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SURFICIAL GEOLOGY OF THE MOUNT MANSFIELD 15 MINUTE QUADRANGLE, VERMONT

by

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INTRODUCTION

Geographic Setting

The Mount Mansfield quadrangle is located in northwestern Vermont, between 44°30' and 44°45' North latitude and between 72°45' and 73° West longitude. It is approximately 15 miles south of the Quebec border and includes parts of Chittenden, Lamoille, and Franklin Counties.

The quadrangle is divided into northern and southern mountainous regions by the Lamoille River Valley. The Lamoille River flows from east to west, just north of the center of the map. The major population centers; the villages of Jeffersonville in the east, Cambridge in the center and Fairfax Falls in the west; are situated in the Lamoille Valley. At the southern edge of the quadrangle the villages of Underhill Center, Underhill, and Jericho are situated in the Brown's River Valley. Mount Mansfield State Forest is located in the southeast portion of the quadrangle and is a major tourist attraction.

The economy of the region is based on tourism and on dairy farming that is concentrated on the floodplain of the Lamoille River and its southern tributaries.

The most prominant topographic feature in the quadrangle is the Mount Mansfield ridge. The maximum elevation is 4393 feet, on The Chin (a prominant peak on this ridge). The lowest point in the quadrangle, slightly less than 320 feet, is west of Fairfax Falls in the Lamoille River Valley. Although the total relief is a little more than 4000 feet, most of the quadrangle is dominated by peaks that crest between 1200 and 2000 feet.

The Lamoille Valley is the principal drainage feature in the region. The Lamoille River flows westward to Fairfax Falls with a rather gentle gradient of about three feet per mile. At Fairfax Falls the stream drops almost 80 feet to the Champlain Valley. The principal tributaries to the Lamoille River flow in north-south valleys. The Brown's River, draining the west flank of Mount Mansfield is a second east-west valley located at the southern edge of the quadrangle.

Geologic Setting

The bedrock geology of the quadrangle was reported by Christman (1959). In general, the map area is underlain by metasediments of probable Cambrian age. These rocks are metagraywackes, schists, phyllites, and greenstones. The metamorphic intensity increases from west to east. The average trend of mappable rock units is about N 20° E. In the vicinity of Sterling Pond, Chidester (1953) describes serpentinized ultra-mafic igneous rocks.

The major structural features are, from east to west, the Green Mountain anticlinorium, the Cambridge syncline, and the Fletcher anticline. These folds have an average trend of about N 15° E. The average trend of the bedding schistosity is N 10° E. Three joint directions are reported by Christman for Mount Mansfield, these are (1) N 30° E, (2) N-S and (3) N 80° E.

The surficial geology is dominated by a cover of glacial deposits of late Wisconsinan age. The entire quadrangle is covered by a blanket of glacial till of variable thickness. Only on Mount Mansfield, and on the east side of Fletcher Mountain are there extensive areas of bedrock outcrop. Some ice-contact deposits are concentrated in the northwest part of the quadrangle and scattered elsewhere. The lowland of the Lamoille and Brown's River Valleys, and the lower reaches of their tributaries, were filled with proglacial lakes during recession of the late Wisconsinan glacier. Lake clays, lake sands, and shoaling gravels are present in these low areas.

Geomorphic Setting

The erosion of the highlands and the filling of the valleys apparently served to lessen the relief of the pro-glacial topography. The topography is rugged at present but was probably even more so prior to glaciation.

The regional drainage pattern is broadly classified as rectangular (see figure 1) although many exceptions occur. The through valleys are oriented east-west while the tributaries are aligned north-south. The east-west valleys may reflect underlying bedrock structure related to the N 80° E joints recorded for Mount Mansfield. The north-south valleys

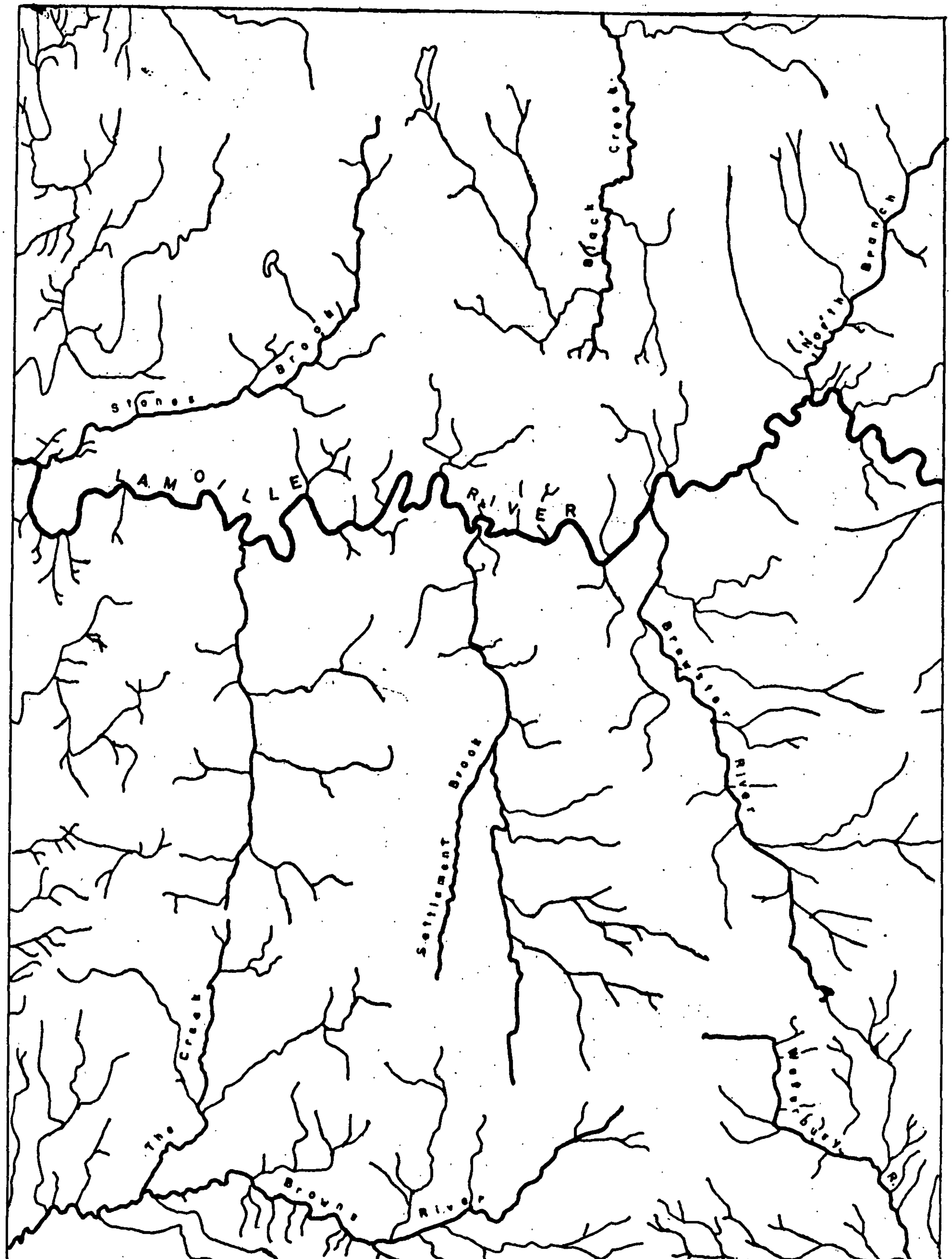

Figure 1. The drainage net of the Mount Mansfield 15' quadrangle, Vermont showing a midified rectangular pattern.

are probably subsequent features and parallel the dominant bedrock trends discussed above. Where north-south tributaries have cut recent channels in glacial sediments they tend to be dendritic.

The ancestral valleys of Black Creek and Wilkins Brook probably drained southward into the Lamoille Valley; however, they now flow northward and westward respectively, illustrating derangement and diversion by glacial or glacio-lacustrine deposits.

The Lamoille River is classified as a mature to late mature stream. It flows on a fairly broad floodplain that is alluvial in part (see page 28). The stream exhibits many meanders and oxbow lakes; however, Leopold, Wolman and Miller (1964, p. 281) would not classify it as meandering due to a sinuosity of only 1.33. The tributaries are in late youth or early maturity and are irregular to straight, having sinuosities close to 1.0.

Previous Work

Although Christman (1959) noted the more obvious glacial features, no detailed work had been done on the glacial geology in this quadrangle previous to this report. Christman recorded the directions of striae at over 200 localities and presented a map (his plate 3.) showing these results. He also mentioned some interesting exposures of till and delineated the lacustrine deposits below 600 feet in the Lamoille Valley grouping the latter at "Lake Lamoille deposits". Earlier writers such as Hitchcock (1906), Merwin (1908) and Chapman (1937 and 1942) have speculated on the origin and association of lake deposits in the Champlain Valley and its tributaries.

Steward (1961) and Steward and MacClintock (1964) summarize the status of knowledge of glacial geology in Vermont at the present time.

Present Work

Field work for this report was carried out during the summer of 1965. The writer, with the assistance of Mr. Franklyn Paris, mapped the surficial geology on the Underhill, Mount Mansfield, Gilson Mountain, and Jeffersonville $7\frac{1}{2}$' quadrangles. This information was then transferred to the 1948 edition of the Mount Mansfield 15' quadrangle that accompanies this report as Appendix 2.

The writer wishes to acknowledge the assistance and encouragement of Dr. Charles G. Doll, State Geologist, State of Vermont; Dr. David P. Stewart of Miami University, and Dr. Paul MacClintock of Princeton University.

GLACIAL EROSION

Although no pebble counts were made in the field, it is obvious even to the casual observer that the glacial drift is dominated by stones of local origin. Thus, an unknown thickness of pre-Pleistocene bedrock was evidently eroded and redeposited as glacial drift during the Pleistocene Epoch.

The topography of the region varies from rugged, in the southeast to knobby in the rest of the quadrangle. In the southwest the bedrock is effectively mantled by glacial till while north of the Lamoille River many bedrock knobs protrude from beneath the till blanket. The preglacial topography appears to have been streamlined by ice erosion, but the ancestral drainage pattern survived glaciation except for possible smoothing of valley walls and some derangement north of the Lamoille River.

On a smaller scale the bedrock has been smoothed, polished and striated. Christman (1959, his plate 3) has recorded striae from over 200 localities, many of which were observed by the writer. No search for additional observations was made however, two northerly sets of striae previously unreported, were observed in the northeastern portion of the quadrangle. These probably reflect flow along Taylor Brook, parallel to Fletcher Mountain, rather than an ice advance separate from that recorded by the other striae. Figure 2 is copied from Christman's Plate 3, with few additions by the writer.

The writer shares the opinion of Christman (1959) and Stewart (1961), among others, that the last ice invasion of northern Vermont came from the NNW. The striae reported by Christman suggest movement from about N 30° W with the exception of the Mount Mansfield and Fletcher Mountain ridges and the Lamoille Valley, where the ice was deflected slightly eastward.

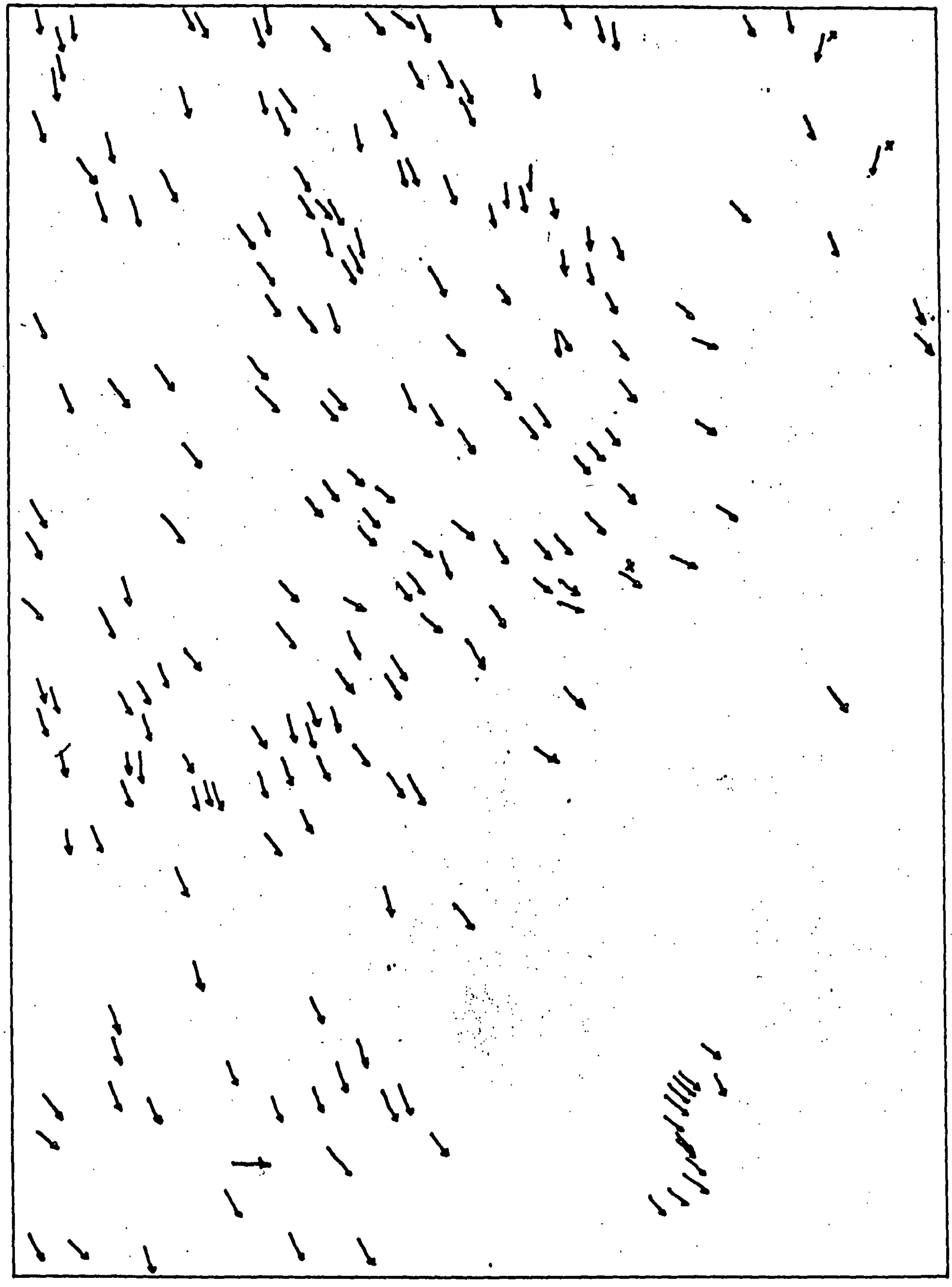

Figure 2. Striae recorded in the Mount Mansfield 15' quadrangle, Vermont after Christmann (1959) with three new localities indicated with an X.

Cirque Glaciation

Christman (1959, p. 69) suggested that "Nivation has modified the form of the (east-facing slope below the main ridge of Mount Mansfield)". With this statement in mind, an attempt was made to examine this slope during the 1965 field season. Only a single day could be spent on this problem so that the writer's observations are not considered conclusive.

The east slope drops vertically for 20 - 180 feet below the main ridge. The vertical slope is a joint-controlled rock wall with minor, joint controlled re-entrants. The floor below the rock wall slopes steeply eastward, is mantled by soil, and supports dense vegetation. No evidence of nivation was observed along the rock wall and the floor could not be examined.

Although local glaciation may have been active, the features observed can more easily be explained by the quarrying action of overriding, eastward moving, continental ice.

GLACIAL DEPOSITION

Ground Moraine

The ground moraine is a discontinuous mantle of glacial till (designated T on the accompanying map) that lies on the glacially eroded bedrock surface. This ground moraine is composed of all sizes from clay-size to boulders (eratics) tens of feet in length. No attempt was made to gather well data, thus, it is not possible to estimate the thickness of ground moraine at present.

There are three types of till that were grouped together during mapping. The first type is a basal (lodgement) till that is very firm, very pebbley, and slightly calcareous. The texture of the matrix is clay-loam and the color is medium-dark-gray (N4) according to the Munsell System (Rock Color Chart, distributed by the G.S.A.) as observed on the west flank of Mount Mansfield (locality 5 of Christman). At North Underhill, in the headwaters of a tributary to the Lamoille River, the till has a silt-loam matrix and is light-olive-gray (5Y 4/2). No other exposures of basal till were found.

A second type of till is a sandy-to-gravelly deposit exhibiting limited size-sorting. Steward (1961) adopted the name ablation till for this type of drift. Ablation till is variable in texture and color, however, it usually has a sandy-loam to loamy-sand matrix and is dark-yellowish-orange, (10 YR 6/6) in color. This till appears on the surface in most till exposures. It is possible that this till represents a distinct glacial advance separate from that which deposited the basal till but presumably it is merely super-glacial till deposited by the wasting of the same glacier that deposited the basal till.

A third type of till is located about one mile north of East Fletcher in the Black Creek Valley. This till has a loam to clay-loam matrix and is pale-yellow-brown (5YR 5/2) to dark-yellowish brown (10 YR 4/2) in color. In the opinion of the writer, this till is composed of the same lacustrine sediments found adjacent to it in the valley bottom.

Till Fabric

Only the two localities where basal till was exposed were thought to be suitable for fabric analysis (see Stewart and MacClintock, 1964). A fabric maximum of N 40° E was recorded on the west flank of Mount Mansfield (with a secondary peak at N 30° W). However this fabric was recorded in a sequence of tills and laminated lacustrine deposits and is thought to represent an oscillating ice margin adjacent to a local lake on the Mount Mansfield flank and not the direction of the continental advance.

At the North Underhill site a fabric maximum of N 40° E was recorded with a strong secondary maximum at N 50° W. Fabric diagrams are included as Appendix 1 of this report.

Although most of the landforms are slightly elongated north-south, this is thought to reflect underlying bedrock structure rather than glacial flow direction. It is concluded that the ice depositing the ground moraine moved from NW to SE.

No drumlins or drumloidal features were noted in the quadrangle.

End Moraine

No continuous end moraines were noted in the quadrangle. Morainal (knob-and-kettle) topography (M on the accompanying map) developed on till appears to be restricted to the area north of the Lamoille River. This type of topography is found in the valley between Buck Mountain and Coons Hill (NE ninth) and along the north bank of Wilkins Brook, west of the village of West Fletcher. It is also found between Fletcher and Parson's School (NC ninth) and in the depression south of Wintergreen Mountain; and again between Fletcher Mountain and the North Branch of the Lamoille River (NE ninth).

The only undoubted end moraine is a small loop athwart the Black Creek Valley, one mile north of East Fletcher. This moraine is composed of the brown, loam till discussed above and is thought to represent a slight readvance over the lacustrine deposits in the Black Creek valley.

Ice-Contact Deposits and Outwash

Included in this category are stratified, waterlaid sediments deposited on top of the ice, within the ice, between ice and topographic highs, or beyond the margin of the ice. These deposits are usually categorized as kames, eskers, kame terraces, and outwash on the basis of topographic form and the presence or absence of ice-contact structures (Flint, 1957). Actually these sediments form a continuous spectrum of glacio-fluvial deposits and cannot be adequately separated according to genesis. They are differentiated in the field only for the sake of convenience in mapping. In many instances, hummocky, knob-and-kettle topography (M) has been mapped as ground moraine only because no exposures are present to prove stratification. It might be that these latter deposits should also be classified as ice-contact deposits.

Kame terraces (KT) are linear features composed of stratified, waterlaid sediments deposited between stagnant ice and valley walls. A sufficient number of accordant, flat-topped remnants are present so that a smooth upper surface can be reconstructed with confidence. These deposits are found in three valleys in the Mansfield quadrangle. They may be seen on the proximal side of the Black Creek moraine loop, north of East Fletcher, on the east side of the valley wall at about 750 feet and at about 600 feet. They are also present on the east and west valley walls flanking The Creek, a tributary to the Browns River, north of Underhill at 800 to 840 feet. They are also present in the vicinity of Irish Settlement School on Settlement Brook, a tributary to the Seymour River, and surrounding the village of Underhill Center.

Kame terraces lie along valley sides and their accordant tops suggest graded deposition from streams flowing beside the glacier. Where similar sediment was deposited on top of stagnant ice the resulting collapse caused irregular topography lacking accordant, flat-top remnants and deposits such as this are mapped as Kame moraine (KM) rather than kame terrace although they probably have a similar origin.

Kame moraine is found around the village of Underhill Center; east of the village of Underhill; on both sides of Macomber Mountain, north of Underhill Center; and in the headwaters of the Waterbury River that drains the east flank of Mount Mansfield in the southeastern corner of the quadrangle. It is probable that the hummocky topography between Buck Mountain and Conns Hill is also kame moraine; however, no exposure is present and it is mapped as ground moraine (M).

Isolated hills of stratified drift were mapped as kames (K). There are many kames in the northwestern portion of the map, north of the Lamoille River, but only isolated kames south of the Lamoille.

Only one ice-channel-filling (esker) was noted on this quadrangle. This stretches from the col between Buck Mountain and Coons Hill on the north, southward across Wilkins Brook, to an outwash plain at about 700 feet 2 miles north of the Lamoille River.

This ridge is not particularly sinuous, however, it probably would be classified as an esker on the basis of topography. This esker is almost three miles long and is manifested as a low, hummocky dissected ridge that begins at an elevation of 1000 feet south of the Buck Mountain-Coons Hill col. It descends southward on the east side of a tributary to Wilkins Brook to an elevation of 620 feet in the Wilkins Brook Valley. It then rises again to 660 feet above Wilkins Brook and terminates at 640 feet at the 600-640 foot outwash apron south and west of Wilkins Brook. In the higher elevations the esker forms a prominent ridge that was opened by construction in 1965. On the north side of the col the hummocky topography was mapped as ground moraine, as discussed above. The esker is composed of local bedrock, a great deal of sand, and some silt and clay. The sediment was poorly washed which might suggest that it represents a short-lived channel.

Cross-stratified outwash (OW) is found in three places in the quadrangle. One area is south and west of the Wilkins Brook esker. Although this outwash is not a well developed esker-fan it is reasonable to suppose that it was deposited by a stream flowing either within or beneath the ice, along this ice-channel and is closely related to it. This outwash has caused the derangement of Wilkins Brook - the Brook now flows westward rather than southward in its preglacial channel.

A second area of outwash lies along the west side of Polly Brook in the extreme northwestern part of the quadrangle. This outwash lies at the foot of massive kame material that has been mapped on the adjacent Milton quadrangle.

The most interesting and informative area of outwash lies in the extreme northeastern part of the quadrangle. Most of this flat-topped, pitted deposit is found on the adjacent Enosburg Falls, Jay Peak, and Hyde Park quadrangles. The pitted outwash extends across the headwaters of the North Branch of the Lamoille River at about 840 feet. Forset bedding, only poorly exposed in borrow pits during the 1965 field season suggests deltaic deposition into lake waters in the Lamoille River Valley to the south. In the Mount Mansfield quadrangle small depressions in the outwash suggest buried ice, either floating or stagnant, was present during deposition. On the adjacent Jay Peak quadrangle large pits, tens of feet in width and depth, undoubtedly attest to buried stagnant ice suggesting to the writer that this outwash delta marks an ice marginal position.

Lacustrine Deposits

Christman (1959) reported the thick lacustrine sediments in the Lamoille River Valley and designated them as undifferentiated "Lake Lamoille deposits" (pp. 72-73 and his Plate 3). Christman gives a brief description of a few localities and a rough map of the overall distribution of lacustrine sediments, correctly reporting that most deposits occur at an elevation below 600 feet but that they have been found up to 800 feet.

The most prominent areas of lacustrine deposition flank the Lamoille Valley. There are also lacustrine deposits north of the Lamoille Valley in the Black Creek Valley and flanking Polly Brook in the northwest ninth. South of the Lamoille, some lacustrine deposits are present on both sides of Macomber Mountain and in the Browns River Valley in the southwest. The deposits consist of stratified clays and sands, gravels deposited by streams entering the lakes as they shoaled, and some reworked beach deposits found along the North Branch of the Lamoille River.

The thin, clean, imbricated beach gravels (BG) occur on terraces that crest at 740 feet and are underlain by lake sand (LS). The beaches vary from 0 to 5 feet in thickness and overlie lake sands except where they overlap till, high on the valley walls. The beach gravels terminate south of the dissected, pitted-outwash delta, previously described, at an elevation of 840 feet. The 840 foot level is proposed as Lake Lamoille as defined by Merwin (1908) while the 740 foot beaches appear to postdate Lake Lamoille and are referred to Merwin's Lake Mansfield.

In the Black Creek Valley lacustrine clays (STC) are common below 500 feet and are present at 600 feet south of North Cambridge. Lacustrine sand overlies these lake clays in the north and may be of deltaic origin from Kings Creek, a tributary of Black Creek. These sands raise to a terrace at 640 feet and probably relate to the Coveville stage of Lake Vermont with an ice dam to the northwest.

The writer agrees with Christman for elevation in the Lamoille River Valley. It appears that the sediments are present below 600 feet in almost all places, the exception being Sand Hill about two miles east of Fairfax Falls. Sand is present at 800 feet on Sand Hill; however, it is not certain that this is all lacustrine sand and some may be eolian. In many places sand is seen to overlie lake clays. This may be interpreted as deposition in two separate lake stages; the clays representing an early, deep phase where streams were not active in supplying coarse sediment; while the sand represents a lower, later phase with active fluvial transport. Alternatively, the clay may represent initial deposits and the sand a shoaling phase of the same lake.

There are several excellent exposures of sand over clay; the ones at Fairfax Falls and Jeffersonville having been described by Christman. The sand plain surrounding Sand Hill and Hedgehog Hill is of special interest as it grades northward into the outwash deposits in front of the Wilkins Creek esker. This sand plain appears to have diverted pre-existing

N-S drainage. Stoney Brook, which once flowed southward into the Lamoille River passed Binghamville, has been diverted into Wilkins Brook that now traverses the same bedrock threshold that causes Fairfax Falls. This threshold, at about 500 feet, suggests a mimimum thichness of 100 feet for the lacustrine sediments in the western Lamoille Valley. No well data was sought to estimate the total thickness in the eastern part of the valley.

Isolated lake deposits of sand and clay are found in the Seymour River Valley to an elevation of 640 feet. They are found also between two areas of kame terrace or kame moraine along the headwaters of Settlement Brook where they rise to 900 feet. The latter is thought to be an isolated lake deposit existing within stagnant ice and might properly be referred to as an ice-hole deposit. Isolated sand plains are found in Stevenville Brook, on the west flank of Mount Mansfield, at 1340 and 1120 feet. These two deposits are thought to be isolated ice-hole deposits or deposits in small lakes present during down valley retreat of the ice terminus.

Within the Browns River valley most lacustrine sediments appear to be gravel however, north of Underhill Center, lacustrine sands are present to almost 900 feet. In the western part of the valley, in the vicinity of Jericho, sands are present to 680 feet and appear to be overlain by fluvial, deltaic gravels, deposited during shoaling of this level. These gravels might be mapped as high level, fluvial gravel or perhaps outwash. However, a decision was made in the field to map these as <u>lake gravels</u> (LG) because, although they might be fluvial deposits, they appear to have been deposited during the shoaling phase of the lake present in this valley. These gravels are present at an elevation of 700 feet in the vicinity of Jericho and have been reworked into beach gravels in one or two places at 680 feet. The gravels rise eastward to 800 feet west of Underhill Center and over 900 feet east of that village. Although separate deltaic levels may be present a smooth, graded profile is inferred. If this is the case then the writer is of the opinion that the gravels are fluvial in origin and that they should be mapped correctly as fluvial gravels (FG) graded to a 680 foot lake level in the vicinity of Jericho. This level is too low for Stewart's Quaker Springs stage and too high for the Coveville stage of Lake Vermont. It is therefore thought to represent a local lake in the Browns River valley that might appropriately be named Lake Jericho.

A similar situation exists in the Brewster River that drains the north flank of Mount Mansfield into the Lamoille River in the vicinity of Jeffersonville. Three, or possibly four levels may be observed here. The upper level is a deltaic deposit near Morses Mill at about 1100 feet. This is thought to be an isolated deposit graded to a small pond present as the glacier terminus retreated northward down the valley. A second level may be present at 940 feet near South Cambridge. The third level is a well preserved, terrace graded from 840 feet to 740 feet south of the falls on the Brewster River. The fourth level is graded from 700 feet to

640 feet north of the falls and south of Jeffersonville. Here a clean, forset cobble gravel was observed on both sides of the Brewster River.

The 1000 and 940 foot levels represent temporary, ice-dammed lakes above the Lamoille Valley. the lower levels appear to represent deposition in lakes of regional extent ("Lake Lamoille" of Christman). The 840 foot level south of Brewster Falls is tentatively correlated with the 840 foot pitted outwash in the North Branch of the Lamoille River; the Lake Lamoille of Merwin. The upper hanging delta, south of Brewster Falls, is thought to have originated from reworking of the Lake Lamoille gravels and to be graded to the 740 foot level documented by beaches in the North Branch and assigned to Lake Mansfield. The lowest hanging delta, north of Brewster Falls, represents trenching and reworking of the Lake Mansfield delta and deposition in the 600-640 foot level that probably correlates with the Coveville stage of Lake Vermont.

POST GLACIAL DEPOSITS

Stream Deposits

High level delta gravel (DG) and fluvial gravel (FG) have been discussed in association with lacustrine deposits. In this quadrangle fluvial gravel was mapped where recent stream channel deposits are dominently coarse-textured even though the term alluvium might correctly be applied.

Medium- to fine-textured alluvium (AL) is related to the floodplains of recent streams. Usually this alluvium is only a thin band not wide enough to be mappable, however, along the Lamoille River a well developed floodplain is present. There also appears to be extensive alluvial fill south of Metcalf Pond in the Black Creek Valley, north of East Fletcher. A wide alluvial floodplain is developing currently on the Browns River and its tributary, The Creek.

Wind Deposits

Active dune (eolian) sand (DS) is present one-half mile east of Fairfax Falls. The eolian sand is located on the outside of a meander of the Lamoille River with a similar deposit on the opposite shore, along Route 104. This sand appears to be reworked lacustrine sediment. A deposit that is apparently stablized eolian sand is present on the lowland immediately west of Fairfax Falls.

It is not certain whether the eolian sand has been active ever since deglaciation or if it is a recent feature. It is possible that dunes were initiated shortly after "Lake Lamoille" drained and have been reactivated recently. The topography is dominated by weakly developed mounds and ridges of sand that are partially stablized with grass. No ventifacts were noted.

Swamp Deposits

There are several recent bogs and swamps (P) that presumably represent the end phase of filling of old lakes. An extensive bog exists along the upper Black Creek Valley bordering the railroad. There is also fairly extensive swamp on both ends of Metcalf Pond. Bogs have been noted along The Creek and on the upland two miles north of Jericho.

GLACIAL HISTORY

Only one glacial advance, from the northwest, is clearly demonstrated within the Mount Mansfield quadrangle. The last continental ice is documented by striae even on top of Mount Mansfield and evidently represents the Burlington advance of Steward and MacClintock (1964). Stewart and MacClintock suggest that at least three preceeding glaciations also left their mark on northern Vermont and the NE fabrics in the lodgement till may represent a pre-Burlington advance: presumably the Shelburne. However, the fabric at Mount Mansfield has already been discussed and that at North Underhill might represent a NW flow direction almost as readily as NE.

Although it is possible that isolated cirque glaciers existed on the eastern face of Mount Mansfield prior to the most recent (Burlington) glaciation, no evidence for post (continental) glacial cirque activity was noted.

Deglaciation

Retreat of the last glacier was evidently accomplished by downwasting and stagnation. As the ice thinned movement ceased and separate blocks of stagnant ice were left in the valley bottoms south of the Lamoille River. The sequence concept of Jahns (1941 and 1953) may be applicable to the ice-contact deposits in The Creek, Settlement Brook, and the Brewster River valleys. Drainage from Settlement Brook and the Brewster

River is inferred to have drained against stagnant ice during early phases of retreat and into the open waters of "Lake Lamoille" during the later phases.

In the The Creek Valley, three sequences may have developed. At Underhill there is a kame moraine complex at 860 - 880 feet with a kame terrace at 780 - 800 feet and an inset fluvial terrace (lake gravel) graded from 700 to 640 feet. Although the upper kame moraine cannot be traced northward to higher levels, the lower kame terrace can be, and perhaps the fluvial gravel also. The higher sequences were evidently deposited against, or over, stagnant ice and had their source north of the col at North Underhill. This valley, from North Underhill to the Lamoille River is free of ice-contact sediments.

On the west side of Macomber Mountain there is a kame terrace flanking Settlment Brook that is inferred to have been deposited against ice remaining between Settlement Brook and the Lamoille River. There is kame moraine mapped about a mile south of this terrace, with lake material between the two ice-contact deposits. An ice mass probably remained south of this lake, as well as north with the small lake dammed between them at 900 feet. North of Settlement Brook only lake sands and clays are present, extending to an elevation of 660 feet. These sediments are probably related to those in the Lamoille Valley.

The series of three, or possibly four, sequences of fluvial gravel (lake gravel) in the Brewster River have already been described. The upper two levels evidently represent isolated ice-dammed water bodies while the lower two are continuous with Lake Lamoille and Lake Mansfield respectively.

North of the Lamoille River Valley morainic topography suggests an ice marginal position. It is not evident whether this ice margin bounded a stagnant ice block or whether it was the margin of active ice. The close association of the Wilkins Brook esker and this marginal position suggests stagnant ice. Outwash from the Wilkins Brook esker evidently emptied into the Coveville stage at 600 to 640 feet in the western Lamoille Valley.

Pitted outwash in the North Branch of the Lamoille River and the evident derangement of north-south drainage along the northern edge of the Lamoille River tends to support an ice marginal position between Merwin's Lake Lamoille and the northern highland ridge (Buck Mountain, Coons Hill, Gilson Mountain, Wintergreen Mountain, Ryan Mountain and Kings Hill).

The Wilkins Brook esker may have been fed by active ice north of the highland ridge as suggested by hummocky topography north of the bedrock col; by morainic topography just north of The Gore; and by the small end moraine in the Black Creek Valley. The writer does not wish to suggest a readvance in the northern portion of the quadrangle, but at least the presence of active ice while the stagnant blocks existed to the south. Stagnant ice is inferred to have faced Lake Lamoille, Lake Mansfield and the Coveville stage of Lake Vermont on the north and probably to have blocked southerly valleys at least during the early phases.

"Lake Lamoille"

Chapman (1937 and 1942) traced various lake levels of "Lake Vermont" from the Hudson Valley to the St. Lawrence Valley. The lowest freshwater level was named the Fort Ann stage and is present at about 540 feet at the Lamoille River's Milton delta west of the Lamoille Valley. A higher level was named the Coveville stage and it was reported to be present at about 670 feet at Milton in 1937, even though the glacier terminus was inferred in the Lamoille Valley in 1942. Stewart (1961) recognized a higher (earlier?) lake phase and resurrected the name Quaker Springs stage. The Quaker Springs stage projects to an elevation above 700 feet at Milton and Steward reported it at 750 feet in the vicinity of Fairfax.

The 840 foot lake phase in the Lamoille Valley is much higher than any phase of Lake Vermont in the Champlain Valley. This phase was recognized by Merwin who designated it Lake Lamoille (or Lake Lamoille 1). This was the initial lake phase of regional extent in the Lamoille Valley.

Although Hitchcock (1906) did not recognize a 740 foot level he did regard the elevation of the col between the Lamoille and Winooski Valleys as significant. Merwin evidently followed Hitchcock in inferring that the waters of Lake Lamoille eroded this threshold at 740 feet. He refers the waters in the Lamoille Valley to "Lake Lamoille 2" until the barrier to the Winooski Valley was breached and then designates the composite water body as Lake Mansfield.

As there is no real distinction between "Lake Lamoille 2" and Lake Mansfield it is preferable to restrict the name Lake Lamoille to the 840 foot phase and use Lake Mansfield for the 740 foot phase. The 740 foot beaches in the North Branch and the 740 foot delta on the Brewster River are referred to Lake Mansfield.

As the 740 foot phase was obviously controlled by the col at the head of the Waterbury River east of Mount Mansfield it would appear that it is not referrable to any event in the Champlain Valley. In order to maintain this level ice blocks must have existed south of, as well as north of, the Lamoille Valley. Thus, the term Quaker Springs is deliberately avoided here.

When drainage commenced to the south, probably by breaching an ice block near Underhill, a third lake phase began at 640-660 feet. The close agreement with the elevation of the Coveville stage suggests that this phase coalesced with, or at least coexisted with Lake Vermont. The majority of lacustrine sediments found below 600 feet in the Lamoille Valley, 640 feet in Black Creek and 660 feet in Settlement Brook are referred to this phase; as is the longest hanging delta (660 feet) on the Brewster River. The close association of the Wilkins Brook esker, its 640 foot outwash apron, and the Coveville lacustrine deposits strongly suggests that the ice margin was immediately north of, as well as west of, the Lamoille Valley during at least part of Coveville time.

When the Coveville stage lowered to the Fort Ann stage it is doubtful that lake waters existed in the Lamoille Valley. However, the apparent 600 foot level may represent an intermediate phase between Coveville and Fort Ann.

The lake that existed in the Browns River Valley is thought to be unrelated to those discussed above. This lake level may be present at 680 feet as suggested in this report or as high as 725 feet as suggested by Stewart (1961). In any case this level is referrable to the Winooski Valley and the name Lake Jericho is tentatively suggested here.

In summary, recent lake history was initiated shortly after or during the stagnation of the most recent glacier. During early phases of deglaciation ice stood west of the Lamoille Valley blocking drainage to the Champlain Valley. At the same time stagnant ice was present in The Creek, Settlement Brook and east of Macomber Mountain blocking southerly drainage. This initiated the 840 foot Lake Lamoille. With dissection of the col east of Mount Mansfield water levels dropped to 740 feet and coalesced with those in the Winooski Valley forming Lake Mansfield. When drainage southward and southwestward to the Champlain Valley became possible the Coveville phase was initiated at 640-660 feet. A further reduction in the level of Lake Vermont to the Fort Ann stage removed lake waters entirely from the Lamoille Valley and present drainage commenced.

POST GLACIAL HISTORY

The principal post glacial events have been the trenching of glacial deposits and the development of graded alluvial flood plains in some of the valleys. The most prominent trenching has occurred in the Lamoille River Valley where the Lamoille River excavated approximately 140 feet of lacustrine sediment. The base level of the Lamoille River from Fairfax Falls eastward is controlled by the bedrock lip at 425 feet at Fairfax Falls. Evidently the river cut down to this level and then commenced lateral erosion and aggradation of the valley. Lacustrine sediments were easily removed and the stream has progressed rapidly to a stage of maturity. An alluvial floodplain is present; almost a mile in width at some places. The Lamoille River is still impinging on the valley walls in many places illustrating active laterial erosion. The thickness of floodplain alluvium is a matter of speculation. Certainly no more than 40 feet is present in the east and very little in the west for the bedrock lip at Fairfax Falls is an effective lower limit for scour, and therefore for fill also.

Trenching and aggradation are present in the The Creek Valley and the Browns River Valley from Underhill Center to Jericho. The Browns River has evidently trenched less than 20 feet at present even though it has a steep gradient, perhaps inherited. The Browns River drops more than 180 feet in the five miles from Underhill Center to Jericho, where base level is controlled by a bedrock lip at about 600 feet.

Alluvial deposition is present in the vicinity of Metcalf Pond and in the Black Creek Valley, north of East Fletcher. South of East Fletcher, swamps have developed and the valley is being filled at present.

Eolian activity did not commence in the Lamoille Valley until the Lamoille had trenched to its present elevation. It is not known how soon after the Fort Ann stage that the Lamoille River reached the bedrock threshold at Fairfax Falls. Active eolian sand is present on the alluvial (?) floodplain today; thus it is inferred to be a modern feature. The stabilized eolian sands west of Fairfax Falls may relate to the withdrawal of Lake Vermont or the ensuing marine invasion (The Champlain Sea).

Many small bogs are present and are presumably the final stage of filling of small lakes and poorly drained depressions.

ECONOMIC GEOLOGY

Gravel

Most of the gravel in the quadrangle is clean, well sorted and is dominated by crystalline lithologies. However, there is a sufficient number of schistose pebbles to cause problems in economic utilization. The best economic gravels are found in the fluvial gravel (Lake gravel) deposits in the Brewster and Browns River Valleys. Other sizable deposits are present along The Creek and Settlement Brook and in the kame and outwash complexes in the northwestern part of the quadrangle.

Sand

A great deal of sand is present with variable amounts of silt and clay present. Small pits have been opened at many points in the quadrangle. The most promising area is the sand plain north of Fairfax Falls where many old pits are present. The sand is dominantly quartz and feldspar and should be stable for construction purposes.

Clay

Although a great deal of lake clay is present, there are probably enough lenses of sand and silt present to severely limit its use in ceramic industries or brick making.

Peat

Although there are small bogs present throughout the quadrangle, it is doubtful that they could be used for anything except humus for local agriculture. These deposits are neither extensive enough nor thick enough, as presently estimated, to be economically attractive.

Foundations

As noted before, the nature of the till is variable. In places where the sandy, ablation till is present, foundations can be excavated easily by hand. In the compact till mechanized labor is necessary for excavation whereas in the areas surrounding mapped bedrock outcrop, bedrock is probably present at shallow depths and would require blasting.

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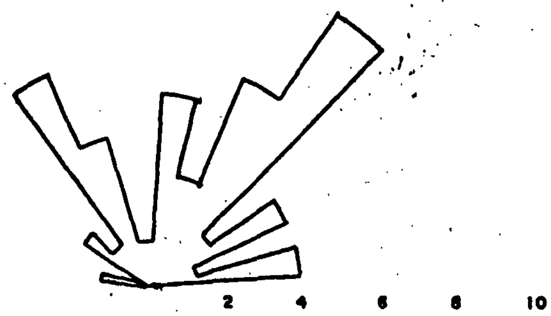
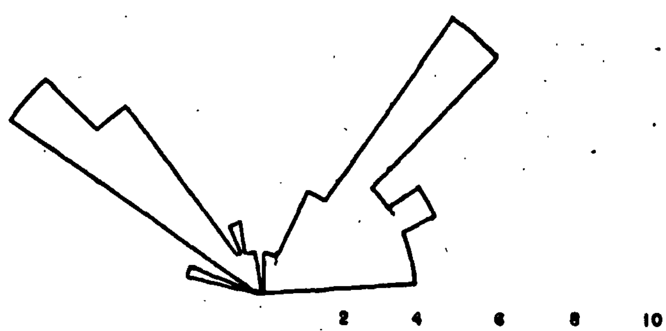
APPENDIX 1

The following rose diagrams show the fabric recorded from the glacial till at two localities in the Mount Mansfield quadrangle. The fabrics were recorded following the technique of Stewart and MacClintock (1964).

Each locality is identified by both a site name and its geographic coordinates. The numbers recorded are the actual number of till stones found in each of the 10° subclasses.



Mount Mansfield site, 44°33'30"N, 72°50'W. This is locality #5 of Christman (1959). A sequence of closely associated tills and intercalated lacustrine sediments record an oscillating ice margin. The upper part of the sequence is a very compact, slightly calcareous, stoney till with a light-olive-gray, sandy-loam matrix.



North Underhill site, 44°35'N, 72°55'30"W. A stream cut at the top of the ridge east of North Underhill. The till is compact, calcareous and pebbley with a light-olive-gray, silt-loam matrix.