Shona Pierce
EGeo. 432
Soil Research
Bach
5/21/07

Sheep Induced Compaction:
Stratigraphy At Woodstock Farm, Washington

Project Description

The topic my group based our research on is the study of impact that the flock of sheep have on soil compaction. To do this, we compared the soils at two different locations. The Control pit as well as the Sheep Trail pit both measured approximately 4 x 2 feet, and went to an average depth of three feet.

This portion of the project focuses on the effects soil compaction has on the stratigraphy of the two sites. By referencing the findings with those stated in the *Soil Survey of Whatcom County Area, Washington* (1992), and other literature, I will be able to determine whether the four sheep at Woodstock Farm have any significant affect on the soil.

The hypothesis is that the main soil compaction area (the sheep trail) will exhibit a lack of differentiation between topsoil horizons. The profile therefore possessing non-existing stratigraphy until the lower sub-soils are unearthed. This will be due to the intense activity brought about by the sheep. Research conducted by Jennifer Lile, Alisha Martin, and myself will prove that upper horizons will have no stratigraphy within the sheep trail because repeated compaction processes will have constantly mixed and mashed the different soil characteristics into one another. While the Control pit outside of the sheep pen will show well-defined stratigraphy.

Site Description

Woodstock Farm is located within a stretch of land that borders Chuckanut Bay in southern Bellingham, WA. The site is approximately ten minutes from campus. The property is supervised by Bellingham Parks and Recreation, mainly Tim Wahl. Woodstock Farm serves as a prehistoric and historic site with archaeological implications in that there is an extensive shell midden in association to an assortment of artifacts. Archaeological activity has largely been restricted to the land bordering the shoreline and the river/estuary where the shell midden is eroding out of the banks.

The area our group worked is situated on the inland portion of the property where a flock of four sheep are usually held. The pens are located on slightly sloping land in a grassy field. A smaller holding pen is located within the larger grazing pen, where the farmer occasionally allows the sheep out to graze over a greater expanse of land. An uphill site, out of the range of the sheep, was selected to serve as our control pit. While a second pit was dug on a sheep path located within the larger holding pen.

Methods

The method for determining horizon stratigraphy was based on the group's classification of the soil pedon. This included the identification of moist soil sample's structure, texture, consistency, pore space, and color. Schaetzl's book, *Soils: Genesis and Geomorphology*, was referenced to aid in our study, as well as texture and consistency handouts saved from the winter quarter Geography 397S class. Based on these classifications, horizon boundaries were thusly identified. The stratigraphy was marked using regular toothpicks. The toothpicks were spaced roughly every two to three inches depending on the nature of the boundary. Measuring tapes were then used to help record accurate positions of the toothpicks onto a scaled, graph paper reconstruction of the soil pits.

Control Soil Pit Description

The control pit is located on the upper southeastern aspect of Woodstock Farm immediately proceeding a shear cliff that drops to railroad tracks and the bay. The locale itself is found outside of the main sheep enclosure on a steep slope of 13º, at GPS coordinates N48º41.803’ W122º29.845’, and an elevation of 119 feet. Primary site vegetation is thick grass that stands 3-5 inches off the ground. Sticks, leaves, various types of seed pods, hemlock, and Douglas fir also represent organic materials found within the immediate area.

This portion of Woodstock Farm is utilized as a picnic area with one picnic table, patches of replanted alder trees, and two main paths meandering through the grassland. In order to avoid mass compaction that could possibly be brought on by the anthropogenic trails, our group decided to excavate a soil pit six feet to the west of one main trail. The height of the grass indicated that this specific area was not widely walk upon.

Excavation for the Control pit took place in the afternoon hours of 5/4/07. One shovel was used to dig a 4 x 2 foot pit that extended roughly 29 inches down. Due to the time of day at which the pit was finally dug, and the position of the sun at that time, stratigraphy was taken on the eastern profile.

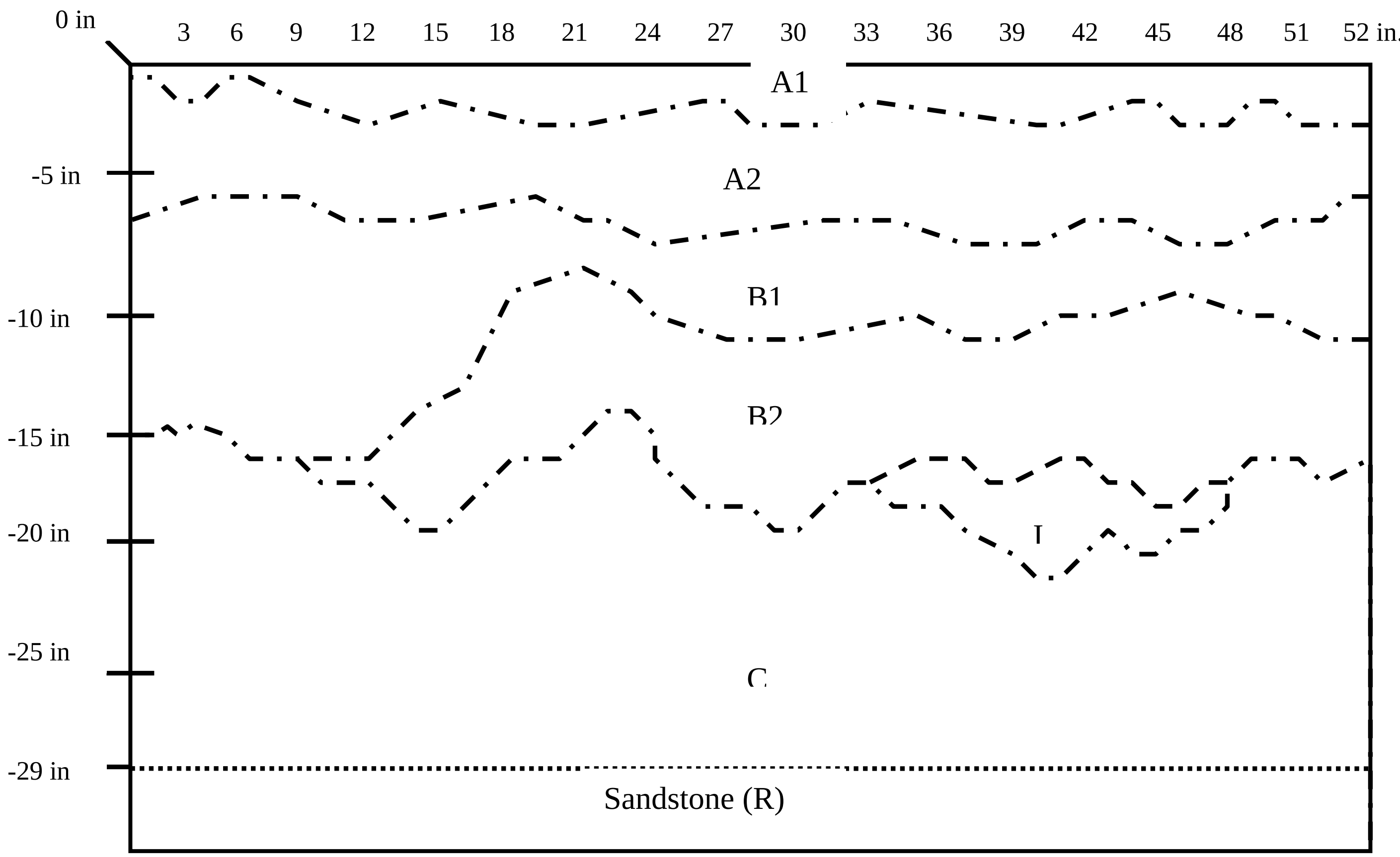

Figure 1. Control Pit Stratigraphy: East Profile

These findings are concurrent with those soils sampled in moist conditions.

Horizon boundaries were defined based on color, structure, texture, consistency, and pore type. Figure 1 and Table 1 provide visuals and descriptions as to what each level was. Horizon A1/A2 had a smooth boundary with large, irregular pores from intense biogenic factors such as worms and ants. The material was a loamy sand that was a friable, granular humus. Horizon A2/B1 had an abrupt smooth boundary that was likewise filled with large, irregular pores, which is also due to various biogenic factors. It was here however that the soil characteristics altered. The soil became lighter in color, as well as turning into a sandy loam with a granular and subangular, blocky structure. Soil consistency, however, stayed friable. Level B1 reflected A2's boundary, as well as its consistency and texture. The soil in this horizon did change to a darker color as well as convert back to a granular structure. Pore type likewise changed to fine irregular spaces, which could be attributed to the lack of worm activity within the layer. Horizon B2 was somewhat harder to differentiate from B1. Here, a subangular, blocky structure was once again assumed within the sandy loam and the consistency changed from being friable to very friable. The B1/B2 boundary type did not reflect previous horizon boundaries though. It is at this level that an abrupt wavy boundary was discerned.

Within the excavated pedon a unique feature was found. The inclusion found between horizon B2 and C consisted of a very fine, granular, charcoal mixed with a sandy loam. Extending 15 inches in length, as well as possessing an abrupt broken boundary, the inclusion was very friable and contained fine irregular pores. Horizon C was the easiest to identify and could have been based on its structure alone, which was an extremely fine grain, fine loamy sand. Like the levels above, it represented very friable material with fine irregular pores and an abrupt wavy boundary. Solid sandstone parent material was unearthed around 29 inches below surface and possessed a smooth surface.

Based on the *Soil Survey of Whatcom County Area, Washington,* the Woodstock Farm soil is part of the Nati loam series. The Nati loam series receives average annual precipitation of 35 to 50 inches, and a mean annual air temperature of about 47 degrees Fahrenheit. This soil consists of coarse-loamy, mixed, mesic Typic Haplorthods (USDA 1992). Control pit horizons were defined based on the amount of organics present, and changes in color, texture, structure, and consistency.

Based on the characteristics found in Woodstock Farms Control pit as compared to those of the Nati loam of the Soil Survey, there is little discrepancy found between the two. The only deviation was a slight presence of mottling scattered throughout the B1 and B2 horizons; as well as a charcoal inclusion found at 17-21 inches below surface. Few small pebbles were found, possibly due to the decaying sandstone parent material. It can therefore be said that the Control pit is relatively undisturbed by anthropogenic compaction, and will serve our needs as an adequate reference against a pedon with trail compaction.

Sheep Trail Pit Description

The Sheep Trail pit is located on the southern aspect of Woodstock Farm, cornered by the bay as well as surrounded by various housing units. The locale itself is found within the larger sheep enclosure on a steep slope of 21º, at GPS coordinates N48º41.835’ W122º29.888’, and an elevation of roughly 56 feet. This test pit is approximately 264 feet west, and downhill, from the Control pit. Primary site vegetation is thick grass, which stands one inch from the ground, possibly due to grazing activities.

Slope did vary within the larger enclosure, providing a few digging problems due to the fact that some aspects reached around 60º in slope. The pit was placed over a well-used sheep trail that was on a relatively flat patch of land. The trail itself consisted of a parting of longer grasses with very little surface exposure. Small mounds were common on the landscape, however, these were avoided as much as possible due to fear of its being anthropogenically influenced.

It should be noted that the lower valley, which our group tested above, used to be a tennis court. Thus the smaller sheep enclosure would have shown signs of heavy equipment compaction and fill materials. By placing our trail pit higher in the pen, we hoped to reduce the risk of hitting fill materials. The group also noticed that the sheep pen site was more sheltered from the breezes coming from the bay, as compared to the uphill Control pit site where the wind was cutting straight through the trees from the cliff.

Excavation for the Sheep Trail pit took place in the afternoon hours of 5/11/07. Two shovels were used to dig a 4 x 3 foot pit that extended roughly 20 inches down. Due to the excellent weather during the day, stratigraphy was taken from the northern wall.

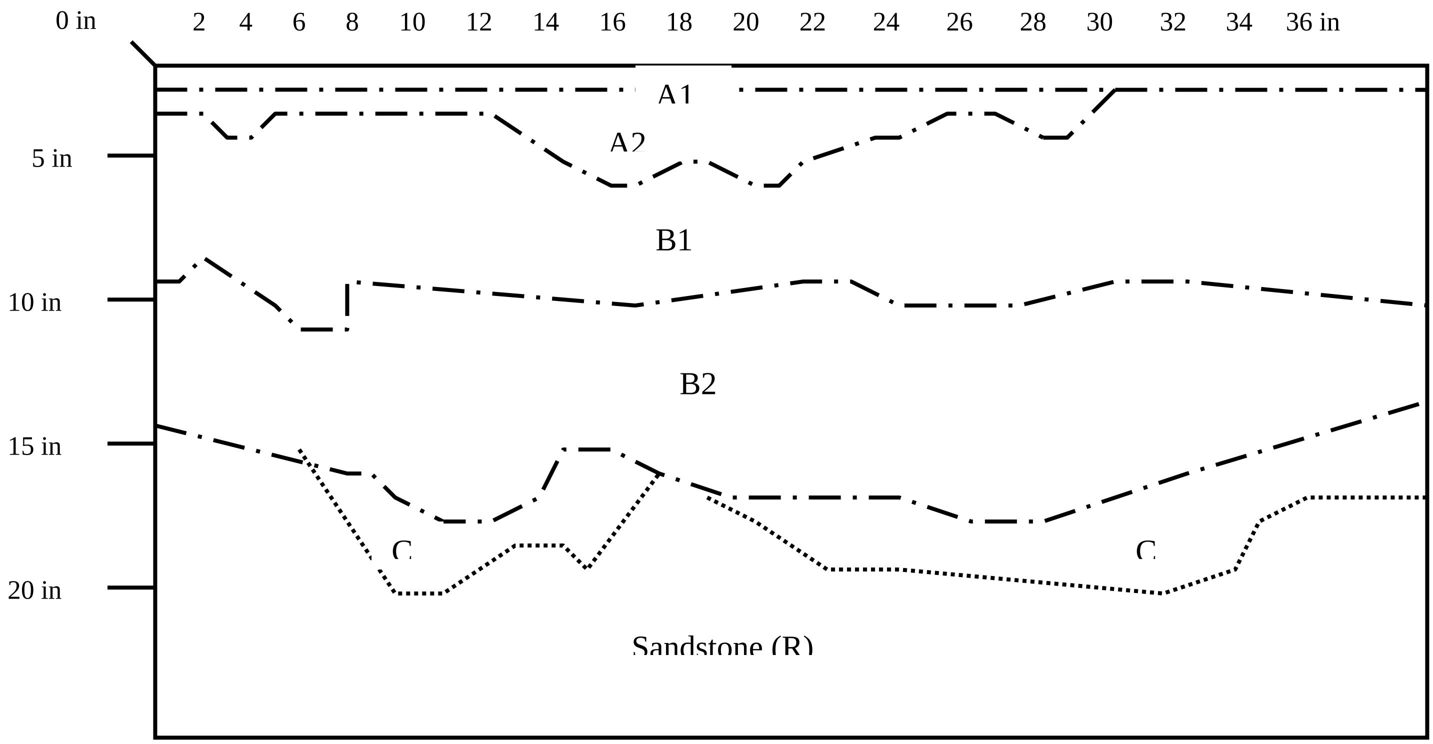

Figure 2. Sheep Trail Pit Stratigraphy: North Profile

These samples are concurrent with those soils sampled in moist conditions.

Pit horizons were determined by root presence, pore type, color, texture, structure, and consistency. Non-uniform banding of the sandstone parent material, at 20 inches of depth, could be an explanation as to why the boundaries between the C, B2, and B1 horizons are the way they are. A full report on the pedon characteristics will be presented in Table 3.

Horizon A1 was a granular, sandy loam level that was friable with a smooth boundary between it and level A2, and contained large irregular pore spaces. The larger pore spaces were contributed to the biogenic factor of worms, ants, and spiders. Level A2, as with the Control Pit, switched texture to a loamy sand, that was granular and slightly blocky in structure. The material itself is friable with fine, irregular pores and a wavy/broken boundary between horizon B1, showing no uniformity to the A1 boundary.

Interesting findings that we ran across in our excavation of the pit was the presence of several brick fragments. These findings were of a small origin and rare within the A2 horizon. These bits of brick were also mixed in with small inclusions of charcoal.

The B1 horizon shared the same characteristics as the A2 level, except for in the case of structure, where the material was angular and blocky in nature. At this level, consistency also seemed to be more plastic than upper horizons. B1/B2’s horizon was also fairly linear in orientation, again differing from the previous level with its wavy boundary.

B2/C horizon changes, yet again, with differences coming from its blocky structure and moderate consistency. As before, the wavy/broken boundary does not mimic the previous one, but could possibly be due to compaction and the proximity to the sandstone parent material. The C horizon reverted to being granular once it was pulled from the profile and showed to be very friable. No pore type could be determined however, and the boundary was irregular and broken due to the decaying sandstone parent material rising up at different levels. Unlike the Control Pit, the parent material from the sheep trail is approximately 20 inches below surface, and consists of solid sandstone that is in the process of decaying into the C horizon. The lack of depth exhibited by the Sheep Trail test pit could be another possible indicator of soil compaction.

Literature Synthesis

All of the articles reviewed discuss the importance of hydraulic compacity when it comes to influencing the rate of compaction. Climate coupled with animal treading creates soils that have increased bulk density at deeper horizons, reduced porosity, infiltration rates, and continuity. Three of the four articles also mentioned that topsoil were not as prone to solid compaction as the lower levels were. The topsoil, usually 0-5 centimeters below surface, contained more macropores. These macropores have more air/water permeability than the lower horizons. Emphasis is also placed, by half of the articles, on the idea that ungrazed to lightly grazed soils will be far less affected than soils that are more than moderately grazed throughout the year. The conclusion for all four articles was that the type of climate at each site plays a vital role in the rate at which compaction takes place. Wet soils were found to be more compactible in three of the four articles (one article not mentioning soil moisture).

Discussion

At the conclusion of the excavation, the Control and Sheep Trail pit's many differences in soil characteristics emerged. One major factor was that the overall depth to sandstone parent material was greater in the Control pit by approximately nine inches.

Individual horizon depths also varied greatly. Thicker layers being found in the Control pit while thin layers were associated with the Sheep Trail pit. Horizon boundaries likewise exhibited different characteristics. As seen in Figure 1, the Control pit has smooth topsoil boundaries that become progressively wavy the deeper horizonation extends. One steeply dipping aspect of the B1 horizon varies in form from the A2 horizon, possibly signaling the occurrence of some impact in lithology or anthropogenic effect. The smooth introduction of the sandstone parent material also coincides with the relative linear continuity of horizons from undisturbed locations (Drewry and Paton 2000).

In looking at Table 2, one gets a vague sense of where the sheep trail ran through the pit, which is around the 20-inch mark. Aside from the relatively wavy topsoil boundaries, the lower horizons are smoother around the 20-inch area with the exception of the boundary between C and R horizons, which can be explained by the non-weathered, intruding parent material. As seen on Table 2, the top of the C horizon bends slightly upward towards the east and west walls, while the top of the B2 horizon stays straight for the most part. The answers to these results can be found in the soil's other characteristics of structure, texture, consistency, pore type, boundary, and water conductivity.

The pore types for both sites were large for both A1 horizons due to biogenic factors and repeated erosional processes. However, the Control pit porosity remained large until it hit the B1 horizon and turned into fine, irregular pores. The Sheep Trail porosity switched from large to fine, vesicular pores once out of the A1 horizon. This continued to the C horizon, where pore type could not be determined and was considered to be non-existing. This finding is backed-up by J.J. Drewry's statement that topsoils have more macroporosity than deeper soils (Drewry, et. al. 2000). It was also shown in another study that treading loosens topsoil, thereby changing the landscape's susceptibility to water and wind erosion (Trimble, et. al. 1995). This would explain the reason for the linearity of the Sheep Trail pit's lower horizon boundaries. The topsoil would have greater erosion and deposition rates, while the lower levels would be constantly compacted. Thirty penetrometer readings, taken by Alisha Martin, from each site confirm this notion. The purpose of the penetrometer is to determine the amount of compaction in the solid due to animal and human interactions. The Control pit had an average reading of 3.25 tons/ft2, while the Sheep Trail pit average was 2.39 tons/ft2 (Martin 2007). Varying results show that compaction rates differ from one another at both sites significantly. It should also be kept in mind that the reason the differences are not significant could be due to the small number of sheep kept within the larger pen. The total number of sheep noted was four, not a high number when it comes to finding significant differences in compaction. Howbeit, it is acknowledged that sheep and other herd animals reuse the same trails (Trimble, et. al. 1995).

Water conductivity was measured by a double-ring infiltrometer. In this study the operator, Jennifer Lile, recorded how much water went into the soil at a chosen interval. The rate at which water infiltrated the soil was then related as the pedon's hydraulic conductivity. At the Control pit it took ten minutes for 103mm of water to empty from the double rings of the infiltrometer into the soil. Compared to the Sheep Trail pit, results showed that two intervals of 15 minutes were needed to make a decent recording. The first interval showed a hydraulic conductivity rate of 9mm per 15 minutes. The second interval (which was simply an addition of 15 minutes to the infiltrometer timer) showed a hydraulic conductivity rate of 18mm per 15 minutes (Lile 2007). It is clear that the Control pit has several features that are lacking in the Sheep Trail pit due to the nature of having either a fully drained infiltrometer or a half-empied infiltrometer. Research has shown that even “moderate” and “light” grazing can reduce infiltration compacity to roughly 3/4 of ungrazed locales (Trimble, et. al. 1995). Drewry also notes in his article of cattle treading that slower hydraulic conductivity is observed in livestock trampled areas (Drewry and Paton 2000). It can therefore be stated that there is indeed some factors playing a role in the differentiation of stratigraphy between our Control and Sheep Trail pits. These factors can include the soil’s structure, texture, porosity, consistency, or a combination of all the factors.

A soil’s structure, consistency, and texture are essential when it comes to perceiving the differences between compacted horizons. Based on Tables 1 and 2 of the pit characteristics, researchers can see that the sand and loam texture will create a material that will have fine pore space between particles, as well as possess the likelihood of compacting together when wet or compressed. This of course depends on the material present in the texture. In the Control pit, the findings show that deeper horizons are primarily composed of a sandy loam. Sandy loam is comprised of >70% sand and is considered to be well drained (Schaetzl, et.al. 2006). Reviewing results of the infiltrometer test, this is proven correct. In the matter of the Sheep Trail pit, lower horizons are comprised mainly of loamy sand. Loamy sand, in addition to course sand particles also have <15% clay particles in them (Schaetzl, et.al. 2006). These clay particles are held together in electrostatic bonding and will adhere to the sand particles, creating slightly less permeable horizons when compacted or wetted. Soils that contain clay are also more susceptible to changes (McNabb, et.al. 2001).

Another factor when it comes to compaction rates is structure. The structure that the soil takes will affect the permeability of the material. When looking at the structure type for the Control pit and Sheep Trail pit, we find that the soil with the largest pore space is found in the upper horizons, while cemented, blocky, materials are found within the middle and bottom of the pedon. In the case of both test pits, results showed that the C horizon was comprised of a fine grained, granular, substance. This is generally decomposing sandstone parent material that is not bonded together very strongly. It was interesting to note, that in the Sheep Test pit, the deeper the pit was dug, the drier the soil seemed. This helps to indicate either an extremely well drained soil, or a soil that is so compacted within the trail area that water is not penetrating the deeper levels. Thus allowing it to be loose in structure. Thereby exhibiting a more compact boundary type.

Consistency is the last factor to be taken into account in this report. Different results were found for both sites, which can be helpful in explaining the differentiation between horizon continuity. Soil consistency in the Control pit shows loose material in the upper three horizons, while very loose soil makes-up the lower three horizons. This could be explained by the high permeability and porosity exhibited by the area. The Sheep Trail pit shows loose material residing in the topsoil, but hardening in the middle of the pedon, only to become very loose before transforming into sandstone parent material. This illustrates that the deeper horizons of B1 and B2 are more compacted than those of the Control pit. Indicating that horizonation will be affected by sheep treading activity.

Due to the soil properties present at this site, as well as the shallow depth of the parent material, both of these sites exhibit strong features resembling that of a wetland. However, another reason for this classification is the catena of the hill and the location of where the soil pits were dug on that hill. This will be addressed in the erosional factors of the Woodstock Farm report. Based on the literature consulted for this research, it was found that the results were similar, but on a smaller scale on Woodstock Farm's side. However, characteristics related by the four article authors, as well as the other references, were indeed exhibited within both excavated soil pits.

Conclusion

The results of the two soil excavations conducted at Woodstock Farm show that the lack of differentiation between topsoil horizons is not likely unless many animals are moving though the same area at a constant rate. This was not the case at the test sites due to there being only four sheep. The hypothesis of the soil profile therefore possessing non-existing stratigraphy until the lower sub-soils are unearthed is inconclusive as a consequence of large-scale factors not being present. However, small-scale factors did allow us to see differences in compaction between the Control pit and the Sheep Trail pit. The soil's structure, texture, consistency, pore space, and infiltration rates provided a rough diagram of the horizon boundaries; which showed loose characteristics and wavy boundaries in the Control pit, while exhibiting soils with dense compaction and linear, downward bending, boundaries in the Sheep Trail pit. This is consistent with the data presented by the literature sources and the results of this study shown in the three Tables showing that deeper horizons would be more affected than upper horizons in terms of compaction processes. As a result, individual stratigraphy is still seen in both excavation pits at Woodstock Farm, however, its the B and C horizon of the Sheep Trail pit that showed intense compaction in association with sparse anthropogenic impacts.

Acknowledgements

My thanks goes to Tim Wahl and Bellingham Parks and Recreation for allowing us to dig at Woodstock Farm at the peril of the sheep and sharing valuable site information; as well as Professor Andy Bach for allowing us the use of assorted field gear needed to complete this study.

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Control Pit Characteristics

Horizon	Depth	Color	Structure	Texture	Consistency	Pore Type	Boundary
O	4-0 inches	N/A	N/A	N/A	Grass	N/A	N/A
A1	0-3 inches	10YR 3/2	Granular Humus	Loamy Sand	Friable	Large Tubular	Smooth
A2	3-8 inches	5Y 2.5/3	Granular/ Subangular blocky	Sandy Loam	Friable	Large Irregular	Abrupt Smooth
B1	8-15.5 inches	7.5YR 2.5/3	Granular	Sandy Loam	Friable	Fine Irregular	Abrupt Smooth
B2	10-18 inches	7.5YR 3/4	Subangular blocky	Sandy Loam	Very Friable	Fine Irregular	Abrupt Wavy
I (Inclusion)	17-21 inches	10YR 5/4	Very Fine Granular	Sandy Loam/ Charcoal	Very Friable	Fine Irregular	Abrupt Broken
C	17-29 inches	5YR 4/4	Fine Grained	Loamy Sand/Fine	Very Friable	Fine Irregular	Abrupt Wavy
R	29 inches	N/A	Blocky Sandstone	Sandstone	Solid	N/A	N/A

Table 1. Control Pit Profile

Nati loam Soil Survey Characteristics

Horizon	Depth	Color	Structure	Texture	Consistency	Pore Type	Boundary
O	3.5-3 inches	N/A	N/A	N/A	N/A	N/A	N/A
O1	3-0 inches	N/A	N/A	N/A	N/A	N/A	N/A
A	0-8 inches	10YR 3/3	Subangular Blocky	Loam	Friable	Fine Irregular	Abrupt Smooth
Bs	8-16 inches	10YR 4/4	Medium Subangular Blocky	Loam	Very Friable	Fine Irregular	Abrupt Smooth
BC	16-31 inches	10YR 6/6	Fine	Sandy Loam	Very Friable	Fine Irregular	Abrupt Wavy
2Cr	31 inches	N/A	Blocky Sandstone	Sandstone	Solid	N/A	N/A

Table 2. Nati loam: Soil Survey of Whatcom County Area, Washington

Sheep Trail Test Pit Characteristics

Horizon	Depth	Color	Structure	Texture	Consistency	Pore Type	Boundary
O	1-0 inches	N/A	N/A	N/A	N/A	N/A	N/A
A1	0-1 inches	7.5YR 3/2	Granular/Humus	Sandy Loam	Friable	Large Irregular	Smooth
A2	1-6 inches	7.5YR 3/2	Granular/Slightly Blocky	Loamy Sand	Friable	Fine Irregular	Wavy/Broken
B1	6-12 inches	10YR 2/2	Angular/Blocky	Loamy Sand	Fairly Friable	Fine Irregular	Wavy
B2	12-17 inches	10YR 4/4	Blocky	Loamy Sand	Moderate	Fine Irregular	Wavy/Broken
C	17-20 inches	2.5YR 3/3	Fine Granular	Loamy Sand	Very Friable	None Determined	Irregular/Broken
R	20 inches	N/A	Blocky/Decaying Sandstone	Sandstone	Solid	N/A	N/A

Table 3. Sheep Trail Test Pit