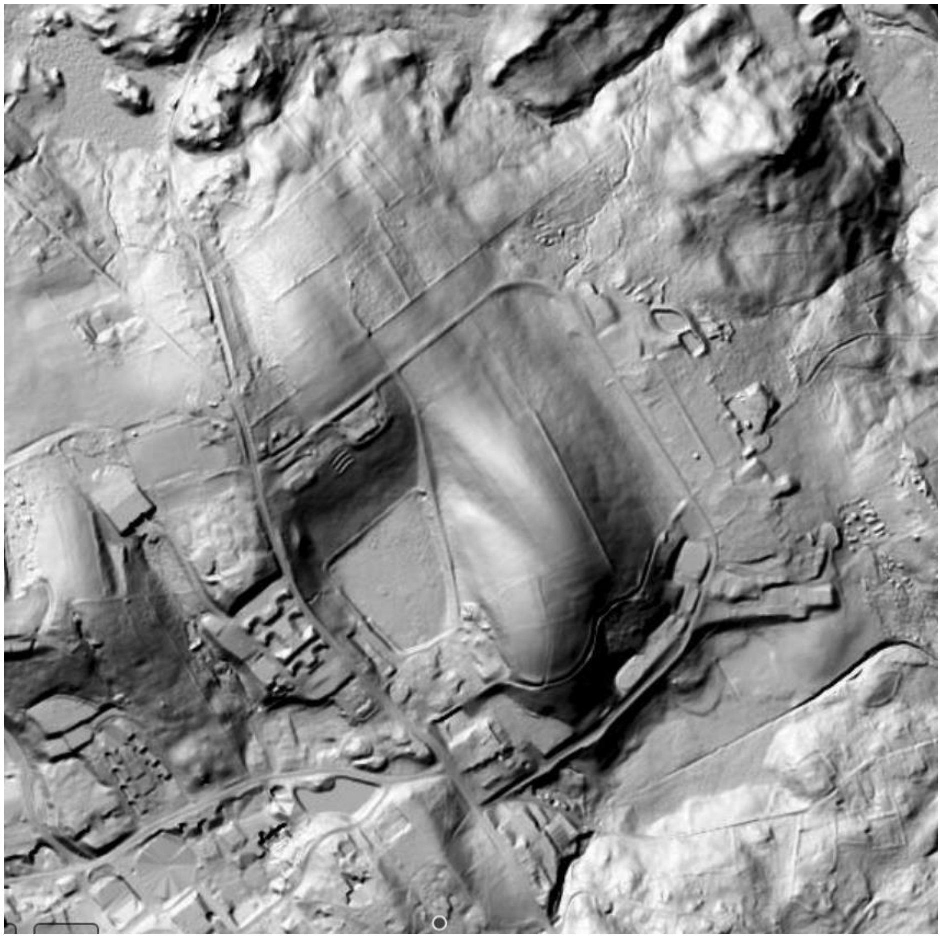
THE SHAPE OF STORRS: A TECHNICAL ADDENDUM

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

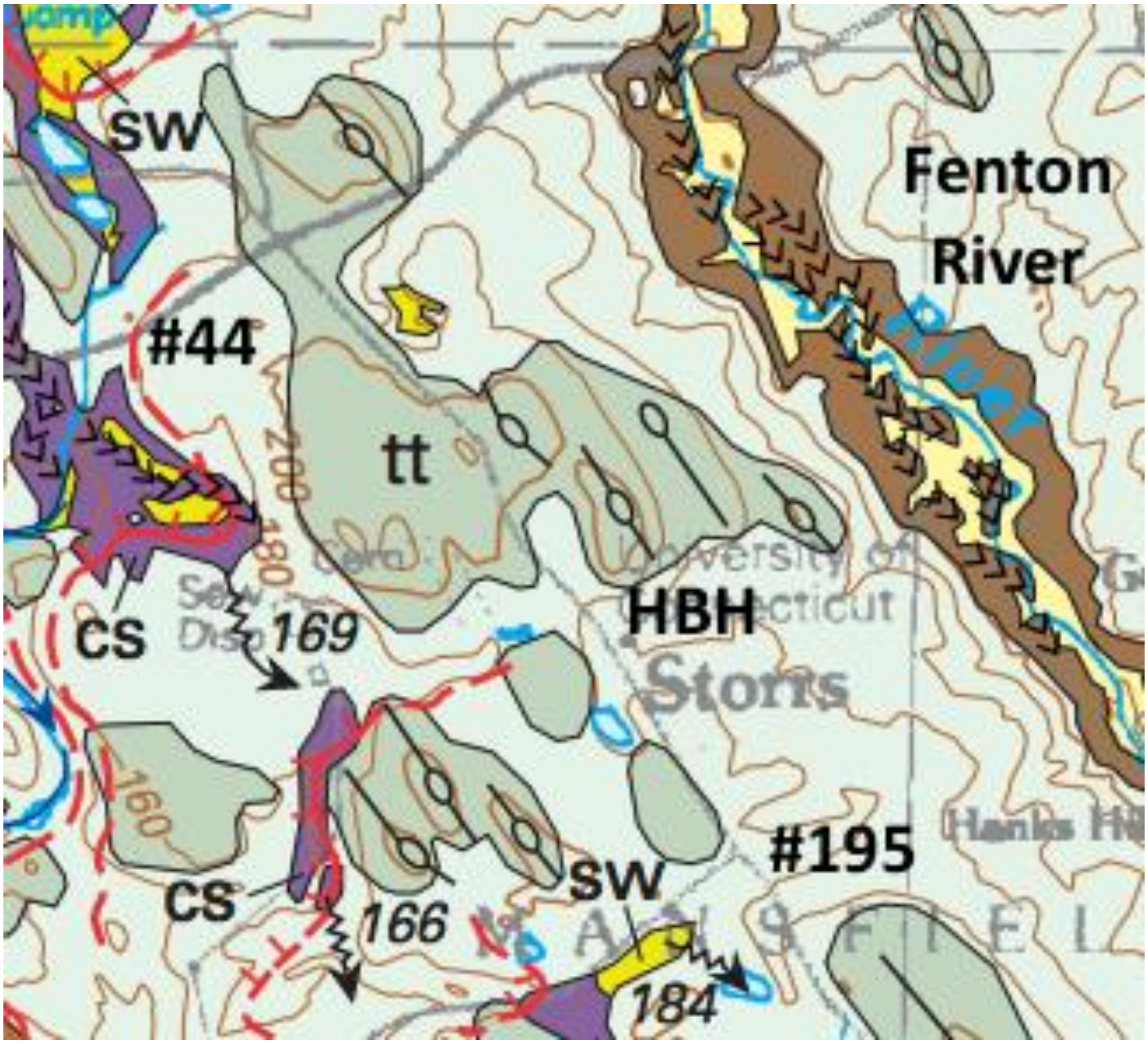
Three Illustrations



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

https://cteco.uconn.edu/viewers/ctelevation/

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 was caused by glacial erosion of that much older material roughly 20,000 years old. The ice flow direction was from northwest to southeast. Note the potent asymmetry of the hills in which their steep sides faces southeast, a direction opposite that of drumlins, which, under ideal conditions, should be broader and higher 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 material 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 patches, the slightly lower, historic campus of UConn located northwest and southeast of Mirror Lake (unlabeled) occurs on smaller streamlined patches of the same dark green unit (tt). These patches are mapped remnants of a once-larger and more continuous patch, as revealed by borehole drilling records (logs) associated with campus buildings.

Building known as "Old Main" and classroom buildings near the close of the 19th century. 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 down in all directions. View to the south with the future Great Lawn" to the left. In the late 1920s, these buildings were removed and the ridge was flattened for the foundation of Beach Hall (1929) and the western portion of the Great Lawn. The key observation is that the original historic campus was built on material (lodgment till) and topography (streamlined ridges) similar to that of Horsebarn Hill, though less prominently.

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.

LODGMENT

The first event was the deposition of the material from which the bulk of the 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, which is short for Marine Isotope Stage 6, which dates elsewhere from about 130,000-191,000 years ago (abbreviated 130-191 ka, for kilo-anno). Though we don't have exact dates, we can assume that deposition took place near the end of this event because only then was the expansion of ice large enough to reach Connecticut at the southern limit of its long flow band originating east of Hudson Bay in subarctic Canada. Assuming a 20,000-year duration for glaciation of southern New England yields a general date of ~ 140 +/- 10 ka. This interval is roughly six times older than the much later final glaciation responsible for shaping HBH into its present form.

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, created by the traction (shear force per unit area) between a stationary surface and flowing, debris-laden ice (Benn and Evans, 2013). The lodgment (sticking) process is usually due to due to an increase in material strength of a dense, viscous dilated paste of crushed rock residues moving forward as a distinct layer between the overlying ice and underlying substrate. A dilated solid is one that is expanded in volume relative to its stationary counterpart as a consequence of forward motion. This occurs only in settings when the pore pressure is high enough to prevent collapse into a stable sediment. The increase in strength leading to deposition is usually due to a decrease in pore pressure caused by water loss, which forces the overburden pressure of the ice to rise proportionately. Essentially, the vertical load of the ice pressing down on the glacial sole inhibits that material from being able to shear forward, causing particles to stick to the bed at various spatial scales from individual grains to sheets of grains. Simply put, its deposition caused by rising frictional resistance.

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. Under the right conditions, lodgment is a continuous, steady-state process, allowing substantial thicknesses (tens of meters) of lodgment ill to accumulate. In Connecticut, typical hilltop thickness are 20-30 meters, ranging up to about 70 m (Melvin et al., 1992; Stone et al., 2003). This material, mapped as "Thick Till" (an unfortunate label), is thickest on the up-glacial (north-northwest) slopes of hills. As this till accreted, the original bedrock relief became subdued as it was buried. 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 have been washed free by flowing water. The overall setting was a wet, moving, stiff slurry or low permeability occasionally rinsed to sandy lenses by thin water films and shallow channels.

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 accretion of sediment to erosion of previously deposited material. The result was the initial shaping of HBH and others into partially streamlined forms as material from lower zones with a higher water flux was more eroded than higher zones with less water.

SOIL FORMATION AND WEATHERING

The second event was soil formation and weathering under a vegetated surface for approximately 100 ka between the onset of local interglacial conditions ~130 ka at the end of MIS-6 and the onset of renewed glacial erosion commencing ~ 30 ka with the arrival of MIS-2 ice. This interval coincides with two non-glacial intervals, the MIS-5 interglacial and the MIS-3 interstadial. It took tens of thousands of years for the Laurentide Ice Sheet to grow back to sufficient size to reach Connecticut again. Evidence for weathering during this interval is revealed by a 3-9-meter-thick zone below the summits of lodgment till highlands that is stained olive-brown (5Y 4-5/2-3) by oxides within what had been a gray to olive-gray till. In this zone are authigenic (created in place) minerals (incipient clays and well-developed rusts of iron- and manganese-oxides) and the development of sub-horizontal and sub-vertical fractures (joints) caused by expansion/contraction of the till and stained by groundwater infiltrating downward from soil above.

Several key observations about this weathering zone are important. 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, the top of this zone, when present, is often missing due to erosion. The overlying, and much younger glacial till lies in sharp contact with it, and masses of the lower oxidized tills are present within the upper, unoxidized till, confirming erosion. These observations indicate that the final shaping of hills we see today took place after the weathering. That shaping 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.

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 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 wooded 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 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).

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.

Evidence for this erosion, and for the potentially frozen and dry 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.

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 "grok" the concept of drumlin as a subglacial bedform analogous to the flue casts of turbidity flows or the ripple marks where fluid currents of water or wind move sediment. This bedform idea 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. To my mind, 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 wouldn't call it that.

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 surface, deep frosts, and strong winds flowing down the lingering ice sheet to the north, concentrated surface stone on hillsides and rapid sedimentation in 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 being fractionated from below. Following this interval, forest returned and indigenous peoples arrived for the first time. Though prehistoric archaeological sites are common along the shore, in river valleys and in wetland settings, the human touch on upland landscapes was very light, generally indicated by only scatterings of stone debitage, and the occasional arrangement of surface stone. HBH and its counterparts on campus were only slightly gullied, owing to the continuous coverage of vegetation caused by 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, 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 were perfect building sites, so their crests were flattened for foundations, sidewalks, and lawns.

However, 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 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 building layout, which was superimposed on that earlier glacial grain. 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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