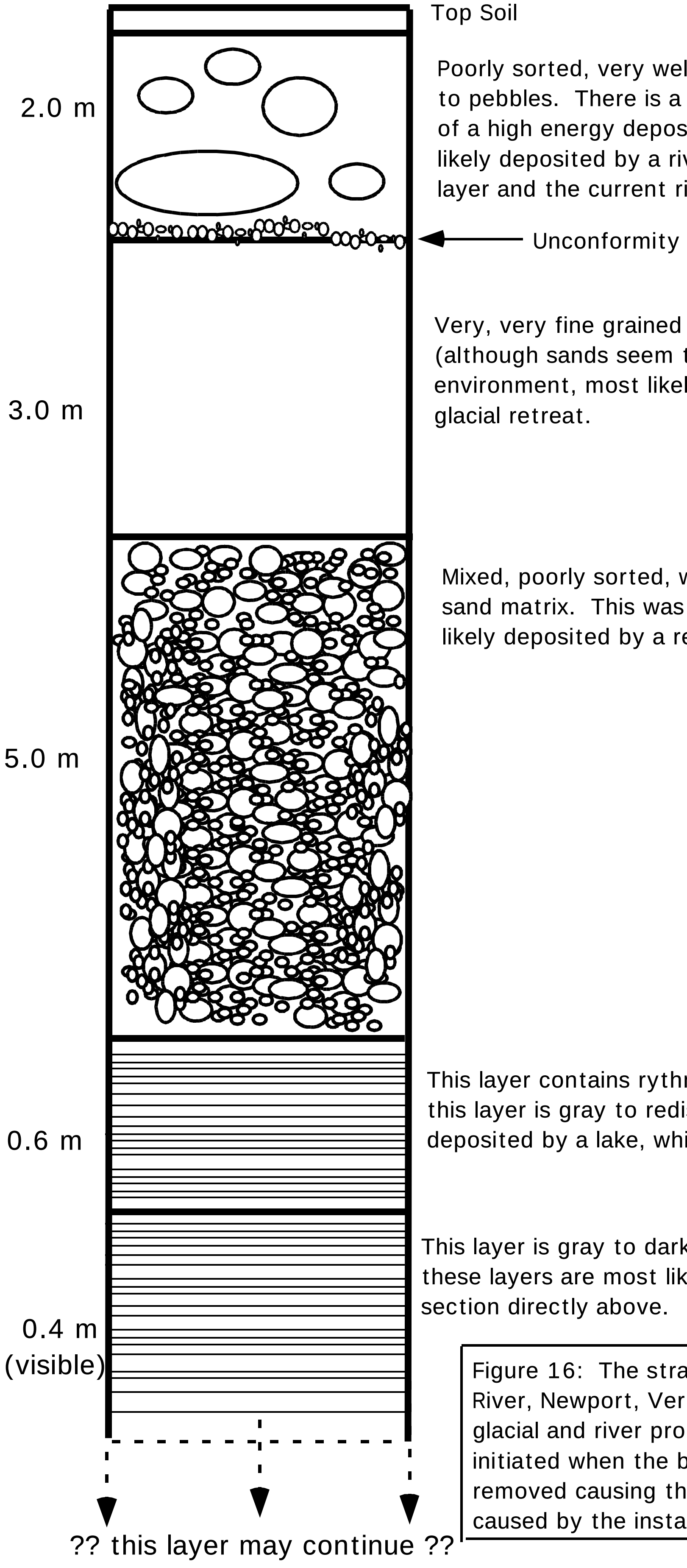


Figure 15

Animal burrows are visible at the top of the slide helping with dating. They are helpful because we know the slide hasn't failed since the burrows were dug.

Stratigraphic Column of Sediments



Poorly sorted, very well mixed layer. Grain size includes large boulders to pebbles. There is a matrix of fine grain sands. This is representative of a high energy depositional environment. These materials were most likely deposited by a river, evidence in the similarity of sediments in this layer and the current river bed.

Very, very fine grained to fine grain sand and silts in alternating layer (although sands seem to dominate). This was a low energy depositional environment, most likely a glacial lake which occured during a second glacial retreat.

Mixed, poorly sorted, well rounded pebbles and cobbles with a coarse sand matrix. This was a high energy depositional environment , most likely deposited by a re-advance of the glaciers.

This layer contains rythmic layers of coarser sands and silt. The color of this layer is gray to redish orange. These layers were most likely deposited by a lake, which was formed by the retreating glaciers.

This layer is gray to dark gray layers of fine silt and clay. The origin of these layers are most likely the same lake that deposited the layers in the section directly above.

Figure 16: The stratigraphic column of the landslide on the Clyde River, Newport, Vermont. The deposition environmnet is a result of glacial and river processes (Wright, 2001).The slide was most likely initiated when the bottom two layers of sand, silts, and clays were removed causing the upper layers to collapse. Further sliding is caused by the instability of the upper sand layer.

Dimensions of The Clyde River Landslide

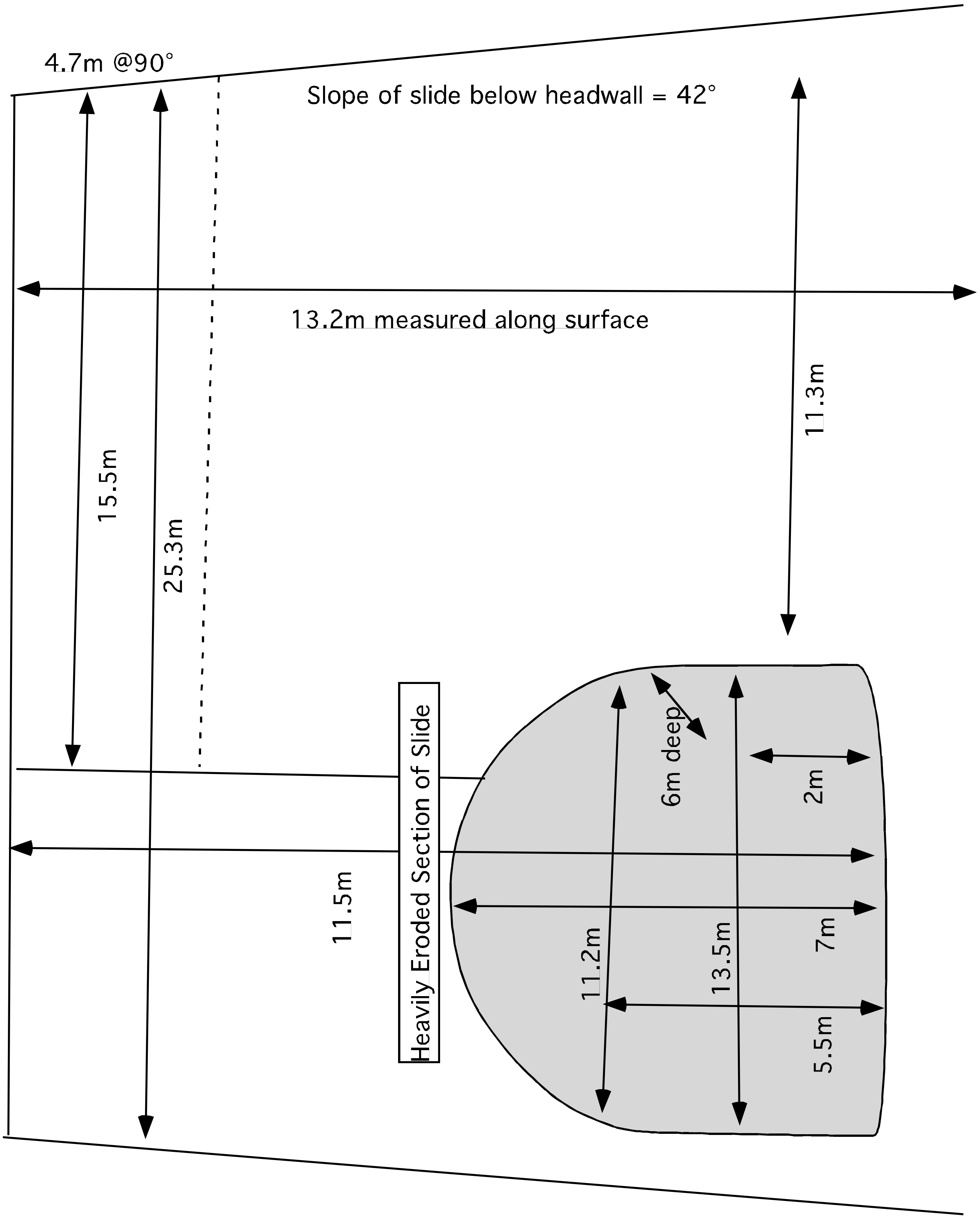


Figure 17: This figure shows the dimensions of the landslide being studied on the Clyde River, Vermont. The calculated slope is 42°. The calculated volume of the slide is 350 m^3. This offers a bird's-eye-view. The gray area represents the section of the slide that was further eroded by stream erosion..