

THE SHAPE OF STORRS: A TECHNICAL ADDENDUM

This online addendum was written to provide additional detail for the article "The Shape of Storrs" (*UCONN MAGAZINE*, Fall 2019, edited by Lisa Stieplock). This addendum has not been reviewed or vetted by other experts.

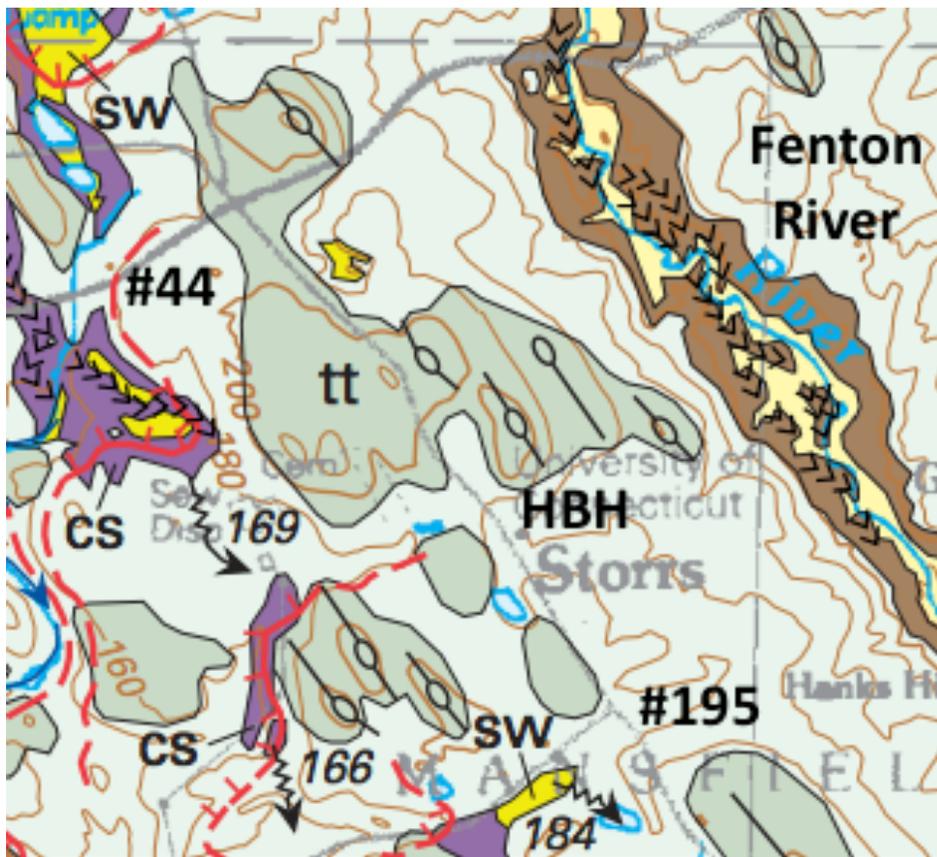
Three Illustrations



Hillside shaded image of Digital Elevation Model (DEM) of Horsebarn Hill reconstructed from Light Ranging and Detection (LiDAR) data. CT Eco Elevation Viewer. See caption on next page.

<https://cteco.uconn.edu/viewers/ctelelevation/>

Horsebarn Hill at center is one of four heavily eroded, glacially streamlined remnants of an earlier, thicker and more gently undulating sheet of compact lodgment till that was deposited between about 130,000 and 150,000 years ago (Marine Isotope Stage 6). The isolation of that patch and shaping of the hills roughly 20,000 years old was caused by glacial erosion of that much older material. The ice flow direction in both cases was from northwest to southeast, creating a "glacial grain" to the landscape that is also present over UConn's historic campus to the southwest. Note the potent asymmetry of the hills in which their steep sides faces southeast, a direction opposite that of most drumlins, which, under ideal conditions, should be broader, higher, and steeper to the northwest.



Detail from the Quaternary Geologic Map of Connecticut, by Stone et al., 2005

http://cteco.uconn.edu/maps/state/Quaternary_Geologic_Map_of_Connecticut_and_Long_Island_Sound_Basin.pdf

Horsebarn Hill (labeled HBH) is one of four streamlined hills (ellipse-line symbol) east of Highway #195 located on a patch of lodgment till mapped in dark green as "tt" (Thick Till). A smaller but similar patch of three streamlined hills including Hilltop Apartments lies to the southwest. Between these elevated patches are lower, smaller streamlined patches of the same dark green unit (tt), on which the historic campus of UConn (northwest and southeast of unlabeled Mirror Lake) was built. Borehole drilling records (logs) associated with campus buildings indicate that these patches are remnants of a formerly more continuous cover of lodgment till.



Building known as "Old Main" and classroom buildings circa 1890-1900. University of Connecticut Photo Collection, Dodd Center, UConn Libraries.

UConn's first large building, the wood-framed "Old Main," sits at the crest of a gently rounded, streamlined ridge sloping downward in all directions. The view is generally southward, with the future Great Lawn" to the left. During the late 1920s, these buildings were removed and the ridge was flattened for Beach Hall (1929). The key observation is that this portion of the original historic campus was built on material (lodgment till) and topography (crest of a southeasterly-trending streamlined ridge) similar to that of Horsebarn Hill, though less prominently. This followed a pattern set in 1906 when Storrs Hall, the first permanent masonry building, was built on the glacial grain.

Geologic Narrative

Beginning the geologic story with the arrival of the Laurentide Ice Sheet, the smoothly streamlined shape of Horsebarn Hill (HBH) and its more subdued counterparts on UConn's historic campus resulted from a series of five very discrete events, each contingent on the previous event.

LODGMEN

The first event was the deposition of the material from which the bulk of our campus hills are composed, a material known to glacial geologists as *lodgment till*. This deposition took place near the end of an interval known as MIS-6, short for Marine Isotope Stage 6, which globally dates from about 130,000-191,000 years ago (abbreviated 130-191 ka, for kilo-anno). Though we don't have

exact dates for Storrs, we can assume that deposition took place near the end of this interval because only then was the expansion of the Laurentide Ice Sheet large enough to reach Connecticut, which lies near the southern limit of a long flow band originating east of Hudson Bay in subarctic Canada. Assuming a 20,000-year duration for local glaciation yields an approximate date of $\sim 140 \pm 10$ ka. This interval is roughly six times older than the much later subsequent glaciation that was responsible for shaping this material into its present erosional forms; the streamlined ridges of campus.

Lodgment till is a massive (meaning generally un-bedded) accumulation of glacially crushed residues that were *lodged* (a.k.a. pasted, smeared, pressed, etc.) to the glacial sole (the ice/bed contact) by actively moving ice. Lodgment till is a special type of subglacial traction till, all of which were created by traction (directed shear force per unit area) between a stationary land surface and the flowing, debris-laden ice above it. The material being lodged is a dense, viscous paste of crushed rock residues moving forward within a transitional layer between the overlying debris-laden ice and the underlying unconsolidated substrate. This moving layer is dilated (expanded in volume) relative to its subsequently deposited counterpart as a consequence of forward motion. When motion slows, or when the pore pressure (water pressure between the grains) diminishes, the volume decreases proportionately, increasing the shear strength due to particle interference. The decrease in pore pressure caused by water loss simultaneously forces a proportional rise in the ice overburden pressure. Essentially, the increased vertical load (weight) of the ice pressing down on a layer of rising strength inhibits that material from being sheared forward, causing particles to stick to the bed at various spatial scales from individual grains to thin sheets of grains.

This lodgment process is controlled by physical conditions at the bed, which are, in turn, caused by the thickness of ice, water pressure at its base, and the velocity of sliding. The overall setting was a wet, moving, stiff slurry or low permeability occasionally rinsed to sandy lenses by thin water films and shallow channels. Under the right conditions, lodgment becomes a continuous, steady-state process that allows substantial thicknesses (tens of meters) of lodgment till to accumulate. In Connecticut, typical hilltop thickness are 20-30 meters, ranging up to about 70 m. This material, mapped as "Thick Till" to differentiate it from the surrounding till, is thickest on the up-glacial (north-northwest) slopes of hills. As this till accreted, the original bedrock relief became buried, leaving a material weak enough to be molded but strong enough not to be washed or extruded away. The bulk of this material is massive (without bedding), dark gray in color (Munsell color 5Y 3.5-5/1) with slightly more silt (range of 40-65% in multiple samples) than sand (35-60%), and little clay sized particles (11-38%). Larger grains from pebbles to boulders make up only 11% or less by weight.

Within this thickness are abundant local variations dominated by clots of glacial stones, the alignment of pebbles (fabric), zones of plastic deformation (squeeze-ups) and localized sheets of sand from which the clay and silt were washed free by films and shallow channels of flowing water.

Near the end of deposition, conditions changed at the bed, likely due to an increase in water pressure during the melting phase. The overall mass-budget regime of the glacier bed shifted from a net gain by lodgment to a net loss by erosion of previously deposited material. The result was the initial shaping of HBH and others into partially streamlined forms and the erosion of material at lower elevations where the water flux was higher, allowing the ice to move faster and the resistant material to be weaker.

SOIL FORMATION AND WEATHERING

The second event was soil formation and weathering under a vegetated surface for approximately 100 ka. This interval began with the onset of local interglacial conditions ~130 ka at the end of MIS-6. It then took tens of thousands of years for the Laurentide Ice Sheet to grow back to sufficient size to reach Connecticut again. This interval ended with the onset of renewed glacial erosion commencing ~ 30 ka with the arrival of MIS-2 ice. Between these two glacial advances were two warmer intervals, the MIS-5 interglacial comparable in warmth to the colonial era, and the MIS-3 interstadial, which was somewhat colder, but still temperate.

Evidence for weathering during this interval is revealed by a 3-9-meter-thick weathered zone below the summits of lodgment till highlands. The initial gray to olive-gray till was stained olive-brown (5Y 4-5/2-3) by oxides. Authigenic (created in place) minerals (incipient clays and well-developed rusts of iron- and manganese-oxides) were created in place. Sub-horizontal and sub-vertical fractures (joints) caused by expansion and contraction were stained by groundwater infiltrating downward from soil above.

We know very little about what environmental conditions were like during the interval from 130-30 ka. Based on correlations elsewhere, however, it was clearly forested, with parts of this interval as warm as the Holocene interglacial epoch. A sample of a boggy paleo-forest obtained beneath the younger till below UConn's Babbidge Library yielded a radiocarbon date of greater than 39 ka, proving that UCONN was forested between the glaciations. During this interval, the land was devoid of humans, whose presence in North America is not documented until about 15 ka. Though humans were not present, the familiar ice-age fauna (North American Rancholabrean Land Mammal Age) was likely present because their distribution elsewhere at the time was widespread. This may have included the charismatic steppe bison, mammoth, mastodon, saber-tooths, dire wolves, short-faced bears, giant beavers, and others.

GLACIAL EROSION

The third event in our series was the shaping of the hills we see today. Based on correlations elsewhere, this took place during a 10 ka-long interval between about 30-20 ka. We know that ice was present at its terminal moraine about 26 ka, and had pulled back from Storrs by about 18 ka (Ridge et al., 2012).

Several key observations about this weathering zone are important here. First, the base of this zone is not horizontal, but descends in elevation away from hill crests, though more gradually than the surface topography, and is commonly truncated midway down the till hills. Second, where present, the top of this zone is often missing due to erosion. Third, erosion under potentially frozen and less fluidized conditions is revealed by the "mixed zone," mapped by geologists at the contact between older (MIS-6) and younger (MIS-2) tills. Blocks and fragments of the older till were entrained, moved, deformed, and smeared out by ice motion, and are retained within the thin cover of recent till at the surface.

These observations indicate that the final shaping of hills we see today was due to streamlining erosion of a previously more undulating and weathered landscape, with the upper parts of the hills

being more resistant than their flanks. A thin cover of younger till is sometimes present near the hilltops, but is much more common at lower elevations.

This erosion was intense enough to remove virtually all of the older MIS-6 lodgment till within the valleys leaving that older material generally restricted to upland plateaus and isolated hills. This is certainly the case for HBH and UConn campus. There, the younger till has different characteristics, being sandier, stonier, and more complex than the older till, generally indicating the presence of higher relief and more abundant water, and a dominance of erosion. The preservation of deep weathering profiles dating to MIS-5 (a full interglacial) through MIS-3 (a prominent interstadial), near the tops of hills indicates that little erosion took place at the top of Horsebarn Hill during the last ice advance. This may suggest that it was frozen, or too dry, or the ice flowing too slowly to accomplish much shaping. Instead, the bulk of ice flow went through the adjacent valleys, where evidence of the older till has been completely removed.

Horsebarn Hill is often classified as a drumlin. This works for most people, who prefer a general definition of the term. It doesn't work for me because I consider the concept of a drumlin as a subglacial bedform analogous to the flume casts of turbidity flows or the ripple marks where fluid currents of water or wind move sediment. This bedform concept is certainly the case for vast drumlin fields, which number in the hundreds to thousands, and in which the typical streamlined form is highest and broadest on the up-glacial side. HBH presents in the opposite direction, being broadest and highest on its down-glacier end, where a bedrock is shallowest. Additionally, HBH and its neighbors crest the tops of bedrock ridges, rather than occupy the broad lowlands where either ice streams or bands of drumlin fields occur. Thus, HBH is an eroded streamlined residual analogous to the yardangs of the desert shaped by wind erosion. It doesn't bother me when people call it a drumlin. I just prefer not to.

During recession, the surface profile of the ice sheet developed a very low gradient owing to such rapid melt rates relative to re-supply from the north. The consequence of this is that deglaciation was mainly a downward process at the scale of HBH, which emerged as an island surrounded by stagnant ice. During this final stage, a complex, but thin mixture of sandy supraglacial melt-out till mantled the landscape, the most prominent component of which are large, uncrushed boulders.

INTERGLACIAL CONDITIONS:

The interval between the final stages of glaciation about 18-19 ka and the abrupt warming leading to woodland vegetation about 14-15 ka was a critical period referred to as the "paraglacial" interval, for "almost-glacial." Full exposure to heavy rains and snowmelts on a largely unvegetated (tundra at most) surface, deep frosts, and strong winds flowing down the still massive ice sheet to the north, allowed surface stone to concentrate on hillsides while sediments washed down into the lowlands. As vegetation reclaimed the surface, dust was captured by pioneering plants. Beneath the woven mat of the roots of surface vegetation, a finer grained upper soil was then fractionated from below.

Following this paraglacial interval, forest returned and indigenous peoples arrived for the first time. Though prehistoric archaeological sites are common along the New England shore, in river valleys and in wetland settings, the human touch on inland, upland landscapes was very light, generally indicated by only scatterings of stone debitage, and the occasional arrangement of surface stones.

Owing to its continuous vegetation cover, HBH and its counterparts on campus were only slightly gullied, thanks to the excellent fertility and drainage conditions of lodgment till soils.

ANTHROPOCENE PRESERVATION

The arrival of Samuel Storrs in 1698 marks the onset of Euro-colonial farming that intensified to a peak development in the middle of the 19th century. By that time, approximately 70 percent of the local landscape had been cleared of its forest and replaced with pasture, tillage, woodlot, and meadow. Lodgment till soils were ideal for growing grass for pasture and hay, and for cultivating cereal crops. Conversely, they were not suitable for quarries or other excavations, meaning they were left in place until the advent of petroleum-powered heavy equipment in the late 19th and first half of the 20th century, when the historic campus was laid out.

Horsebarn hill was left preserved because it was too high and too removed from the main historic campus. The lower till-covered streamlined ridges of campus, however, were perfect building sites, so their crests were flattened for foundations, sidewalks, and lawns.

Beneath and between these flattenings, the original glacial "grain" of the landscape is still preserved. This is best shown at Storrs Hall. The foundation for this oldest (1906) remaining (masonry/brick) building was laid on the crest of a glacial ridge aligned by flowing ice. This building set the precedent for aligning other buildings in the same direction, or in a perpendicular direction.

Thus, the article title "The Shape of Storrs" refers both to the glacial shaping of the streamlined hills of the pre-colonial landscape and to the human shaping of the campus layout, which was superimposed on the earlier glacial shape. Left out of the article completely are the earlier antecedents of the regional slope, which guided the ice sheet, and the tectonic creation of the Atlantic continental shelf, toward which it was inclined.

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