Investigation of Hillslope Erosion in Centennial Woods, Burlington, Vermont

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ABSRACT
Analyses of three environments in Centennial Woods, Burlington, Vermont, suggest that slope angle is the largest factor in determining the erosion rate. A 40° slope angle increases the amount of sediment runoff by a factor of ten compared to a slope angle of 22°, given similar vegetation conditions. Two comparable slope angles with drastically different vegetation yields relatively little change in the amount of collected sediment (1.8g vs. 3.9g), however, the types of sediment do differ. More vegetation leads to a slightly higher concentration of organic matter (8.7g vs. 12.8g).

INTRODUCTION

Sedimentation and erosion rates are critical knowledge for land management. These are often difficult to predict, especially on hillslopes, where surface erosion is characterized in the short term by episodic pulses, with a high degree of spatial variability (Wells, 1987). This degree of variability is brought on by spatial differences in erodability.

The rate of erosion in many areas is much higher than the natural rate due to human impact. Increases in rates as extreme as 400 times the past rates have been witnessed (Stone, 1996). High rates of sedimentation shorten the life of reservoirs, clog culverts, and fill stream channels to the extent that they can no longer contain streamflow within their banks. Erodabilty is largely determined by texture, organic content, and the structure and permeability of the soil, which is unique to each location (Goldman, 1986). Human impact on the land has essentially altered all of these factors.

This experiment investigates the impact that varying slope angles, vegetation and climatic factors have on the sediment transport in three locations in a discrete area. The human impact on this area is slight, though still notable. Locations for analysis were chosen in such a way that topographic variability would be maximized, and vegetation types would differ. Higher sediment delivery is largely brought on by steeper topography and more rainfall (Wasson, 1982). To increase the mass of sediment obtained, moderately steep slopes were analyzed. Gutters of a specific volume were used to trap sediment, which closely mimics the experiments executed by Wells (1987).

In this instance, it is proposed that most sediment was launched by the impact of falling raindrops. The more protection the soil has rainfall impact, the less sediment will be displaced. More soil splashes downhill than uphill when a raindrop hits due to the force of gravity and the angle of raindrop impact (Ellison, 1944). The infiltration rates in forested areas are far too high for there to be surficial runoff. Forested areas have higher infiltration rates because the soil particles are "held together in aggregates by organic matter"(Dunne, 1978).

Slope angles are critical factors in erosion potential, since they largely determine the velocity of the runoff (Goldman, 1986). The sediment trap that is located on the slope with the greatest angle will usually have the largest mass of sediment. The higher slope angle allows more sediment to bounce into the traps by the raindrop effect. Other factors such as vegetation and soil consistency will play a significant, yet indeterminate roll on the variation. The sites chosen have similar soil consistency, and vegetation has variable effects on erodability (Parker, 2000).

METHODS

Preparation and installation of the sediment traps

The sediment traps were constructed out of common storm gutters. Each was measured and cut to a length of 66.5 cm and closed off on either side by plastic caps made to fit the shape of the gutter. Each had a volume of 4.3L.

Three different sites were selected in Centennial Woods. The first site chosen (site 1) was located on a 26˚ slope. The ground was covered with fallen leaves, and trees were present, but sparse (figure 2). Beneath the leaves, the soil was homogeneous with sand-sized grains. The undergrowth was thinly distributed. The second site selected (site 2) was on a 22˚ slope covered with grass and dense undergrowth, with similar soil as site 1. The third site (site 3) was on a 40˚ slope situated in exposed, heterogeneous soil with grain size ranging from silt to gravel. This slope was adjacent to a paved parking lot and lacked trees directly above the collection site.

A shallow trench (11cm) was dug at each site enabling a sediment trap to be installed, with the upper edge flush with the ground level. As the traps were installed, we were careful not to disturb the land above the collection sites because loosening the sediments can lead to an inaccurate increase in collected volume.

Analysis of the collected sediment

Each collection period lasted four to five days, and will be referred to here as a trial. The first trial lasted from 10/31 to 11/4, the second from 11/4 to 11/7, and the third from 11/7 to 11/11. At the end of each of three collection periods, the sediment traps were emptied into their own Mason jars through a coffee filter to isolate and dry the sediments. A separate filter was used for each trial, totaling nine data sets. All the filters with sediment were left out to dry then weighed (see data, figure 3). The amount of precipitation that fell during each trial was also recorded (see figure 3).

L.O.I. analysis (figure 4) was conducted for thirteen samples selected from the three sites. This determined the amount of organic material collected. The sediments sat in an oven at 60°C for forty-two hours to ensure dryness. A crucible was filled with dry sediment from each coffee filter, and the weight was recorded. These crucibles were then placed in an oven set at 450°C for two hours and twenty minutes to incinerate organic matter. The crucibles were cooled and weighed again in order to determine the loss of mass upon ignition.

DATA

The heaviest sediment load came from the steepest slope angle (site 3, see figure 1). Sites 1 and 2 yielded similar results. These two sites had between three and eight percent of the total collected sediment while site 3 had over eighty-five percent of the total collected mass. Site 2 showed the highest organic content, followed by site 1.

DISCUSSION

The relevance of slope

The hypothesis that slope controls the erosion rate was supported by the outcome of the experiment. Slope clearly had a strong impact on the volume of sediment that was retrieved from each location (see figure 3). The location with the highest slope angle accumulated the most sediment. No specific measurements were made regarding the distance from the peak of the slope to the traps. It is likely that this factor was reduced in this instance, because the hills were relatively small, and all of the traps were located in close proximity to the peak of the slope.

Organic concentration analysis

The organic analysis showed us that there were drastically different quantities of plant and animal matter within the samples. Table 2 reveals that the collection on the grassy slope was consistently about one-sixth organic matter. The slope with the leaves covering the surface (site 1) had a much lower percentage of organic content, about half that of the vegetated slope. Sites 1 and 2 had very similar slope angles. The third site, with almost no apparent vegetation, had insignificant organic content compared to the other sites. It appears that the more dense the vegetation in the area, the higher the organic content of the soil.

Error analysis

There was certainly some error in this experiment. The main purpose the data serves is as a comparison. It was difficult to work with the land to situate each trap in a way that would allow the traps equal opportunity to collect sediment. That is, there were slight gaps in the rear of the traps, between the hill and the trap, which were not identical for each site. Figure 3shows that the relative percentage of total sediment in each trap is quite similar for all trials, which shows that this effect was minimal. Disturbing the land may have caused more sediment collection in the first trail in comparison to the second trial, even though the precipitation amount was nearly identical for the two trials.

SUMMARY

Since the “vegetation effect” on the surface runoff cannot be quantified, and the soil type is nearly the same in terms of infiltration and texture, the most important factor determining potential erosion for Centennial Woods appears to be slope angle. The steeper the slope, the greater the effect raindrops have on sediment displacement. The data strongly support this statement. Sites 1 and 2, which had drastically different vegetation densities, but similar slope angles, the sediment yield was quite similar. However, the third site, which had nearly double the slope angle of the other two, had almost ten times the sediment mass of the others.

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1A

1B

FIGURE 1: This shows the areas where the various sites were located. Site 3 is shown in 1A, with the trench visible on the left. The thick vegetation surrounding the second site is show in 1B. 1C shows the general installation of the trench, with the upper lip flush with the overlying ground, and a minimal amount of disturbance above the installation.

2B

FIGURE 2: These photos show the methods which were used to extract the sediment from the trenches after each trial. 2A shows the initial pour of the sediment into the filter. 2B shows the rinsing procedure that we used to remove the remaining sediment. 2C shows the filter draining water from the sediment into the jar.

2A

SEDIMENT VOLUMES AND PRECIPITATION

figure 3

Site #	slope steepness	GPS Coordinates	trial 1	trial 2	trial 3	% of total collected sediment
1	26 degrees	18T0644270 UTM4926173	1.05g	.42g	.33g	3.76%
2	22 degrees	18T0622271 UTM4926171	1.98g	1.27g	.6g	8.05%
3	40 degrees	18T0644302 UTM4926075	18.62g	16.14g	7.43g	88.19%

Trial #	dates	duration	precipitation
1	10/31 - 11/4	96 hrs.	0.965cm
2	11/4 - 11/7	72 hrs.	0.914cm
3	11/7 - 11/11	96 hrs.	0.127cm

Figure 4: **LOSS ON IGNITION**

site #	trial #	crucible mass (g)	crucible + dry wt. (g)	dry wt. (g)	crucible + burned wt. (g)	mass lost (g)	% loss on ignition (LOI)
1	1	4.569	5.305	0.736	5.233	0.072	9.783
1	2	4.81	5.915	1.105	5.826	0.089	8.054
1	3	4.664	5.143	0.479	5.103	0.04	8.351
2	1	4.408	5.763	1.355	5.599	0.164	12.103
2	2	4.657	5.006	0.349	4.955	0.051	14.613
2	3	4.788	4.985	0.197	4.962	0.023	11.675
3	1	4.6	6.879	2.279	6.703	0.176	7.723
3	1	4.885	7.27	2.385	7.125	0.145	6.08
3	1	4.599	7.5	2.901	7.386	0.114	3.93
3	2	4.706	7.766	3.06	7.668	0.098	3.203
3	2	4.683	7.983	3.3	7.797	0.186	5.636
3	3	4.755	7.569	2.814	7.486	0.083	2.95
3	3	4.596	7.504	2.908	7.415	0.089	3.061

* Trial numbers 1, 2, and 3 at sites 1 and 2 did not yield enough sediment to fill a crucible, thus allowing room for error during loss on ignition tests

Figure 5

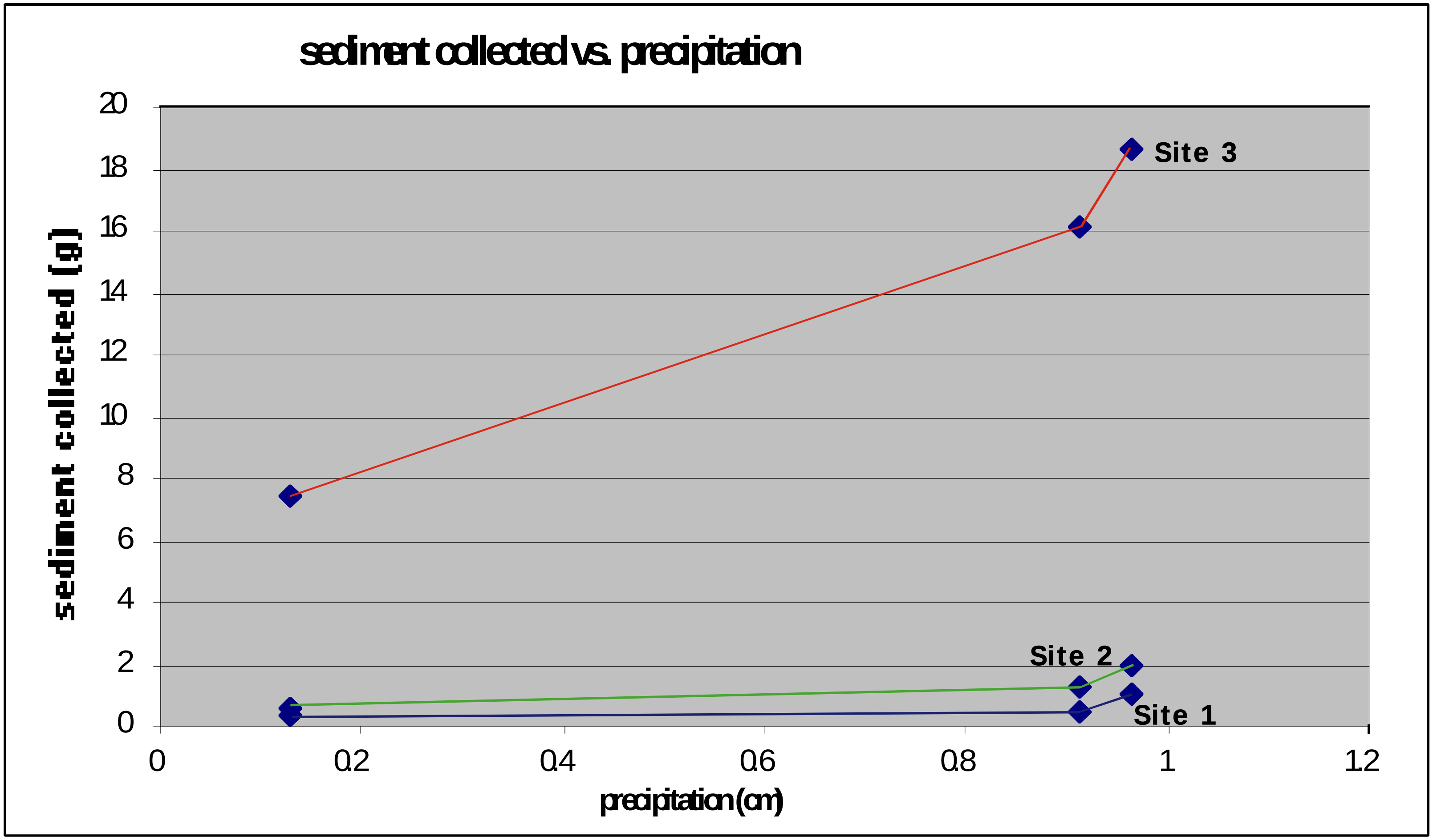


Figure 5: **The graph shows how the sediment collected depends on the amount of precipitation. The three curves represent the three sites used in the study.**

Figure 6

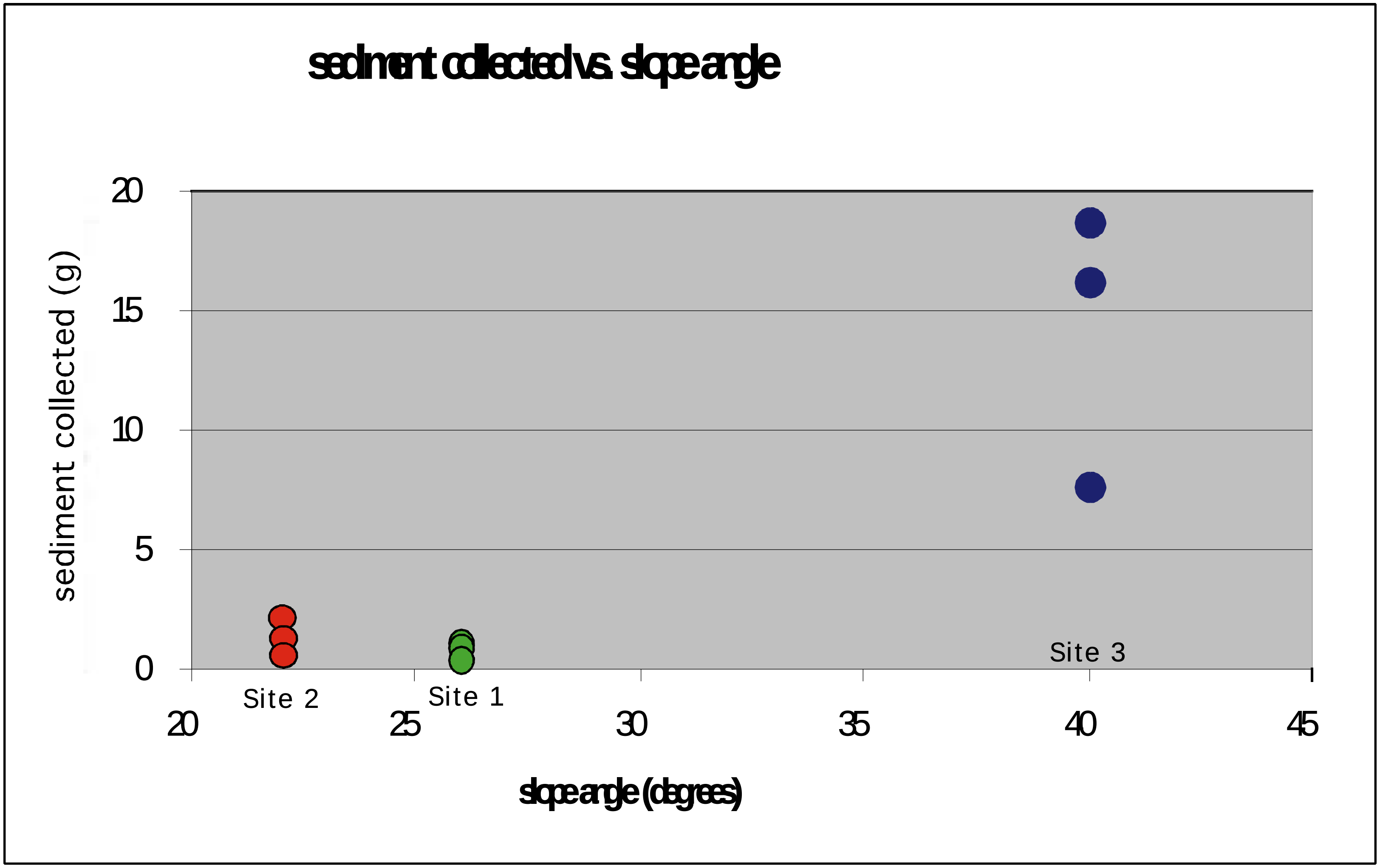
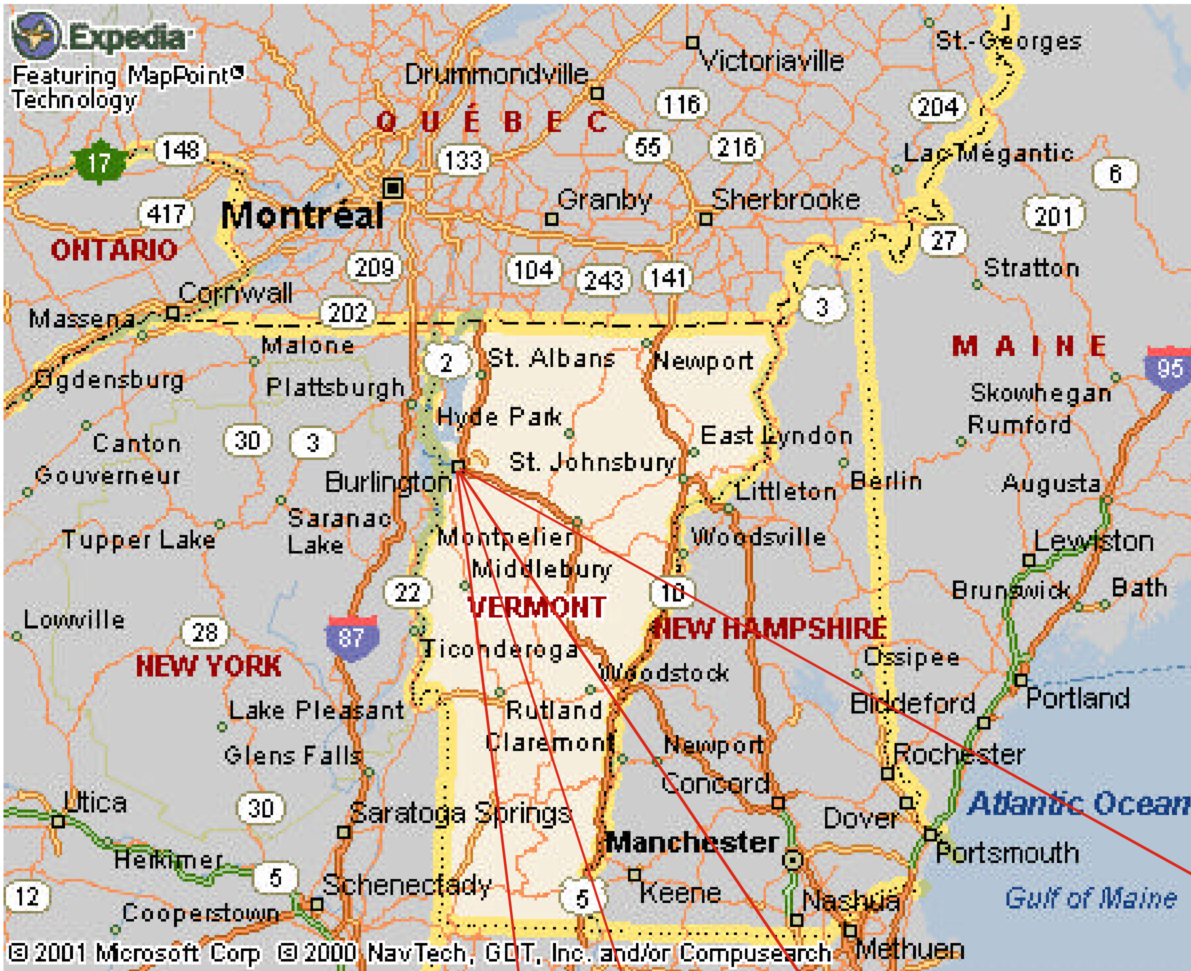


Figure 6: The graph shows how slope angle affects the amount of sediment collected. The greater the slope angle, the more sediment that is propelled downslope by raindrops.



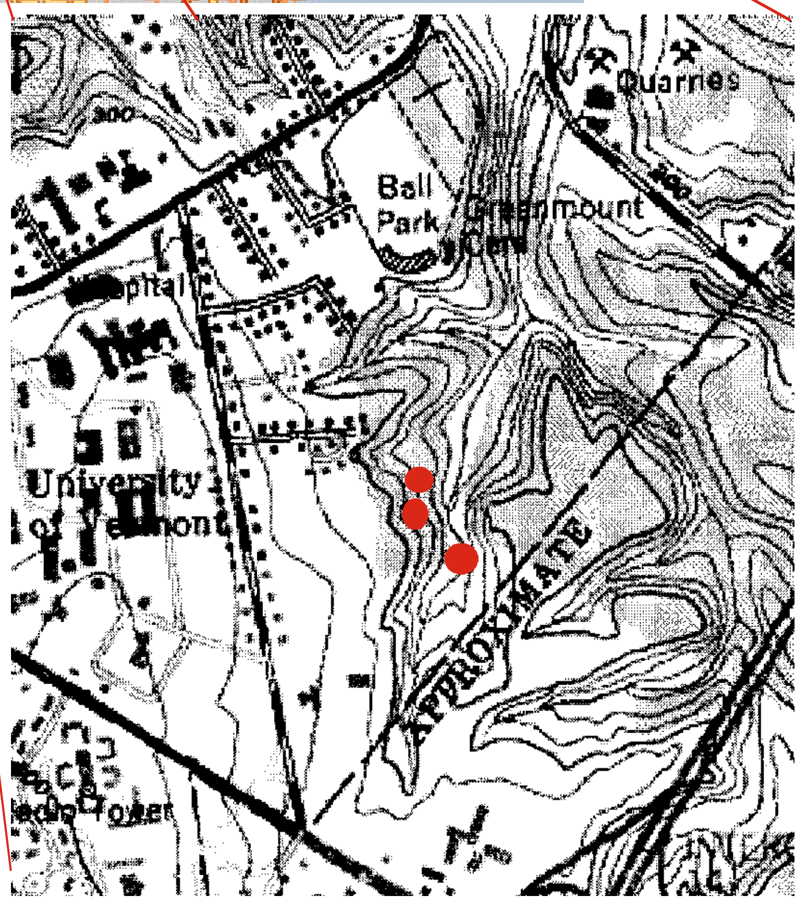


Figure 7:
This figure shows the location of the 3 sites that were studied, and the surrounding region, which puts the site in context. Site 1 is the furthest point north, with site 2 and 3 being further south, in that order.