# The Surficial Geology of the Branford Quadrangle

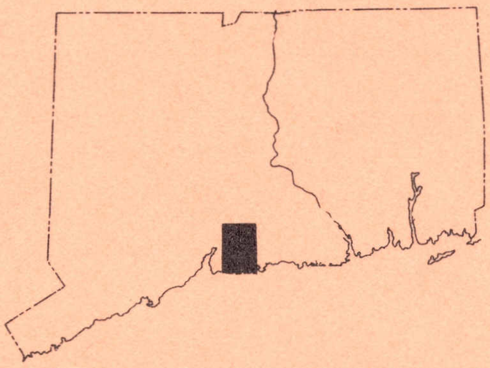
WITH MAP

Open Map

Open Figure 4

Open Figure 5

BY RICHARD FOSTER FLINT



STATE GEOLOGICAL AND NATURAL HISTORY SURVEY
OF CONNECTICUT

A DIVISION OF THE DEPARTMENT OF AGRICULTURE
AND NATURAL RESOURCES

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QUADRANGLE REPORT NO. 14

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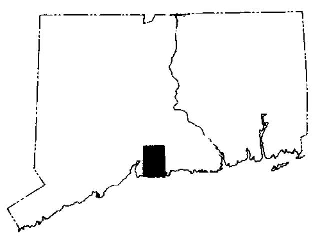

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## TABLE

# The Surficial Geology of the Branford Quadrangle

by

Richard Foster Flint

## ABSTRACT

The Branford quadrangle straddles the boundary between the Central Lowland and the Eastern Highland in southern Connecticut. Its surficial geology consists principally of the effects of glaciation. Features made by glacial erosion include striations and grooves, streamline hills, and crag-and-tail features. Till covers a large proportion of the area but is thin or absent over many ridges and hills. All of it is referred to a single glaciation. The former glacier crossed the quadrangle in a direction west of south. During the following period of deglaciation stratified drift was deposited in many of the lower parts of the quadrangle. Much of this drift is represented by three bodies or groups of bodies. One is a group of deposits related to valleys in the southeastern third of the area, and consisting largely of ice-contact stratified drift. A second is the Farm River valley train, a well-defined belt of drift that traverses the quadrangle from end to end. The third is the Muddy River delta, a body of sand built into a former glacial lake in the Quinnipiac Valley and grading into rhythmically stratified silt and clay which constituted the lake-bottom deposits.

The lacustrine sediments are overlain unconformably by distinctive glacial outwash brought down the Quinnipiac Valley from the Western Highland. This formerly constituted a massive valley train, only a small part of which enters the Branford quadrangle. Thorough postglacial dissection has destroyed the greater part of the valley train.

During dissection of the glacial drift, streams deposited thin ribbons of alluvium, some of which cap low stream terraces. Also related to the building and dissection of valley trains are wind-blown sand and silt, in thin patches along the valleys and in low sand dunes. Swamps are numerous in the area and swamp deposits, locally thick, have yielded an impressive record in the form of fossil pollen. Most of the swamps along the shore are tidal marshes.

The principal soils of the area, eight in number, are shown in a table. Substances of potential or possible economic value include ground water, sand and gravel, humus, and clay.

## INTRODUCTION

The Branford quadrangle (pl. 1, in pocket), with an area of about 57 sq. mi., lies in the central part of southern Connecticut (fig. 1). It is wholly within New Haven County and includes parts of the towns of Branford, North Branford, North Haven, New Haven, and East Haven. Its chief center of population is Branford.

Mapping of the surficial geology, on the scale of 1 :24,000, was done at various times in 1960, 1961, and 1962. Data for the map

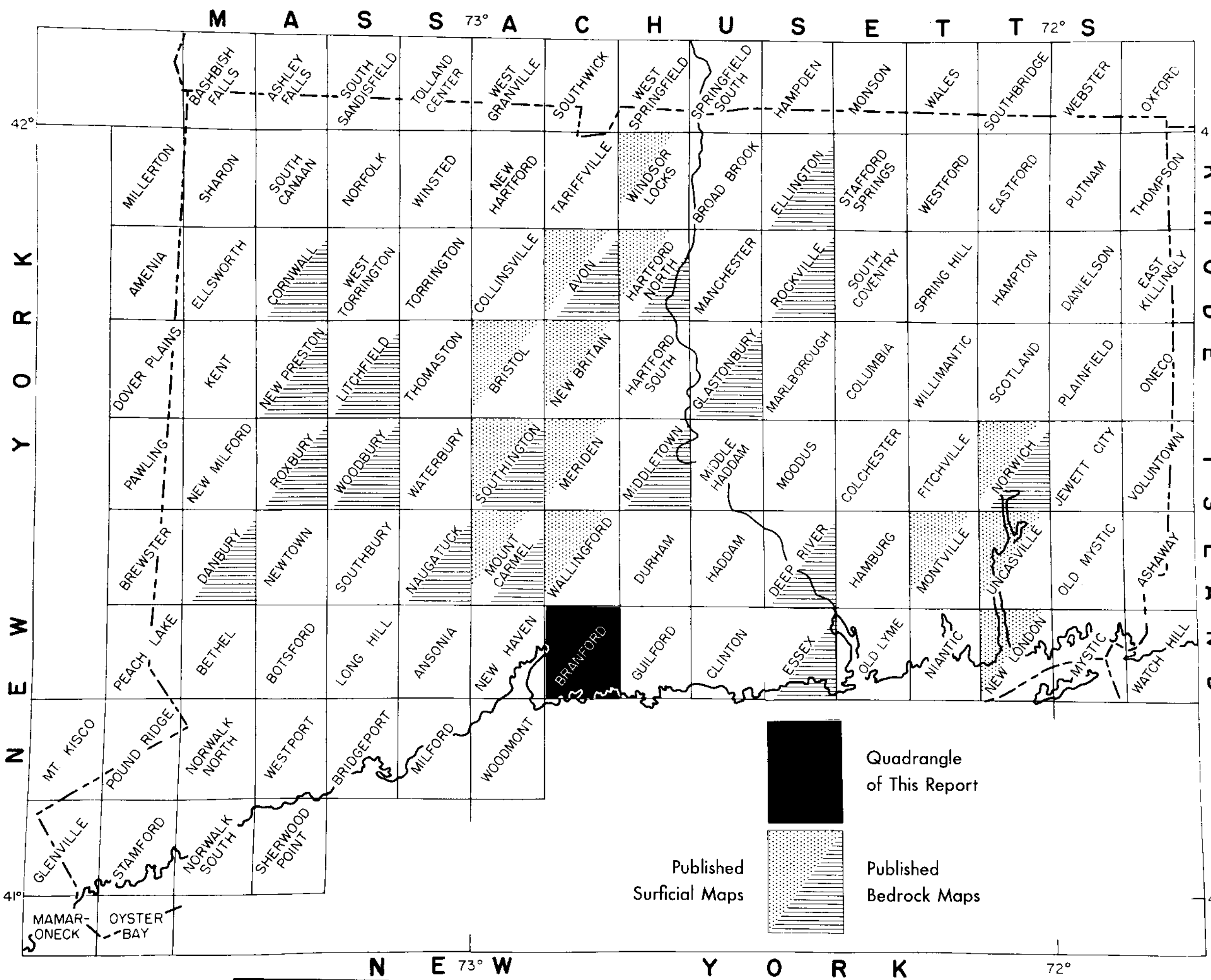


Fig. 1. Index map of Connecticut showing the location of the Branford quadrangle, and of other published quadrangle maps. See Appendix for list of published maps.

were obtained chiefly from observations in natural and artificial exposures, test holes made with hand tools, and analysis of land forms. Subsurface information was obtained from files of the State Highway Department, the U. S. Geological Survey, the State Water Resources Commission, and the office of the Town Engineer, Branford.

By special arrangement the northwest corner of the quadrangle, the area bounded by 72°50′ and 72°52′30″ W. Long. and by 41°20′ and 41°22′30″ N. Lat. was mapped independently by A. M. La Sala of the U. S. Geological Survey and by R. F. Flint. The northwest corner of the final map (pl. 1) embodies elements of the two resulting field maps.

That southern Connecticut had been glaciated was firmly established by J. D. Dana (1870, 1871). General discussion of the glacial features of Connecticut, although without special reference to the Branford quadrangle, are found in Rice and Gregory (1906, p. 227-259) and in Flint (1930, 1934). Ward (1920) made a more detailed study of the greater New Haven area, including that part of the Branford quadrangle which lies west of Saltonstall Ridge and Totoket Mountain. Brown (1925, 1928) published maps, including the area of the Branford quadrangle, in which the distribution of till and stratified drift was shown on the scale of 1 : 62,500.

## BEDROCK GEOLOGY

The bedrock geology is discussed in detail by Sanders (1962). Two very different groups of rocks underlie the quadrangle. They are separated clearly by a major fault, the Triassic Border Fault, that trends southwest-northeast from west of the William E. Gillis School in East Haven through the intersection of the Boston Post Road with the railroad in Branford, Interchange 54 on the Connecticut Turnpike, along Pisgah Brook, through Cedar Pond, North Branford, and along Munger Brook (pl. 1). Northwest of the fault the rocks consist of pink, brown, and red arkosic sandstone, conglomerate, siltstone, and shale of Triassic age. Interbedded with these sedimentary rocks are flows and intrusive bodies of diabase and basalt, greenish black to bluish black on fresh surfaces but brown where weathered. Southeasterly dips of 10° to 30°, accompanied by local cross folding, control the trends of ridges and valleys in this part of the quadrangle.

Southeast of the fault the rocks consist chiefly of granite and gneiss of pre-Triassic age. These rocks, believed to have resulted from the metamorphism of earlier sedimentary rocks, have whitish, grayish, and pinkish hues. They are generally massive, and are cut in most places by conspicuous joints. The granitic and gneissic rocks are cut by a conspicuous diabase dike that trends northeast-southwest, parallel with the fault, from south of Branford center through Interchange 55 (Connecticut Turnpike) and Notch Hill.

The identities and patterns of outcrop of the various kinds of bedrock are important to the surficial geology of the quadrangle, in that the occurrence in the glacial drift of rock fragments having identifiable areas of origin makes it possible to determine direction of movement of former glacier ice.

Exposures of bedrock, most of them small, are shown individually on the map (pl.1) in areas that are covered nearly continuously with glacial drift. In many areas, however, the drift that overlies the bedrock is generally less than three feet thick and is discontinuous, so that exposures of bedrock are numerous and are spaced close together. Such areas, most of which constitute the tops and steep slopes of ridges and hills, are mapped with a special pattern, as bedrock, and the thin material that overlies the bedrock is not shown separately.

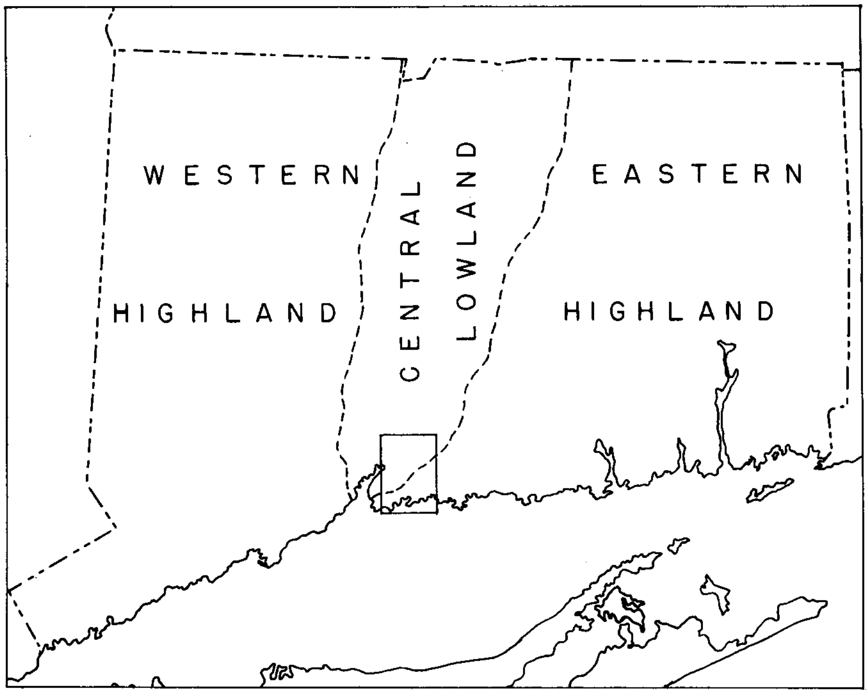


Fig. 2. Map of Connecticut showing boundaries of its three natural regions, and location of the Branford quadrangle.

## TOPOGRAPHY AND DRAINAGE

The northwest half of the quadrangle, underlain by Triassic rocks, lies within the Central Lowland of Connecticut; whereas the southeast half, underlain by metamorphic rocks, lies within the Eastern Highland (fig. 2). The southern edge of the quadrangle follows the coast of Long Island Sound. Off the coast are numerous small islands, which are the tops of hills not completely submerged.

Altitudes range from sea level at the shoreline to 470 ft on the summit of Totoket Mountain at the northern margin of the quadrangle. The highest and most conspicuous topographic features in the area are the long, curving Saltonstall Ridge and Totoket Mountain, both of which are expressions of a massive lava flow in the Triassic sequence. These and a parallel, unnamed ridge half a mile to a mile farther west inclose the well-defined valley drained from end to end by Farm River.

Northwest of the Triassic Border Fault the topographic features tend to be elongate, trending northeast-southwest. They are underlain mainly by Triassic sandstones and other sedimentary rocks, and local altitudes reflect rather closely the erodibility of the various bedrock layers. In the extreme northwest corner of the quadrangle is a low area that forms part of the Quinnipiac Valley. Southeast of the fault the hills are more irregular and uneven in form, being controlled mainly by joints and other structures in the massive pre-Triassic rocks. Here the hills are short and cliffy, in contrast to the long, rounded, ridgelike hills in the area of Triassic rocks.

This morphology is typical of the coastal belt of dissected hilly country which crosses Connecticut. Within this belt hilltop altitudes decline southward at about 50 ft per mi., the whole surface passing gently beneath Long Island Sound. Where intersected by the sea this surface forms an irregular shoreline, with numerous rocky points separated by coves. Some of the coves are lined with narrow beaches. Streams enter the sea through estuaries fringed with tidal marshes. The very irregular rocky shoreline and the numerous offshore islands suggest that this part of the Connecticut coast has been submerged beneath the sea since the valleys and ridges were sculptured. It is apparent, furthermore, that submergence postdates glaciation, for terrestrial sediments, including freshwater swamp deposits, occur beneath tidal-marsh peat at positions well below low-tide level in the Quinnipiac Valley opposite New Haven.

The mantle of glacial drift that overlies the bedrock is generally so thin that it does not mask the general form of the bedrock hills. In most places it masks only the small details of relief, and in the area of granitic rocks some hills have scarcely any cover of drift. Locally, where the glacial drift is thicker than usual, individual hills and groups of hills exist by virtue of accumulations of drift. But even this local relief is subordinate to the greater relief attributable to the irregular surface of the bedrock. In some valleys and in a few places on hillsides accumulations of stratified drift tens or scores of feet in thickness take the form of collapsed masses, kames, kame terraces, ice-channel fillings, kettles, and dissected bodies of glacial outwash.

Three principal watersheds are present within the quadrangle. The largest are those of the Farm River-East Haven River-Lake Saltonstall system and the Branford River system including Lake

Gaillard. Of lesser extent within the quadrangle is the Quinnipiac River watershed, dominated here by the tributary Muddy River. In addition, along the coast there are a few short independent streams.

It can be seen on the geologic map (pl. 1) and in figure 4 (in pocket) that the three chief streams in the quadrangle, the Muddy, Farm, and Branford Rivers, sweep southwestward in nearly parallel fashion. The Muddy River is tributary to the north-south Quinnipiac River, whose channel barely enters the Branford quadrangle at its western edge. In glacial time the Farm River entered the Quinnipiac at what is now the mouth of New Haven Harbor; and probably the Branford River, also, emptied into the Quinnipiac farther south. This was possible because at that time the level of the sea was lower than it is today.

The drainage pattern as a whole is closely related to the composition and structure of the bedrock. The predominating trend of stream units is northeast-southwest, parallel with the strike of Triassic rocks. In the southeastern part of the area there are strongly marked north-south directions, parallel with foliation and other structures in the granitic rocks. This general relation of drainage to bedrock characteristics is what would be expected if the region had not been glaciated, and leads to the inference that glaciation had little effect on the general form of hills and valleys, which were already present in preglacial time. On the other hand, the weathered regolith that must have been developed in the surface of the bedrock in preglacial time has been removed by glacial erosion. Regolith on similar rocks in the nonglaciated part of eastern United States is at least 5 to 10 ft thick. Hence it can be inferred that glacial erosion stripped off a surface layer at least a few feet thick but did not remove enough rock to destroy the close relationship between topography and lithology that had developed during a vast period of preglacial time.

The rather small depth of glacial erosion in the Branford area is shown in another way. At no place is glacial diversion of drainage, a not uncommon feature of glaciated regions, clearly evident. Nevertheless glaciation has influenced streams in other ways. The Quinnipiac River and other streams are now flowing, in places at least, on thick deposits of glacial drift, and hence may be at higher altitudes than they were before glaciation. Also some streams otherwise continuous are interrupted by swamps and ponds. Examples are Munger and Pisgah Brooks and the unnamed brook that flows into Lake Saltonstall between the Connecticut Turnpike and the Boston Post Road. Most of these swamps and ponds occupy basins created by irregular deposition of glacial drift. The presence of such basins is one result of the recency of glaciation; the time since that event has been too short to permit re-establishment of uninterrupted stream flow.

There are many lakes within the quadrangle. Notable among them is Lake Saltonstall. To increase its water-storage capacity its surface has been raised about 15 ft above its original altitude of around 9 ft. Its former, natural outlet was over the Holyoke basalt of Saltonstall Ridge, and its basin, with a maximum depth of 112 ft before the lake surface was raised, occupies the belt of sandstone and shale of the East Berlin formation adjacent to the basalt.[1] Probably the lake basin is the result of exceptional erosion by glacier ice flowing southward and confined within a narrow preglacial stream valley developed in the sandstone and shale.

The only other large lake in the quadrangle is Lake Gaillard. It too occupies a position on the East Berlin formation and is rimmed on the west by the Holyoke basalt of Totoket Mountain. The lake, with a maximum depth of about 100 ft, is an artificial reservoir created by damming the headwaters of the Branford River. Most of the small lakes in the quadrangle are artificial. Several of them were originally mill ponds, but Bruces Ice Pond and the pond one-quarter mile southwest of the cemetery at Montowese occupy large former clay pits. Among the natural ponds are Cedar, Linsley, and Lidyhites Ponds. Lidyhites Pond occupies a basin in till and possibly bedrock as well. Although now only 3 ft deep, the pond is underlain by fine-grained lake sediments at least 33 ft thick (Deevey, 1939, p. 699). Linsley Pond occupies a basin rimmed at various places by bedrock, till, and stratified drift. Forty-two ft deep, it is underlain by at least 43 ft of lake sediments; hence the original basin is at least 85 ft deep (Deevey, 1939, p. 698). Cedar Pond occupies a basin created by a barrier of stratified drift. About 18 ft deep, the pond is filling with organic matter, and a cedar swamp entirely surrounds it. It is underlain by at least 30 ft of lake sediments (Deevey, 1943, p. 724).

## GLACIAL GEOLOGY

### *Glacial-erosional features*

Striations and grooves, etched into the surface of bedrock by rock particles imbedded in the base of flowing glacier ice, are exposed at a few places within the quadrangle (pl. 2, A). The areal distribution of these marks is very irregular. This results partly from the ease with which the various kinds of bedrock yield to glacial abrasion, but more commonly from the ease with which weathering destroys the marks, especially the smaller ones, after they have been exposed. Where recent erosion, natural or artificial, has stripped away the glacial drift from over bedrock, striations and grooves in the rock are commonly visible. But hills and smaller bosses of bare bedrock, whose forms indicate that they were shaped by glacial erosion, show striations only rarely. Their surfaces, roughened and granulated by weathering, suggest that any striations they formerly bore have been destroyed during long exposure to the atmosphere.

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[1] Data from Dana (1870, p. 61); altitudes adjusted to mean sea level.

For these reasons striations or grooves were seen and recorded at only 17 localities. At those places (shown on the map, pl. 1) the bearings range from N. 10° W. to N. 22° E., with an average of N. 6° E.

The localities where striations are shown most strikingly are on the top of Totoket Mountain, where the Holyoke basalt has been laid bare by stripping at the New Haven Traprock Company's quarry, and on sandstone and basalt of the Talcott formation 0.2 mi southwest of the southwest end of Graniss Pond. At the latter locality the bedrock, stripped of its cover of till in 1958, exposes a striking assemblage of grooves and striations. Quartz pebbles in the conglomeratic sandstone were especially resistant to glacial abrasion. They form well-defined protuberances above the general surface of the sandstone. Streaming southward behind each is a rat-tail ridge in the sandstone, where the latter was protected by the quartz pebble. The rat tails show that the glacier ice flowed from north to south, whereas most of the grooves and striations do not exclude the inference that the flow direction was from south to north.

At a number of places within the quadrangle low hills of rock are smoothed at their northern ends to whaleback form, whereas their southern ends are steep cliffiets controlled by joints in the rock. Such stoss-and-lee features are reliable indicators of direction of flow of glacier ice. Their usefulness is enhanced by the fact that they remain long after striations have been destroyed by weathering.

In some parts of the quadrangle the surface has been molded by glacial action into streamline hills or drumlins (fig. 3). These are ovate in plan and range in length from a few hundred feet to about a mile. The long axes of most of them are parallel with the trends of structures in the local rocks, such as the strike of dipping beds and of foliation. The hills occur on a wide variety of rocks, but those on the Triassic sedimentary rocks are more symmetrical than those on the metamorphic rocks. Most of the hills evidently consist mainly of bedrock, because bedrock is exposed frequently in them. Others, such as Sea Hill and its neighbors east of Lake Gaillard, expose no bedrock and probably consist mainly or wholly of till. There is little if any difference in form between hills believed to consist principally of bedrock and those believed to include a large amount of till. The fact that elongation of streamline hills parallels rock structure implies that structure exerted a strong local influence on direction of flow of the basal part of the glacier. The influence was exerted through topography; that is, the pattern of hills and valleys, developed in conformity with structure in preglacial time, in turn influenced the flowing ice.

### *Glacial stream channels*

Only three features in the Branford area are thought to be stream channels that carried water temporarily while glacier ice was pres-

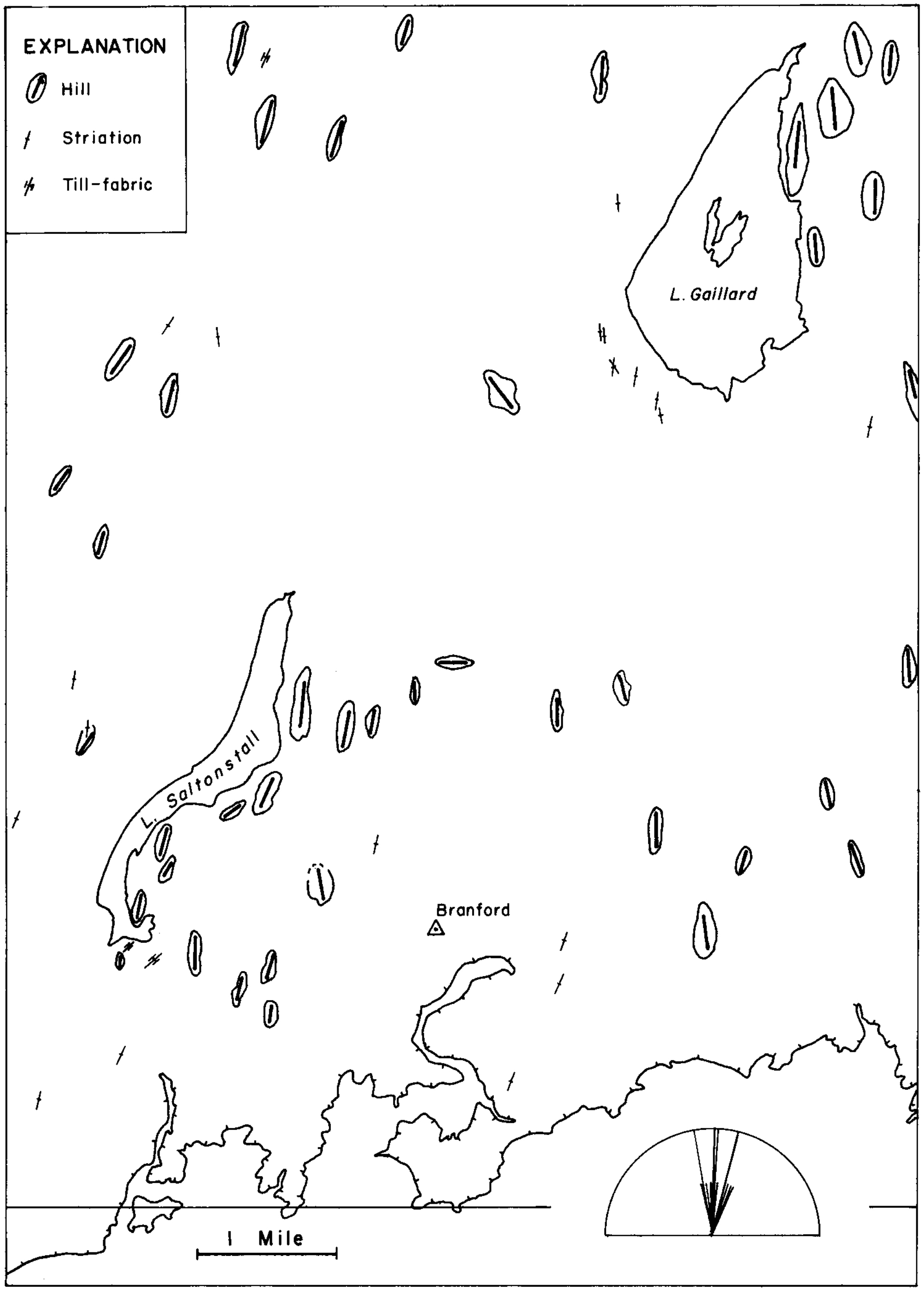


Fig. 3. Sketch map of the Branford quadrangle showing locations and trends of streamline hills (including drumlins), glacial striations and grooves, and till fabric.

ent nearby. One is occupied by Hartens Pond east of Montowese. A quarter of a mile long and 100 to 200 ft wide, it parallels the strike of the local sandstone and is floored with sand of unknown origin. Its altitude, 70 to 80 ft, approximates that of the lake-bottom sediments 1,000 ft to the east. Possibly it represents a temporary outlet of the lake, although the connection between channel and lake is not clearly evident. If lake water passed through the channel it must have continued southward along the margin of the glacier that then occupied the Quinnipiac Valley.

Two small troughs that are certainly stream channels cut the sand and gravel of the Farm River valley train. One, about 400 ft wide and 10 ft deep, is crossed by Augur Road. Its present length is not much greater than its width, but this anomalous proportion is believed to result from collapse of sand and gravel as buried ice melted out both north and south of the surviving segment of what was originally a channel at least 3,500 ft long, connecting two kettles, the one at Augurs Ice Pond and the one crossed by Village Street.

The other channel in the Farm River valley train is smaller and leads westward out of the Foxon Pond basin, a kettle. Apparently it represents a brief flow of proglacial water at about the time when upbuilding of the valley train came to an end. Possibly many similar channels existed, but were so thoroughly altered by collapse that they are no longer recognizable.

Anomalous valley-like features, open at both ends, occur in bedrock in various parts of the quadrangle. Examples are the north-south valley, half a mile long and hanging at both ends, 0.5 mi. west of Totoket and the parallel, longer valley 0.7 mi. farther west. Both are floored with till and are related to fault structures. Such valleys were doubtless in existence long before glaciation occurred.

## *Glacial sediments*

Sediments of glacial origin, collectively known as glacial drift, are of two general kinds: those deposited directly by glacier ice and those deposited in streams and lakes consisting of water derived from the melting of glacier ice. Both kinds are present in the Branford quadrangle.

### TILL

*General character.* Till, a glacial sediment consisting of nonsorted, nonstratified rock particles of all sizes, is the most widespread of the surficial deposits in the area. It forms a general, although discontinuous, mantle over the bedrock surface of hills and valleys alike, and thereby shows that most of the topography had been created before the glaciation began. In about 20 percent of the aggregate land area of the quadrangle the till is either extremely thin and discontinuous or is lacking altogether. Most of this aggregate area consists of outcrops of diabase and basalt, granite and gneiss. Such rocks resist glacial erosion and evidently supplied little material from which till could be made. Also they form hills with steeper average slopes than the hill slopes on the sedimentary rocks, so that till is eroded from them with relative ease.

Where stratified drift is present the general mantle of till commonly passes beneath it. This relationship is confirmed by records of some wells, which show that till occurs between bedrock and overlying stratified drift.

Thickness of the mantle of till is notably variable. Except in some streamline hills the till is generally thinnest on hilltops and thickens downslope. The till smooths the relief by filling small valleys and pockets in the bedrock surface. Road cuts, stream banks, and other surface exposures rarely show more than a few feet of till; the three longest sections seen exposed in the quadrangle were respectively only 25, 20, and 18 ft thick, respectively. The subsurface data available show few thicknesses greater than these. Average thickness of till within the area is estimated at between 8 and 15 ft, but because of abrupt variations and the small number of well records available the estimate is not considered accurate.

Generally throughout the quadrangle the till mantle has little constructional relief, that is, relief resulting from local variations in till thickness independent of the relief of the bedrock underlying it. The till appears to have been smeared by the glacier, in a blanket-like manner, over the bedrock. However, on the southeast slope of the upland immediately northwest of Cedar Pond the till has conspicuous constructional topography with local relief of 5 to 10 ft. This area of till, which scarcely exceeds 0.2 sq. mi., is the only area within the quadrangle that could be properly classed as ground moraine. Possibly similar areas exist but have not been perceived because of the close-growing forest that covers much of the Branford area.

*Composition.* The till in the Branford area includes a coarse fraction consisting of pebbles, cobbles, and boulders and a fine fraction consisting of sand, silt, and clay. As in Connecticut generally, the coarse fraction is conspicuous in surface exposures, but when measured is found in most samples not to exceed 20 percent of the total. Within the fine fraction sand and silt are abundant; hence the till is commonly rather friable.

The pebbles, cobbles, and boulders are generally subangular in shape, reflecting the positions of joints and stratification surfaces in the bedrock from which they were derived. Most of them show some degree of smoothing as a result of the abrasion they received while in glacial transport. Corners and edges between facets are rounded, and the surfaces of a few are marked with glacial striations. A very few are well rounded; probably these had been carried in a stream before being last picked up by glacier ice. The sand-size particles are mainly very angular.

In composition the till resembles the bedrock that immediately underlies it. In the area of Triassic rocks till is conspicuously brown to reddish brown (color range when dry, 10R 4/6 to 5YR 4/4),[2] approximating (but less red than) the color of the bedrock. Close to the large bodies of diabase and basalt the color of the till becomes more dusky, because there the reddish sedimentary rocks in the till are diluted with a larger proportion of dark-colored igneous rocks. In the area of granite and gneiss, on the other hand, till commonly ranges from yellowish gray to light olive brown (5Y 7/2 to 5Y 5/6) and again consists chiefly of fragments of the local bedrock and of its mineral constituents.

Because of these differences the character of the till changes with change in the bedrock, although with a lag of half a mile or more. The most conspicuous change of this sort occurs southeast of the Triassic Border Fault, which marks the contact between Triassic rocks and the granites and gneisses southeast of them. At the contact itself there is no obvious change, but within half a mile southeastward from the contact pebbles of sandstone and basalt are greatly reduced and pieces of granitic rock are conspicuous. Within a mile of the contact, pebbles of Triassic origin are reduced to a small proportion of the whole. The same rate of change, however, is not true of stratified drift, as is noted further on.

Although some of the cobbles and boulders in the till of the Triassic-rock area consist of sandstone, these larger fragments are more commonly basalt or diabase despite the fact these latter rocks occupy a far smaller aggregate area within the quadrangle than do the sandstones. The anomaly results from the fact that the diabase and basalt bodies are cut by joints that transect them in various directions, and in some places the joints are widely spaced. This permitted the invading glacier ice to tear away large chunks of these rocks. In contrast, the sandstones, being more friable, were more readily crushed and disaggregated, despite the presence of well-developed joints in some of them.

Although till is not stratified, in a few places it has distinct fissility consisting of closely spaced, subparallel partings that are also approximately parallel with the ground surface. The origin of this structure is not well understood.

It is generally known that at many localities the long axes of stones in till have a preferred orientation that gives the till a distinct fabric. A statistically significant proportion of the stones commonly lie with their long axes paralleling the direction of flow of the glacier as inferred from striations and other indications. Three fabric measurements were made during study of the till in the Branford quadrangle; their locations are shown on the map (pl. 1). All three have a northeast-southwest orientation, in general agreement with the average trend of the striations; yet two of the

[2] Colors are described according to the Munsell rock-color system (Goddard, 1948).

three have a greater easterly component than has any of the striations.

*Stratigraphy and correlation.* In the Mount Carmel quadrangle, northwest of the Branford quadrangle, two distinct till sheets (Lake Chamberlain till and Hamden till) have been identified (Flint, 1962, p. 9). These tills, and striations related to them, record a glacial flow in a direction nearly north to south followed later by flow in a direction northeast to southwest. In the Branford quadrangle no basis was found for assigning the till exposed at any place to more than a single till body. That body is believed to be equivalent to the Hamden till of the Mount Carmel quadrangle. If, as seems likely, the Lake Chamberlain till is present in the Branford quadrangle, probably it lies buried in some of the deeper valleys and has not yet been uncovered by natural erosion or artificial excavation.

A variety of indirect evidence suggests that correlation of the Hamden till with at least part of the classical Wisconsin drift in the Great Lakes region is probable. If this correlation is correct the Hamden till dates from the latest major glaciation of United States territory. Many radiocarbon dates agree in placing that glaciation between about 25,000 years ago and about 10,000 years ago. What part of that period of about 15,000 years is represented by the Hamden till is not known.

## Erratic boulders

Erratic boulders, consisting of rock that differs from the bedrock underlying the boulders, are found in the quadrangle. Some lie free on the surface whereas others are partly imbedded in till. Many boulders 4 to 6 ft in longest diameter occur, but only those 10 ft or more in longest diameter are shown on the map. Of these 15 were recorded, 8 being diabase or basalt, 6 granitic rock, and one sandstone. Not unnaturally all 8 granitic boulders lie southeast of the southeast limit of the Triassic rocks. However, four of the diabase/basalt boulders lie on granitic rocks, and the remaining two on sandstone. The single sandstone boulder overlies sandstone of a different kind.

The chief factor that determines the maximum diameters of boulders is the spacing of joints and stratification surfaces in the parent bedrock. In much of the area of granitic and gneissic rocks and locally in some of the diabase/basalt bodies (notably the Holyoke basalt which underlies Saltonstall Ridge and Totoket Mountain) joints are widely spaced. This explains why 14 of the 15 largest boulders observed were derived from those rocks. In the Triassic sandstone, beds are rarely as much as 10 ft thick and joints are spaced more closely. It is not surprising therefore that only one boulder of this rock type, as much as 10 ft in diameter, was encountered, although boulders 2 to 4 ft in diameter are rather common.

## STRATIFIED DRIFT

*Kinds of stratified drift.* The sorted and usually stratified sediments that have been deposited in streams of water derived from melting glaciers, and in other water bodies as well, are collectively known as stratified drift. Some stratified drift is merely reworked and redeposited till. In the Branford quadrangle stratified drift is of two kinds, constituting the two end members of a gradational series. At one end is the drift deposited in contact with melting ice near the glacier margin. At the other end is the drift deposited by streams flowing away from the glacier, miles or tens of miles from the glacier in which it originated. The sediments are the same, although like all stream sediments they become finer grained and otherwise better sorted in the downstream direction. But as long as ice, residual from the glacier, is present beside or beneath the accumulating stratified drift, the drift will have characteristics that betray its peculiar place of deposition, and is labeled *ice-contact stratified drift.* Downstream from the point where the meltwater stream has passed over the last remnant of buried ice, the sediment will have different characteristics and is labeled *outwash,* although it is essentially the same body of sediment.

We define ice-contact stratified drift, then, as sediments deposited in streams and other bodies of water against, upon, beneath, or otherwise in immediate contact with melting glacier ice. Such sediments (pl. 3, A) include sand, gravel, silt, and clay, and commonly possess one or more of these characteristics: great internal variability; poor sorting; large and abrupt changes in grain size both vertically and horizontally; inclusion of small bodies of till, erratic boulders, or flowtill;[3] deformation of sedimentary laminae by subsidence or other displacement activated by melting of underlying or adjacent glacier ice.

Rounding of individual particles, although highly variable, is commonly slight or only partial. In addition, ice-contact stratified drift has, in places at least, constructional topography that includes basins (known as kettles), partial basins, and knoll-like mounds. These features reflect the presence of irregular bodies of melting ice during accumulation of the drift.

In contrast, outwash is defined as stratified drift deposited by streams beyond the glacier and free of obvious influence of buried ice. It is characterized by lenticular beds each consisting of parallel laminae dipping downstream. Range of grain size is relatively small (most outwash consists of sand and pebble sizes), and stratification is more regular and systematic than in ice-contact sediments (pl. 2,B; 3,B).

In the Branford quadrangle are several bodies of stratified drift that consist of one or both of the kinds described. They are discussed, as physical units, in the following sections. Figure 4 (in

[3] Till-like sediment deposited by landsliding off adjacent ice.

pocket) shows the extent of each unit and figures 5 and 6 (in pocket) show the long profiles of some of them. Two of the drift bodies, being elongate and confined to specific valleys, are referred to as *valley trains*, notwithstanding the fact that the literature commonly applies this term to bodies of drift said to consist exclusively of outwash.

*Farm River valley train.* The name Farm River valley train (fig. 5) is used to refer to the much-dissected body of sand and gravel that extends down the Farm River from above Northford, on the Wallingford quadrangle, through the Branford quadrangle to East Haven, and thence southeasterly to Long Island Sound at Morris Cove on the New Haven quadrangle. In length this unit is about 13 mi. overall. It descends from an altitude of 250 ft at its head to about 15 ft at Morris Cove. Its average slope is 18 ft per mi.; in the 7-mi. segment from Totoket to Morris Cove, where its profile is not affected by buried glacier ice, its slope is 13 ft per mi. The width of the body varies from 0.4 mi. at the northern edge of the quadrangle to 0.9 mi. near Pages Mill Pond, narrows to 0.2 mi. just north of the Connecticut Turnpike, and widens again to 1.7 mi. between East Haven and Morris Cove. These variations are controlled by the width of the Farm River valley, down which the valley train was built.

This body of sand has been dissected by the Farm River and its tributaries to form a pair of terraces, between which the river flows on an alluvial plain of variable width. Dissection has removed a substantial proportion of the sediment, some of which has been reworked to form alluvium. Original thickness is unknown, inasmuch as the base of the sediment is concealed except near the sides of the valley where it is thin. The maximum thickness seen in any pit exposure was about 20 ft. However, a boring made in 1937 by the State Highway Department for the U. S. 1 Highway bridge over the Farm River penetrated 30 ft of outwash sand and then bedrock directly beneath it. Another boring made in 1957 where Maple Street, East Haven, crosses the Farm River, penetrated 52 ft of outwash sand without reaching the base of that body.

The Farm River valley train has two distinct facies. From its head downstream to the vicinity of Foxon Pond it consists of ice-contact stratified drift, whereas from Foxon Pond to the Sound it consists of outwash. This composite nature implies that while the valley train was accumulating, masses of ice residual from the glacier, most of them buried, continued to occupy the valley of Farm River as far downstream as Foxon Pond. Drift, including large boulders, slid off or melted out of the ice on to the sand and gravel of the valley train and became incorporated in it. Sand and gravel that had been built against slopes and walls of ice slumped down as the ice melted away. The melting of deeply buried ice caused the sand and gravel overlying it to subside, collapsing the valley train. In the segment upstream from Totoket collapse of this kind created a great variety of constructional topography in the form of gentle knolls, hummocks, and basins now containing swamps. The exceptionally wide body of alluvium half a mile upstream from Pages Mill Pond is believed to be essentially a collapse basin now drained by Farm River and partly filled with alluvium.

In 1961 and 1962 the characteristics of the ice-contact facies of the valley train were well exposed in the Cinque Brothers' gravel-pit face, 18 ft high and 200 ft long, on the south side of a large knoll 0.4 mi. north of the intersection of Village Street and Augur Road in North Branford. Uniformly stratified sand and gravel alternated with collapsed sediments, contorted and faulted strata, dumps of boulders, and erratic boulders up to 10 ft in diameter, in a seemingly endless jumble (pl. 3, A). In the same years the characteristics of the outwash facies were exposed in the East Haven Town pit off Maple Street, 0.4 mi. southwest of Foxon. There a face 20 ft high showed outwash (sand 85 percent; pebbles 15 percent) with beds, each a few inches thick, of foreset laminae dipping southwest down the valley (pl. 3, B). Such beds record the former presence of a braided stream consisting of many small interlacing channels, such as characterize proglacial streams in regions where glaciers still exist. No evidence of disturbance by slumping or collapse was present in the exposure.

Downstream from Foxon Pond no evidence of buried ice was seen. From Totoket to Morris Cove grain size diminishes progressively, with even small pebbles becoming very rare and most of the sand fraction becoming fine grained. The sediments of the entire valley train approximate moderate brown (5YR 3/4) in color and were derived from Triassic rocks, mostly sandstones. Clearly most of the sediments were contributed from the area upstream from Totoket, including the southeastern part of the Wallingford quadrangle. Nothing seems to have been contributed from the valley of Lake Saltonstall, which at that time also apparently contained a lake. Almost nothing was contributed to the southern end of the valley train from the local granitic rocks.

Where the proglacial Farm River emerged from narrow confinement between Saltonstall Ridge and the ridge of basalt to the west, it built an alluvial fan having an apex near the Old Stone Church. The fan slopes radially, southeast toward the East Lawn Cemetery and the Gillis School, and also (on the New Haven quadrangle) southwest past the New Haven Airport, and northwest toward Turnpike Interchange 51. When, later, the braided proglacial stream was converted into the single-channel Farm River, the radial fan slope was steep enough to lead the river from the site of the Turnpike crossing southeast to the East Haven River, the course it still follows. The main body of the fan is without surface drainage; no doubt this condition has existed since upbuilding came to an end. Postglacial dissection has cut away the outwash extensively between East Haven and the Gillis School. The cut-away part is now covered with tidal-marsh peat.

*Branford River valley train.* The Branford River valley train is shown in figures 4 and 6 (in pocket). It originates in the Guilford quadrangle about 0.7 mi. east of the eastern limit of the Branford quadrangle and occupies the valley of Munger Brook downstream to North Branford, where that brook joins the Branford River. For the next mile downstream the river occupies a narrow gorge in granitic rocks and the drift body is not present, having been completely removed by postglacial erosion. At the mouth of the gorge the valley train resumes, and has tributary arms that occupy the valley of Notch Hill Brook and the unnamed valley followed by the New Haven Traprock Company's railroad. This segment of the drift body is succeeded downstream, in the rocky terrain surrounding Wards Mill Pond, by another discontinuity. Downstream from the pond the valley train resumes but is indistinct. Between the Branford River and U. S. Route 1A it is represented by low terrace-like forms, but at and downstream from Branford these are not traceable, having been cut out by erosion.

The valley train is of ice-contact character from its head downstream as far as it can be traced, but in the downstream direction knolls and kettles become less conspicuous, grain size diminishes to sand and small pebbles, and sorting increases. Throughout, most of the valley-train sediment is derived from Triassic rocks despite the fact that the greater part of the body overlies granitic and gneissic rocks.

*Pine Orchard body.* The Pine Orchard body of stratified drift occurs in two parts, both of which are of ice-contact character and are rich in sediment of Triassic origin. A southern part heads near and east of Griffing[4] Pond and leads south through two valleys, each of which subdivides so that the stratified drift crosses the site of today's shoreline along four parallel routes. The character of the surface is seen best on the golf course of the Pine Orchard Club, where it has been very little dissected. A northern part, separated from the southern by a rocky narrows, occupies the unnamed valley followed by the Traprock railroad from the vicinity of Gould Road southward through about 0.8 mi. At its northern end it is continuous with the Branford River valley train, toward which it slopes northward. The slope is believed to be at least in part the result of collapse over buried ice. Deposition of the Pine Orchard body may have begun when the valley of Branford River, immediately north of that body, was still covered by the margin of the glacier. Possibly later the waters which built the valley train down Munger and Notch Hill Brooks were flowing over ice sufficiently thick to block the valley of Branford River and divert them southward to Pine Orchard. This could explain the large amount of Triassic sediment in the Pine Orchard stratified drift. Whether or not this occurred, the final development of the Branford River valley train must postdate the Pine Orchard body because it has a lower altitude.

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[4] Erroneously labeled Griffin on the map (pl. 1).

*Sunset Hill body.* The Sunset Hill body occupies an unnamed valley between Sunset Hill and Damascus Road in Branford. It is of ice-contact character from end to end and is flanked on its western side by large kettles now occupied by swamps. It therefore has the character of a kame terrace. The body contains a large proportion of pebble gravel, stands higher than the Pine Orchard body, and in consequence is very likely slightly the older of the two.

*Branford-Indian Neck body.* The area along the lower part of the drainage basin of the Branford River, from the Branford Supply Ponds southward to Branford Harbor, includes a complex pattern of stratified drift. The moderately uniform internal character and gently undulating surface form of this drift suggest that its deposition was completed at a time when the immediate area had been extensively deglaciated and only thin scattered masses of residual glacier ice remained. The southern parts of it, north of Indian Neck and southwest of Branford center, stand slightly higher than the rest and may therefore be slightly older, but no clear contacts supporting this relationship were found.

The meltwater responsible for these deposits flowed at least in part down the valley of the lower Branford River and down Pisgah Brook, and spread part of the sediment (sand and pebble gravel) outward in a fanlike mass reaching from Tabor Cemetery to Talmages Ice Pond. The streams reached the site of today's Branford Harbor by several different routes, as can be seen in the reconstruction, figure 4. After this meltwater flow ceased there occurred some dissection of the stratified-drift body, which now stands some fifteen feet higher than the Branford River valley train (fig. 6). Such dissection is expectable, because by the time the valley train was built the margin of the thick continuous glacier had shifted northward several miles to the latitude of the head of the valley train.

The relative ages of the stratified-drift bodies described thus far, based on altitude and secondarily on grain size and surface form, are recapitulated as follows: (1) The Sunset Hill, Pine Orchard, and Branford-Indian Neck bodies are the oldest of the group and probably are nearly contemporaneous. (2) The Branford River and Farm River valley trains are younger and are likewise broadly contemporaneous, although building of the Farm River unit continued after the Branford River unit had been completed. (3) The Muddy River-Five Mile Brook body, described in a following section, is mainly contemporaneous with the Farm River valley train, but may be in part slightly younger.

*Muddy River-Five Mile Brook body.* Northwest of the units already described, in the drainage basins of Muddy River and its tributary, Five Mile Brook, is a large irregular mass of ice-contact stratified drift. It extends from the vicinity of Clintonville on the Wallingford quadrangle, through an area east of the Muddy River, and southward in the Branford quadrangle to the headwaters of a branch of Five Mile Brook south of Arrowdale Road. Within the

Branford quadrangle this drift is thin; hills of till-mantled bedrock project through it. Its surface is primarily one of smooth, unsystematic undulations, which include low knolls and shallow basins. This surface is thought to be primarily the result of gradual collapse of the drift brought about by slow melting of glacier ice buried underneath it. Two narrow ridges of sand and gravel, the longer one about half a mile long, each trending northeast-southwest between Five Mile Brook and North Hill Road,[5] well delineated by contours on the map (pl.1), are probably the fillings of former tunnels or open channels in thin glacier ice. A similar feature occurs just west of Eight Mile Brook 0.3 mi. south of the northern edge of the quadrangle.

Associated with this drift body is the area of lake-bottom sediments centered at the west end of Arrowdale Road and described in a following section.

*Unnamed bodies of ice-contact stratified drift.* In addition to the ice-contact drift bodies already described, there are in the quadrangle a few small and undistinguished units of similar character. These occur (1) along Pisgah Brook, (2) along Augur Road at the North Haven-North Branford town line, and (3) at the New Haven Municipal Golf Course.[6] In addition to these bodies there are two related areas of such drift in the northeast corner of the city of New Haven, at the extreme western edge of the quadrangle. This drift, primarily sand and locally much eroded so that it no longer retains its original constructional surface, extends up to an altitude of more than 100 ft on Crow Hill, the high rocky hill west of Quinnipiac Avenue. This is believed to be a rather early deposit or possibly series of deposits, built originally in the form of a kame terrace, at a time when the Quinnipiac Valley at this latitude was partly filled with glacier ice, and when drainage from the exposed country to the east was flowing southward between the ice and the steep eastern side of the valley. However, as the original top of the accumulation of sediment has been destroyed by erosion, few inferences can be drawn from what is left. Also, some of the drift in this outcrop area, at altitudes lower than 50 ft, might be part of the Muddy River delta described in the following section.

*Muddy River delta.* Along the two-mile segment of the Muddy River immediately upstream from its mouth there is developed an extensive body of sand with subordinate gravel, here called the Muddy River delta (fig. 4). This body, with an area of more than two square miles, not only occupies the outcrop area shown on the map as delta sediments but also underlies areas of outwash sediments, alluvium, terrace alluvium, and swamp deposits shown in the northwest corner of the map and extends through short distances into the adjacent Wallingford, Mount Carmel, and New Haven quadrangles. The western edge of this body is shown as a straight

[5] Incorrectly labeled Velvet Street on the map (pl. 1).

[6] Incorrectly labeled New Haven Country Club on the map (pl. 1).

line, because it has been so thoroughly obscured by cutting and filling in the railroad yard and the adjacent clay pit that the actual boundary could not be determined. The delta sediments overlie till and bedrock in some places; in others they overlie the margin of the Muddy River-Five Mile Brook body of stratified drift.

The delta sediments are characteristically stratified in the form of foreset beds (pl. 4, A) grouped in units that overlap and cut across each other. Many of these units are as much as 20 ft thick, and one of them has a thickness of nearly 25 ft. The foreset beds dip at angles ranging generally between 15° and 25°. Direction of dip is predominantly west and southwest (the down-valley direction) but local dips in other directions occur (fig. 4). In at least three places delta lobes, marking the positions of distributary channels, were represented by radial dips of foreset beds. The inferred lobes were 100 to 200 ft in diameter. In places the foreset units are interbedded with thin units consisting of nearly flat-lying, gently crossbedded sand and pebbles.

The body as a whole evidently varies greatly in thickness, reflecting the irregularities in the floor that underlies it. At the Elm City Construction Company's pit, 0.8 mi. northwest of Montowese, thickness exceeds 120 ft and the sediment extends at least 62 ft below sea level.

Composition is mainly sand, principally of medium- and fine grain size. Small pebbles occur in some of the sand beds; some exposures show beds of pebble gravel and others show interbedded silt and clayey silt. The foreset beds constituting any one unit are generally parallel. Ripple-laminated beds (pl. 5) occur in a number of exposures. Although disturbance of stratification, caused by subaqueous sliding, is present it is not common, possibly because silt is only a minor constituent of the sediment.

Exposures in the eastern and northern parts of the Elm City pit and in the extreme northern part of the Cedar Hill Yard of the New Haven Railroad show bodies of diamicton (Flint, Sanders, and Rodgers, 1960), 1 to 4 ft thick, interbedded with some of the flat-lying, crossbedded units (pl. 4, B). A diamicton is a sediment that contains a wide range of particle sizes and that lacks sorting and stratification. Till is one kind of diamicton. Although the bodies of diamicton in the Muddy River delta resemble till, they are not of glacial origin, as shown by the following observations: (1) Some of them contain very little silt or clay. (2) Many of the pebbles and cobbles they contain have shapes and surfaces that suggest transport in water rather than in ice. (3) In places a diamicton grades downward, upward, or laterally into stratified sediment. (4) The diamictons appear to be lenticular, with limited horizontal extent.

Whereas the specific manner of deposition of the diamicton bodies is not known, it seems likely that they represent turbidity currents or subaqueous earthflows, or both. They may have flowed through abandoned channels in the delta, and their points of origin may have been places where steep channel sides caved and slumped. More information than could be drawn from the available exposures, as to the shapes of the diamicton units, would be needed to fix their origin more precisely.

In addition to the diamictons there are scattered erratic pebbles, cobbles, and boulders, at least two of the latter being as much as 5 ft in diameter. These erratics are rare in the foreset sands and occur mainly in the layers of silt and clayey silt. They are thought to have been rafted out on floating ice and dumped into position during melting of the ice. The rather small number of erratics and the absence of compelling evidence of drag deformation of the inclosing sediment, such as would be caused by the grounding of bergs, lead to the inference that the floating ice need not have consisted entirely of icebergs derived from the glacier. It could have included small pans of lake and river ice formed during winter seasons and broken up and dispersed during spring and summer. The delta therefore is not necessarily of ice-contact character. Probably it was built after deglaciation of the area it occupies. The absence of kettles and the lack of evidence of collapse in the upper surface of the delta would seem to support this opinion, but could be merely the result of extensive erosion. There is reason to believe that the upper surface of the delta is not its original surface but has been planed off by post-delta streams. At every place where the delta sediments were seen exposed extensively, including four of the highest places on the surface of the delta, the topset beds which every delta possesses were missing; the foreset beds extended up to the surface and were cleanly truncated. The four localities and altitudes are: Elm City Construction Co. pit, Montowese, 60 ft; former pit of New Haven Railroad, north end of Cedar Hill Yard, 0.2 mi. south of Sackett Point Road at west edge of Branford quadrangle, 50 ft; former pit of Webb Asphalt Paving Co., 0.4 mi. southeast of the North Haven High School, 55 ft; sand pit west of Elm Street, North Haven, 0.2 mi. north of the north edge of the Branford quadrangle, 50 ft. It is concluded that the original upper surface of the delta is not exposed in section, although it is possible that that surface stood no more than 10 ft above the highest existing surface in the vicinity of the Elm City pit. Probably the original surface was removed by meltwater streams during the deposition and subsequent erosion of the Quinnipiac Valley outwash sediments described in a subsequent section.

The sediments of the delta consist almost entirely of particles derived ultimately from the local Triassic sandstones and basaltic rocks. They were deposited by the Muddy River, which was carrying sediment resulting from erosion of ice-contact stratified drift, till, and bedrock. Whether the river at that time was proglacial, or postglacial in the narrow sense, is not certain because upstream the delta has not been differentiated from adjacent ice-contact stratified drift. At any rate the delta postdates at least some drift of the latter kind and antedates the Quinnipiac Valley outwash.

Closely related to the delta is a body of fine-grained lake-bottom sediments in the Quinnipiac Valley. The relationship is described in the section immediately following.

*Lake-bottom sediments.* Four areas within the quadrangle are underlain by lake-bottom sediments having a reddish or brownish tinge indicative of derivation from the Triassic rocks. The most important of these three areas is in the northwest corner of the quadrangle, where five small outcrop units are shown on the map. All five are situated in sand or clay pits and are exposed only by virtue of artificial excavation. Prior to about 1948 there were also exposures 0.6 mi. southwest of Montowese in the Montowese Brick Co. pit, now abandoned and occupied by a pond.

All these exposed sediments constitute a small part of a single body, the New Haven clay (Flint, 1933, p. 968) which extends continuously up the Quinnipiac Valley from near the south end of the Cedar Hill Yard on the New Haven quadrangle to at least North Haven on the Wallingford quadrangle.

The New Haven clay consists, in order of decreasing abundance, of silt, clay, and fine sand, in general color moderate brown (5YR 3/4). The sediment is stratified in parallel layers a fraction of an inch to two inches in thickness. Many of the layers are couplets consisting of a silt layer grading up into a thinner clay layer. The couplet is then abruptly overlain by the silt layer of the next couplet. A sequence of such couplets implies deposition by a rhythmic or at least frequently repeated natural process. It has been inferred (Antevs, 1922, p. 1) that the couplets are varves; that is, that they are rhythmic and that the period of the rhythm is one year. The sediments are held to have been deposited in a glacial lake by meltwater flowing from a glacier at the northern end of the lake. The silt fraction was deposited during the spring and summer thaw; the clay fraction was kept in suspension until the lake froze over in the autumn and wave agitation ceased; then it settled out on to the bottom, ready to be covered by silt during the ensuing spring thaw. The New Haven clay shows little evidence of deformation by ice, either in glaciers or bergs; but a few erratic pebbles and cobbles found imbedded in it were probably dumped from floating ice.

Without question the sediments accumulated in a lake fed in part by meltwater, but whether glacier ice was in contact with the lake throughout its existence is not known. More likely, during the later history of the lake, meltwater entered the lake via proglacial streams. At any rate the presence of the bulky Muddy River delta shows that a sizable side stream helped to feed the lake after glacier ice had melted away from the immediate vicinity.

The thickness of the New Haven clay within the Branford quadrangle is known only from borings, for its base has never been exposed. Thicknesses as great as 16 ft have been observed in the past (Antevs, 1928, p. 185) but the total thickness is probably much greater. Only about 8 ft can be measured in today's thickest exposure, on the north side of Bruces Ice Pond. Seven borings made by the State Highway Department in 1960, adjacent to the southwestern part of the abandoned pit of the Montowese Brick Company, showed thickness varying between 80 and 100 ft, with increasing proportion of silt and fine sand toward the base. The sediment at that locality directly overlies bedrock.

The New Haven clay grades laterally through a facies of silt and fine sand into the foreset sand of the Muddy River delta. This relationship was exposed in 1947 and 1948 in the eastern part of the Montowese Brick Co. pit; the exposure establishes that delta and clay are contemporaneous. Later in 1948 continued excavation in the pit showed about 8 ft of New Haven clay lying against a lobe of the delta, with foreset beds dipping 18° SW. The two exposures, combined into an idealized sketch diagram, are shown in figure 7. The relations shown are those of an active distributary lobe of a delta, built of sandy foreset beds with bottomset beds developing beyond it. Later the lobe was abandoned, and bottomset beds related to other distributaries accumulated against it, without break in bottomset sedimentation.

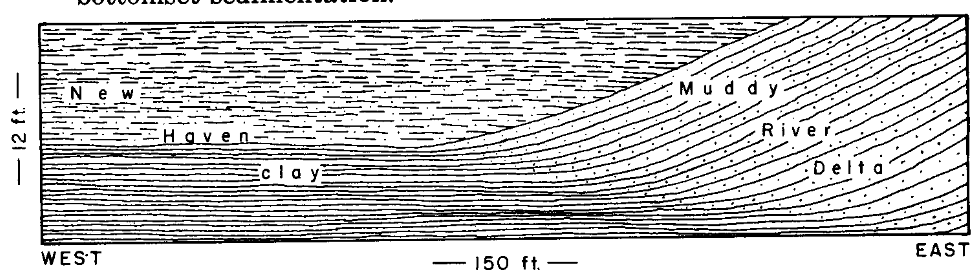


Fig. 7. Idealized sketch diagram showing relation between a distributary lobe of Muddy River delta and New Haven clay, exposed in Montowese Brick Co. clay pit, 1947-48 (from field notes and sketch by R. F. Flint).

The original top of the lake-bottom sediments has not been seen; in every exposure the sediments are overlain unconformably by a younger unit. However, at localities on the west side of the Quinnipiac Valley in the New Haven quadrangle, the typical rhythmic silt-clay sequence grades upward into thicker bedded, rhythmically layered silt and sand, the sand resembling that of the Muddy River delta. Probably these sediments, at altitudes between −10 ft and +10 ft, are not far below the local position of the lake bottom; if so the lake there must have been at least 60 ft deep.

If the sedimentary couplets are truly varves, then the lake must have endured at least 364 years, as can be inferred from the counting of exposed couplets (Antevs, 1928, p. 184), plus an unknown and probably much greater time represented in underlying clay that has never been either exposed or core sampled.

Although none has been reported from the Branford quadrangle, fossil leaves of tundra plants have been found in the New Haven clay in the New Haven quadrangle. This indicates that an arctic climate prevailed in the area during the existence of the lake.

The second of the four bodies of lake-bottom sediments exposed in the Branford quadrangle lies in the headwaters of Five Mile Brook and centers at the intersection of Arrowdale Road with North Hill Road in North Haven. Its surface is nearly flat. There are no exposures, and information on the sediments was obtained solely by auger borings. The body consists of brown silty clay grading downward into sandy silt and fine sand; the sediments contain erratic pebbles. Contact with till on the southwest and ice-contact stratified drift on the north and northeast is abrupt as well as topographically distinct; hence the lake-bottom sediments are younger than the surrounding drift. Probably collapse of the Muddy River-Five Mile Brook drift body, described in a foregoing section, created a shallow basin in which a lake formed and sediments accumulated. The lake had an outlet at its northwest end; this is still the path of Five Mile Brook today.

Occupying the headwater area of the small stream that joins Farm River 0.1 mi. downstream from Pages Mill Pond is a third body of lake-bottom sediments. Smaller than those described above, it is the clay-silt half of a larger body. The northern half consists of sand. The two halves, related gradationally, together form a plain sloping gently southward and lacking ice-contact characteristics. They occupy a shallow basin in till. Evidently the basin contained a shallow temporary lake which filled with sediment from its northern end. Probably the lake was contemporaneous with its neighbor a mile to the west.

The fourth and smallest body lies in the northwest corner of New Haven, in the Bishops Woods residential section east of Quinnipiac Avenue. It occupies a pocket in bedrock at altitude about 120 ft. The pocket opens toward the north. Exposures made during construction in 1960 showed flat-lying, parallel-laminated silt and fine sand at least 12 ft thick, directly overlying bedrock. The sediment represents a small ephemeral glacial lake, formed when the melting glacier had uncovered the pocket but still constituted a blockade at its northern end.

*Quinniuiac Valley outwash sediments.* In the northwestern part of the quadrangle distinctive yellowish sand with pebbles constitutes remnants of a once-extensive body of outwash sediments that partly filled the Quinnipiac Valley and subsequently was largely destroyed by erosion. It overlies ice-contact stratified drift, sediments of the Muddy River delta, and the New Haven clay. This Quinnipiac Valley outwash lacks the hematite that is chiefly responsible for giving the other surficial sediments in the quadrangle their reddish color; its color is yellowish gray (5Y 7/2). In places, where mixed with reworked local reddish sediments, it is reddish gray (10YR 5/4 to 7R 4/2). Furthermore, it contains a mineral assemblage different from that of the Triassic rocks but characteristic of the rocks exposed in the drainage basins of the Pequabuck and Farmington Rivers in the Western Highland (Krynine, 1937). It is extensively exposed in the Wallingford quadrangle (Porter, 1960) and is nearly continuous up the Quinnipiac Valley to the place, about 30 mi. north of the Branford quadrangle, where the Farmington River enters the Central Lowland.

The Quinnipiac Valley outwash has cut-and-fill stratification and other fluvial cross lamination (pl. 2, B). It was built up by a braided proglacial stream, constructing a valley train resembling the down-valley portion of the Farm River valley train, but much larger. In places near the valley margin it is unusually fine grained and parallel laminated, suggesting local shallow ponds along the margins of the accumulating stream-laid sediment. Apart from these places there is no evidence in the stratification of the outwash that the sediment was built into a lake. On the contrary, remnants of the Muddy River delta formerly exposed along Sackett Point Road in the New Haven quadrangle are clearly trenched by stream channels filled with the outwash. On this evidence it is concluded that the lake had ceased to exist before deposition of the outwash began.

Two outcrop areas of Quinnipiac Valley outwash are shown in the map. The larger is a group of areas northwest of the Muddy River, forming a terrace at about 35 ft. The outwash itself, however, is no more than 10 ft thick. The smaller straddles the New Haven-North Haven boundary line east of Quinnipiac Avenue and north of Glen Haven Road. It occupies a north-facing pocket in bedrock and has an altitude of nearly 60 ft. Also, between 1932 and 1939 this sediment was exposed, with a thickness of 13 ft, in the Montowese Brick Company pit, but it is now concealed. It also underlies parts of the area mapped as terrace alluvium in New Haven and North Haven. In 1962 a lacustrine facies of it, 65 ft long and 9 ft thick, was exposed in a building excavation in the southeast intersection of Quinnipiac Avenue and Foxon Hill Road, New Haven, at altitude 40 ft.

Two remarkably high exposures of this peculiar sediment are on record. One is at 1601 Quinnipiac Avenue, 0.2 mi. south of Foxon Hill Road, where in 1937 and 1938 a 20-ft thickness was exposed, with its top at altitude 78 ft. Subsequently the exposure was cut back more than 50 ft, so that in 1961 only a remnant, 56 in. thick, overlying bedrock at 78 ft, remained. The other exposure existed during the construction, in 1961, of the Fairview Gardens housing project on the west side of Easton Street, New Haven (New Haven quadrangle), at altitude about 85 ft. The section exposed there consisted of fine sand of Quinnipiac-outwash type grading downward into red silt and overlain by till. Another high exposure occurs on the west side of the Quinnipiac Valley in the New Haven quadrangle.

From the known data within the Branford quadrangle it is not possible to fix the position of the top of the former valley train.

The broad surface underlain by outwash sediments northwest of the Muddy River is not the top of the outwash, but is a terrace surface planed across those sediments by later stream erosion. However, it is mapped as underlain by outwash because the surficial part of the sediment beneath it, consisting of sand without stratification, possibly in part eolian and in part fluvial, is less than 3 ft thick and is therefore not mappable separately. The valley train, of which extensive remnants remain, had a higher profile before dissection than that reconstructed for it within the Wallingford quadrangle (Porter, 1960, p. 26). Possibly valley-train sediments of more than one age are involved.

*Sand and gravel, undifferentiated.* Two small bodies of sand with pebbles are designated on the map as sand and gravel, undifferentiated, because the conditions under which they accumulated are not clearly evident. One, occupying the headwater area of the small stream that joins Farm River 0.1 mi. downstream from Pages Mill Pond, is gradationally related to a small body of lake-bottom sediments described in a foregoing section. Probably it dates from the time of deglaciation of the locality.

The other body lies 0.1 mi. east of Thompson Road, East Haven, where that road skirts two small ponds. It may be related in time to the ice-contact stratified drift with which it is contiguous, or it may be postglacial.

## POSTGLACIAL SEDIMENTS

### *Terrace alluvium*

Alluvium consisting chiefly of pebbly sand constitutes thin veneers on the surfaces of some stream terraces within the quadrangle. It is therefore designated terrace alluvium (pl. 2, B). It overlies, at various places, ice-contact stratified drift, delta sediments, New Haven clay, and outwash. Its maximum thickness rarely extends to 5 ft. Where it overlies New Haven clay the surface of contact is sharply defined, but the contact between terrace alluvium and underlying sand or gravel is vague, especially in places where the alluvium is less than 3 ft thick. Exposures of Quinnipiac Valley outwash commonly show a surface zone 2 to 4 ft thick, which lacks stratification and which grades down into stratified outwash. Very likely this surface zone is in part terrace alluvium derived from the outwash and in part wind-blown sand. The vagueness of its basal surface can be attributed to growth of roots, burrowing organisms, freezing and thawing, wind-throwing of trees, and agricultural activity.

In all exposures the sediment is not compact, and color normally ranges between light brown (5YR 6/6) and dark yellowish orange (10YR 6/6), according to the character of the underlying sediments from which much of the terrace alluvium was derived.

The stream terraces on which the alluvium occurs are cut from the Quinnipiac Valley outwash and older sediments. In places along the Muddy River, and along the Quinnipiac River in the Wallingford quadrangle, the inner margins of the terraces form the bases of meander scarps. Hence terrace cutting and deposition of terrace alluvium occurred after the outwash was deposited and after the regimen of the Quinnipiac River had changed from one of braiding to one of meandering, its present habit. Probably the change marks the transition from glacial to postglacial in a broad sense, when glacial meltwater ceased to enter the head of the Quinnipiac River, leaving the river dependent on local rainfall for its supply of water.

If terraces exist along the Farm River and smaller streams within the quadrangle, they lie only a few feet above the floodplains and have not been distinguished from them. Hence the map shows alluvium, but not terrace alluvium, along those streams.

### *Alluvium and colluvium*

Alluvium, ranging in grain size from cobble gravel to silty sand, occurs on valley floors and in stream channels throughout the quadrangle. The coarsest alluvium is found along small streams having steep gradients; the finest along streams of gentle slope. Although most of the sediment mapped as alluvium lies on floodplains, which are inundated at times of high water, some may overlie very low terraces, not inundated under existing regimens.

The Quinnipiac River, by far the largest stream within the Branford quadrangle, has no mapped alluvium associated with it. Submergence of the river's mouth beneath the sea has drowned whatever alluvium was formerly at the surface and has resulted in the building of a body of swamp deposits on the floor of the valley. Of course these deposits include alluvial silt brought to them by the river and trapped by the swamp vegetation, but all such material is mapped as swamp deposits.

The lithologic character of the alluvium varies with that of the local bedrock. As the sediment is very poorly exposed its thickness is not known; in most places it is probably less than 5 ft thick. At some points along the bases of steep slopes alluvium is overlain by or is interbedded with colluvium that has crept or washed down the slopes.

As it is very discontinuous and mostly very thin, colluvium is included on the map either with alluvium or with bedrock, except for conspicuous bodies of sliderock in the form of taluses. These are aprons consisting of angular blocks of diabase or basalt that mantle parts of cliffs and that have been formed since deglaciation, mainly by seasonal freeze and thaw in joints within the bedrock. Examples are seen on the west slope of Rabbit Rock, the west slope of the ridge east of Clintonville Road in East Haven, and along the northwest slope of Saltonstall Ridge south of Foxon. Small taluses occur also in at least two large quarries, but these are not mapped.

### *Wind-blown sand and silt; ventifacts*

A thin cover of sediment believed to have been deposited by the wind is present discontinuously over parts of the quadrangle, mainly in the vicinity of the Quinnipiac, Muddy, and Farm Rivers. In most places it is less than 2 ft thick, and rarely exceeds 3 ft, although at one place on the east side of the Farm River valley a thickness of 9 ft overlying sand and gravel was exposed in 1961. The sediment is generally sand or silty sand without stratification. Its color in Farm River valley exposures is light brown (5YR 6/4) and in the Quinnipiac Valley dark yellowish orange (10YR 6/6). In most exposures it is included within the modern soil profile. It occurs overlying Quinnipiac Valley outwash, sediments of the Farm River valley train, and terrace alluvium, but has not been seen on alluvium. Therefore it is believed to antedate the alluvium.

The general cover of wind-blown sediment described is not shown on the map because it is very thin and occurs in poorly defined patches. However, four sand dunes are shown near the northwest corner of the map. These are low, gently sloping mounds of irregular shape and with a maximum height of 6 ft, and consist of medium sand of grayish orange (10YR 7/4) color. In the only exposed section (in the dune 0.3 mi. south of the North Haven High School) no stratification was seen through an 8-ft thickness. There the dune sand overlies, with moderately distinct contact, Quinnipiac Valley outwash, which in one part of the exposure is faintly darkened, suggesting an incipient soil zone that antedates the dune. Lack of visible stratification perhaps reflects the narrow range of grain size in the sand.

The wind-blown sand in both dunes and thin mantle is believed to have accumulated mainly during the building and the beginning of dissection of the outwash valley trains. Possibly it may have been added to at unusually dry times of still later date. The shapes and orientations of the dunes tell nothing significant about wind directions at the time of building.

At several localities ventifacts (pebbles, cobbles, or boulders faceted or polished by the abrasive action of wind-blown sand and silt) are imbedded in the eolian sediments. Probably the abrasion occurred during the general period of eolian deposition. Wind directions cannot be learned from the orientations of facets on the stones because the ventifacts have been moved and in some instances completely overturned, possibly by wind-throwing of trees, freezing and thawing, and similar activities.

### *Swamp deposits*

Swamps occur in many parts of the Branford quadrangle and have an aggregate area of more than two square miles. The deposits in them, which underlie the living swamp vegetation, consist mainly of muck, a dark-brown to black mixture of silt, clay, and fine sand with a high percentage of comminuted decayed plant matter, and also of peat, which is nearly pure organic matter. Such deposits in the small swamps are seldom more than 10 or 12 ft thick, but thicknesses beneath the larger ones are probably much greater. During construction of the Connecticut Turnpike in 1958 part of the large swamp east of Lake Saltonstall was excavated immediately west of Interchange 53. Muck, peat, and decayed wood there had a thickness of about 35 ft.

Swamps in the quadrangle are of at least five kinds: (1) Swamps occupying basins in till, for example the large swamp east of Lake Saltonstall. Underlain by peat and organic mud at least 35 ft thick, this swamp was formerly a lake. (2) Swamps in basins created by dams of ice-contact stratified drift, for example the swamp surrounding Cedar Pond in North Branford. (3) Swamps in kettles and in basins in collapsed surfaces; for example Totoket bog and its smaller neighbor, 0.3 mi. north of Totoket; also the swamp northwest of Sunset Hill. (4) Swamps that lie on valley floors but that do not occupy definite basins; they reflect conditions in which drainage is impeded by variations in the permeability of the floor material, including plant matter. An example is Burrs Brook, 0.3 mi. south of Totoket. (5) Tidal marshes, which are discussed later in this report. The tidal marshes and a few freshwater swamps such as Totoket bog are open, but most of the freshwater swamps in the quadrangle are forested.

The thicker swamp deposits preserve a fossil record of changes in vegetation and climate since the time when the glacier melted away from the area. Core borings taken from Totoket bog show that the swamp deposits there are at least 11 ft thick. Analysis of the fossil pollen at many levels in the cores has revealed the kinds and relative numbers of trees and other plants that grew in the vicinity throughout the period of accumulation of the peaty sediments. That period, which probably began shortly after deglaciation had uncovered the site of the bog, is believed from radiocarbon dates of sediments at the bottom of the bog, to have embraced at least the last 14,000 years (Deevey, Gralenski, and Hoffren, 1959, p. 146-147). At the beginning the vegetation was tundra and the climate was arctic; throughout the rest of the period mentioned the general trend of the climate was toward warmer and drier conditions but there were intermediate fluctuations (Leopold, 1955). The tundra at the bottom of the core is compatible with the presence of leaves of arctic plants in the New Haven clay. A postglacial sequence of climatic changes is recorded also from the organic fine sediment, at least 43 ft thick, beneath Linsley Pond (Deevey, 1939), and the sediment, 30 ft thick, beneath Cedar Pond (Deevey, 1943, p. 724), both in North Branford.

Tidal marshes constitute a special category among the swamps within the quadrangle. They do not occupy basins but occur at and upstream from the mouths of streams, and hence are open to the sea. In this quadrangle they are a result of submergence or "drowning" of the lower parts of valleys. The tides move in and out, creating an environment for the growth of plants, mostly grasses, specialized to brackish water. Within the quadrangle every valley or lowland that extends to the coast is floored wholly or partly with tidal marsh. Stream channels within the marshes normally have an intricate pattern of meanders, well shown in the marshes of East Haven River. In most of the marshes, however, the meandering channels have been replaced by straight artificial drainage ditches and are filling with vegetation.

The vegetation of the marshes grades upstream from plants specialized to salt water, through brackish-water varieties, into reeds, cattails, and other sorts characteristic of fresh water. The gradation is very irregular and patchy, so that it is not feasible to separate true tidal marsh from freshwater swamp by a line on the map. Consequently all swamps within the quadrangle are indicated by a single map convention.

The deposits of the tidal marshes consist of peat and peaty mud, and form crudely wedge-shaped bodies that thicken seaward to a maximum of 10 ft or less. Their seaward parts are underlain generally by gray, shell-bearing estuarine mud, their landward parts generally by alluvium. In the Quinnipiac Valley extreme high tides reach as far upstream as the northwest corner of the Branford quadrangle. The relations described indicate that the Connecticut coast has been undergoing gradual submergence by rise of sea level, subsidence of the land, or both.

### *Beach sand and gravel*

Sediments of modern beaches, consisting of sand and gravel, occur along many segments of the shoreline. The beaches are discontinuous and mostly short, and within the quadrangle their combined length is less than half that of the shoreline as a whole. The coast is rocky and the beaches consist of narrow crescent-shaped bands lying between pairs of rocky points. The longest and widest beach is Momauguin Beach, which like most others in the quadrangle, fronts an area of till. Where bedrock fronts the shore, beaches generally do not form. An exceptional beach on Kelsey Island, north of Darrow Rocks, fronts only a tidal marsh. Probably it first formed as a bar connecting two small rocky islands, before the area north of it became tidal marsh and created Kelsey Island.

The beach sediments rarely exceed a very few feet in thickness. They are maintained by a precarious balance between local erosion and deposition by surf and longshore currents, and are easily altered by the building of structures on the beaches themselves or on the points between them. This fact is being taken into account increasingly in the planning of construction programs, so as to protect what has become a valuable recreational asset.

### *Artificial fill*

Artificial fill, deposits made by human activity, include railroad, road, and building-construction fills and large accumulations of trash. Most of the fill material mapped in the Branford quadrangle was obtained from areas close to the fill bodies. Exceptions are some of the fill bodies along the Connecticut Turnpike, the material for which was brought from sources distant from the fills. The largest body of fill within the quadrangle connects the Turnpike with the Boston Post Road just west of Branford center; it consists of fills for railroad, roads, a Turnpike interchange, a housing project, and a shopping center.

In densely populated areas much of the surface material underlying streets, driveways, and lawns is fill. However, fill is mapped only where it is known or judged to be at least 5 ft thick and where it is large enough in area to be shown at the scale of the map. Areas of conspicuous artificial cutting that are continuous with areas of fill are mapped as fill.

## WEATHERING AND SOILS

Where the contact between bedrock and overlying till is exposed, the surface of the bedrock is fresh and unweathered, just as it was left after glacial abrasion. But in places where no till was deposited or where overlying till has been stripped away by erosion, the surface of the bedrock is slightly but noticeably weathered. In rocks of all kinds it is slightly roughened. In sandstones it is slightly bleached, in granitic rocks it is oxidized yellowish, and basaltic rocks invariably are covered with a thin rind, a small fraction of an inch in thickness, of brown limonite. These weathering changes extend down, well below the surface, along joints. This is the extent of postglacial weathering in rocks.

In glacial drift, wind-blown sediments, and terrace alluvium the most obvious effect of weathering is oxidation, which in most places is limited to a depth of about two or three feet. Oxidation gives a yellowish or brownish hue to the fine-grained particles in the drift and also forms rinds of limonite on basaltic stones. At greater depths the surfaces of basaltic stones are fresh. Within this thin zone of weathering, soils are developed.

The Branford quadrangle lies within the region of Brown Podzolic soils of northeastern United States. Brown Podzolic soils are imperfectly developed Podzols characterized, in forested areas, by a thin gray leached zone beneath a thin mat of partly decomposed organic matter. These soils, having weakly developed profiles, are normally less than 30 in. thick. In the Branford quadrangle there are eight chief soil types, some of the characteristics of which are set forth in table 1. As the quadrangle lies within a single zone of climate and vegetation, differences among its soils must result mainly from differences in parent material, relief, and drainage. Of these factors parent material is believed to be the chief. In table

Table 1. Characteristics of soils in the Branford quadrangle.

| Soil type | | Wethersfield soils | Cheshire soils | Holyoke soils | Gloucester soils |
|---|---|---|---|---|---|
| Parent material | | Compact till derived mainly from Triassic sandstones and siltstones | Coarse sandy till derived mainly from Triassic sandstones | Diabase, basalt, and colluvium derived from them | Coarse-grained till derived from granitic rocks |
| Profile horizons | A | Reddish-brown to dark-reddish-brown loam | Reddish-brown fine sandy loam or light loam | Brown to reddish-brown, friable loam with numerous fragments of traprock | Medium to dark brown sandy loam with boulders |
| Profile horizons | B | Reddish loam or silt loam | Yellowish-brown sandy loam or loam | Yellowish-brown mass of traprock fragments mixed with yellow clay | Light-yellowish-brown, friable sandy loam |
| Profile horizons | C | Reddish very firm compact till | Reddish-brown loamy sand and stony till | Traprock | Gray to brownish-gray rubble of sand and granitic rock fragments of all sizes |
| Thickness (in inches) | A | 8 | 8 | ½-4 | 1-2 |
| Thickness (in inches) | B | 10-16 | 10-16 | 15-20 | 4-20 |
| Topography | | Slopes and broad summits of hills | | Lower parts of steep slopes | Mostly slopes of steep hills |
| Drainage | | Well drained | Well drained | Well drained | Well drained |

1 the eight soils are grouped so that the first four columns represent soils developed in till and bedrock, whereas the next four are developed from sorted, stratified sediments.

## GLACIAL AND POSTGLACIAL HISTORY

Before glaciation of the Branford area began, the principal valleys, ridges, and hills had already been shaped by long-continued erosion and were broadly similar to those of today. Probably the surface was mantled with a thick regolith developed by weathering of the underlying rocks.

Evidence from outside the area indicates that Connecticut was overrun by a sheet of glacier ice at least twice, and probably several times, during roughly the last million years. The glacial features of the Branford quadrangle seem to relate only to the last of those invasions, which, in the Great Lakes region of the United States, endured from about 25,000 to about 10,000 years ago, as evidenced

(Data compiled from Morgan, 1930, and other sources).

| Hinckley soils | Manchester soils | Hartford soils | Merrimac soils |
|---|---|---|---|
| Ice-contact stratified drift | Gravelly ice-contact stratified drift of the northern part of the Farm River valley train | Sandy outwash and delta sediments and sandy terrace alluvium | Quinnipiac Valley outwash sediments |
| Light-brown to brown friable sandy, gravelly loam | Dark-reddish-brown gravelly, sandy loam | Brown to reddish-brown, friable sandy, gravelly loam | Dark-yellowish-brown sandy loam |
| Yellowish-brown, compact sandy, gravelly loam | Yellowish-orange gravelly sandy loam or fine sandy loam | Reddish-brown to yellowish-brown, compact sandy loam | Yellowish-brown sandy loam |
| Sand, gravel, and silt | Reddish sand or gravel | Reddish sand; locally sand and gravel | Yellowish-gray sand and gravel |
| 2.6 | 1-1½ | 4-8 | 6-10 |
| 6-12 | 8-12 | 10-18 | 12-18 |
| Flats and gentle slopes | Undulating plains | Subflat surfaces | Nearly flat surfaces |
| Well to excessively well drained | Well to excessively well drained | Well drained | Well to excessively well drained |

by radiocarbon dates. When the glacier reached its maximum extent the quadrangle was completely buried beneath ice, as shown by the fact that evidence of glaciation is present on the highest hills as well as in the valleys. Because the buried bedrock floor of the Quinnipiac Valley lies more than 200 ft below sea level in the adjacent Wallingford quadrangle and more than 280 ft in the New Haven quadrangle, the glacier must have had a minimum thickness of 750 ft in this area. It may have exceeded that thickness by a wide margin.

The last glacier flowed across the quadrangle in a direction somewhat west of south. The cumulative effect of this and earlier glaciers was to smooth, round off, and generally streamline the hills and ridges and to smooth and widen some of the valleys. Possibly before 15,000 years ago hills within the quadrangle began to reappear from beneath the ice. At least throughout a wide belt near the margin of the glacier, melting occurred to a large extent by general thinning of the ice body. Thickness within this belt was so reduced that the ice ceased to flow and became inert. Thinning exposed the highest hills and then progressively the lower hills, while tongues and detached masses of ice remained in the valleys. Streams of meltwater flowed between the margins of such ice bodies and the adjacent valley sides and built up high embankments of sand and gravel. In places coverings of stratified drift completely buried residual ice masses. In this way were built up the Farm River and other valley trains, the downstream ends of some of which were accumulating in a zone that had become entirely ice free. On the other hand the distribution of ice-contact features in the Farm River Valley suggests that the zone of separated bodies of residual ice was at least 5 mi. wide.

During this process the Quinnipiac Valley in and adjacent to the Branford quadrangle was occupied by a lake, in which the terminus of a lobelike tongue of the ice sheet retreated mainly by the calving of icebergs. When the mouth of the Muddy River was cleared of ice, that river built a sandy delta into the lake. At that time the vegetation of the area consisted of dwarf willow, dwarf birch, and other tundra plants. The climate was colder and cloudier than that of today.

The delta was then eroded, and when deglaciation opened a path from the Pequabuck and Farmington Rivers to the mouth of the Quinnipiac River, a stream of meltwater with braided pattern built up the large body of distinctive yellowish outwash sand that crosses the northwest corner of the Branford quadrangle. The outwash body covered a very irregular surface of the underlying dissected sediments. The altitude of the upper surface of the outwash at the close of upbuilding is not known, but it was higher than that of the broadest remnant now remaining within the Branford quadrangle.

During the period of activity of meltwater streams in all parts of the Branford area, sand was blown from valley floors and was spread as a very thin, discontinuous blanket over adjacent slopes. Probably this activity was brought to an end by the establishment of a continuous cover of vegetation over valley floors, first in the smaller valleys and last of all in the Quinnipiac Valley, where deposition of outwash continued long after it had ceased elsewhere. The vegetation changed from tundra to spruce forest, and was thus still quite different from that of today.

When deglaciation had progressed far enough to open a low-level path between Farmington and Tariffville, the Farmington and Pequabuck drainage was diverted to its present route via Tariffville to the Connecticut River, and the present shortened Quinnipiac River, confined to the area of Triassic rocks, came into existence.

With the disappearance of the temporary and extraordinary glacial source of abundant sediment, streams in the Branford area became relatively underloaded, assumed the single-channel, meandering habit they have today, and began to dissect the glacial sediments. This resulted in stream terraces and valley floors cut into ice-contact stratified drift, outwash, and delta sediments and covered with thin veneers of sandy alluvium deposited from the bed loads of the streams. The vegetation became one of pine forest, which was gradually replaced with the mixed deciduous forest characteristic of the region at present. The climate became warmer, but with fluctuations.

Throughout postglacial time the existing soils formed and developed beneath the surface, under a cover of largely forest vegetation. The youngest soils are those on postglacial terraces and on alluvium bordering the streams. The accumulation of peat in swamps and the postglacial return of forests have altered the landscape appreciably, but the deforestation, cultivation, and construction of various kinds brought about by man constitute changes that are even more conspicuous.

When settlement of the region by European people began in the seventeenth century, the entire land area of the quadrangle was forest, with the exception of tidal marshes, some of the other swamps, and some patches of bare rock. Today more than 50 percent of the area consists of woodland. The podzolic character of the local soils reflects the influence of the forest cover.

## ECONOMIC GEOLOGY

### *Sand and gravel*

The largest production of sand and gravel within the quadrangle is from sediments of the Muddy River delta. For many years the Elm City Construction Company has actively operated a large pit lying between the Muddy River and the Cedar Hill freight yard. The product is washed and size graded and is used extensively as concrete aggregate. The Quinnipiac Valley outwash, worked for concrete aggregate at a number of points in the Wallingford quadrangle, is too thin in the Branford quadrangle to be an attractive prospect.

Several large pits exist in the Farm River valley train. Those in the northern part either are worked intermittently or have been abandoned. The sediments there contain so wide a range of grain sizes that unless put through a washing process they are unsuitable for aggregate and find their greatest market locally in the form of fill. Farther south, however, several pits have been worked in the better sorted outwash facies of the valley train. At present the large pit off Maple Street, East Haven, 0.3 mi. southwest of Foxon, is operated by the Town of East Haven.

Small pits have been opened in other bodies of ice-contact stratified drift and outwash within the quadrangle, but all have to contend with wide range of grain size and the sporadic occurrence of unwanted silt, and few are operating currently.

## *Brick clay*

In the past two large operations have produced extensively from the New Haven clay for the making of brick. One, a quarter mile southwest of the cemetery at Montowese, active until about 1949, created a large pit, now a pond. The other, abandoned much earlier, is at the site of Bruces Ice Pond, which fills the old pit. The New Haven clay at these localities contains more silt than clay, and the brick must be burned very thoroughly in order to be durable. Probably the product was competitive with imported brick of better quality only because of the high cost of transportation of the imported product.

## *Swamp deposits*

Organic swamp deposits within the quadrangle are potential sources of garden humus. However, most of the swamp areas are small, and with the possible exception of the swamp east of Lake Saltonstall it is doubtful that economic development would be feasible.

## *Ground water*

Various bodies of stratified drift within the quadrangle constitute potential sources of ground water for domestic use or for small industrial plants. However, as the sand and gravel of which they consist are very permeable, water tables are generally low, being rather closely adjusted to the nearest surface streams. In consequence, development of a reliable water supply from such material depends on thickness of the sediment in the zone below the water table. This is a matter for local investigation in each case.

Till is generally too thin and in some places too impermeable to be a source of water other than for shallow wells of low yield. Most users of water within the quadrangle prefer to derive their supplies either from surface reservoirs or from wells drilled into bedrock.

Ground water in the Branford area is discussed by Brown (1928).

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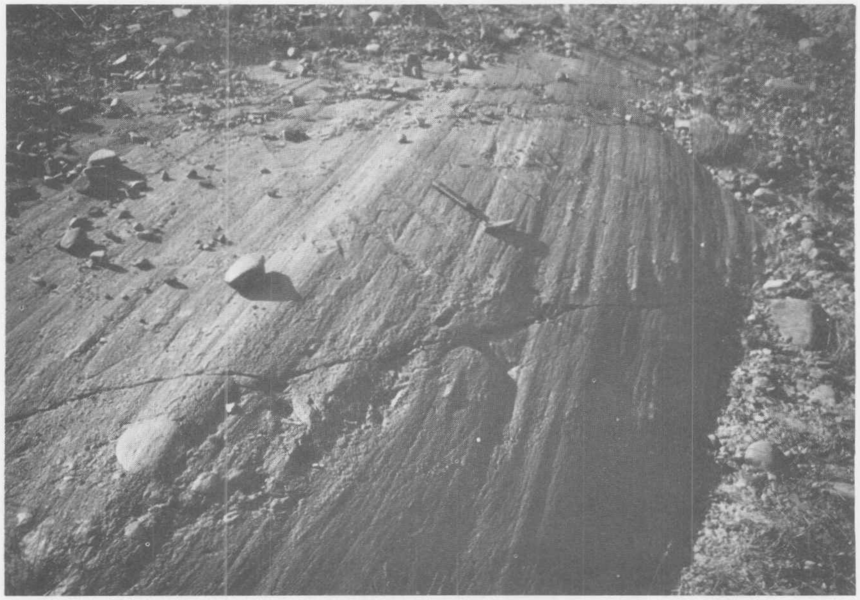
Plate 2.

*A.* Typical glaciated surface of New Haven arkose with whaleback form. Overlying till, mostly stripped away in pit operation, is visible in background and at right. View looking south, parallel with glacial striations and grooves. Long rattails stream southward from quartz pebbles in the arkose where the finer grained matrix was protected by the hard pebbles. Broad gouges parallel with pick handle were made by teeth of power shovel. (Exposure east of Laurel Street, East Haven, 0.25 mi. southwest of Grannis Pond.)

*B.* Outwash sand of the Quinnipiac valley train overlain by sandy terrace alluvium. Outwash sand has cut-and-fill stratification with foreset laminae dipping mainly southward (L), down valley. Blade of digging tool marks contact between the two bodies of sediment. Tool handle is 20 in. long. (West end of Bailey Road, North Haven, just off the north edge of the Branford Quadrangle.)

Plate 2.



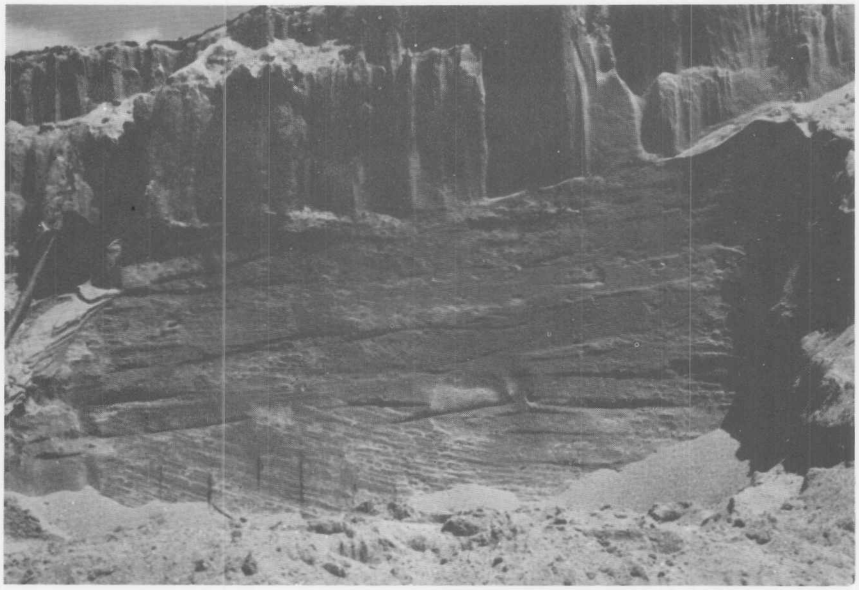


Plate 3. *The two contrasting facies of the Farm River valley train*

*A*. Ice-contact facies showing abrupt changes in grain size, wide range of grain size, and contorted stratification. Largest boulder is 50 in. in longest diameter. Top of sediment has been stripped. (Cinque Bros. pit off Village Street, North Branford.)

*B*. Outwash facies showing cut-and-fill stratification, and grain sizes confined to sand and small pebbles. Top has been stripped. Digging tool is 20 in. long. (Maple Street, East Haven, 0.4 mi. southwest of Foxon.)

Plate 3.

**Plate 4.** *Characteristic features of the Muddy River delta, exposed in the Elm City Construction Co. pit, Montowese*

*A.* Delta foreset beds dipping west, with topset beds missing. Delta was formerly overlain by outwash of Quinnipiac valley train.

*B.* Detail of one of the diamictons interbedded with the foreset layers, showing lack of sorting and stratification. Handle of digging tool is 20 in. long.

Plate 4.

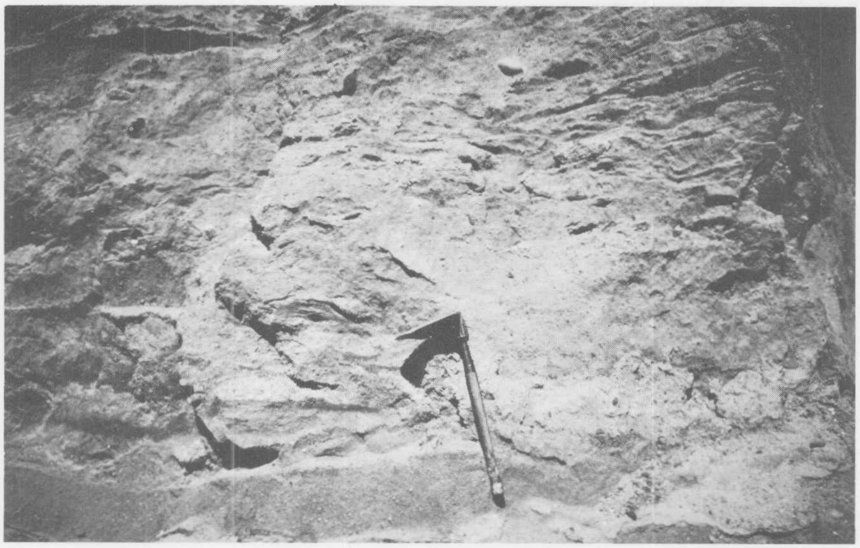
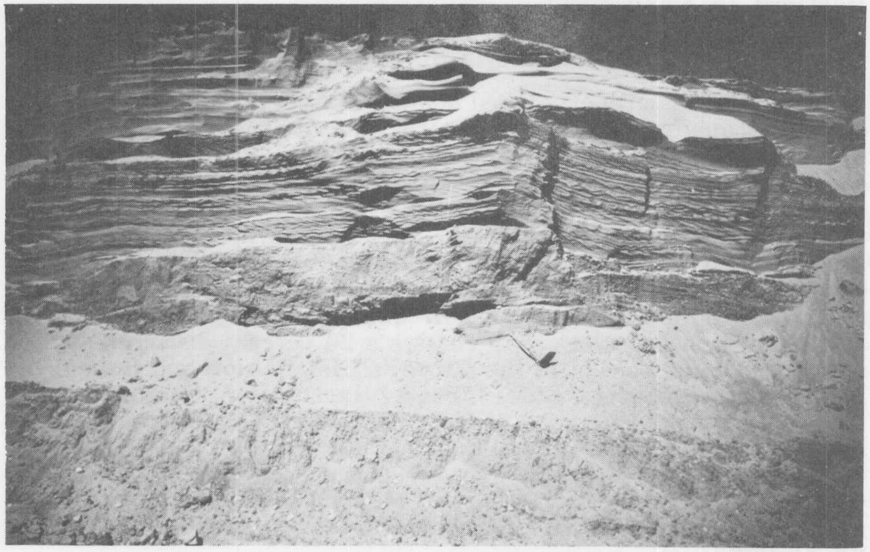


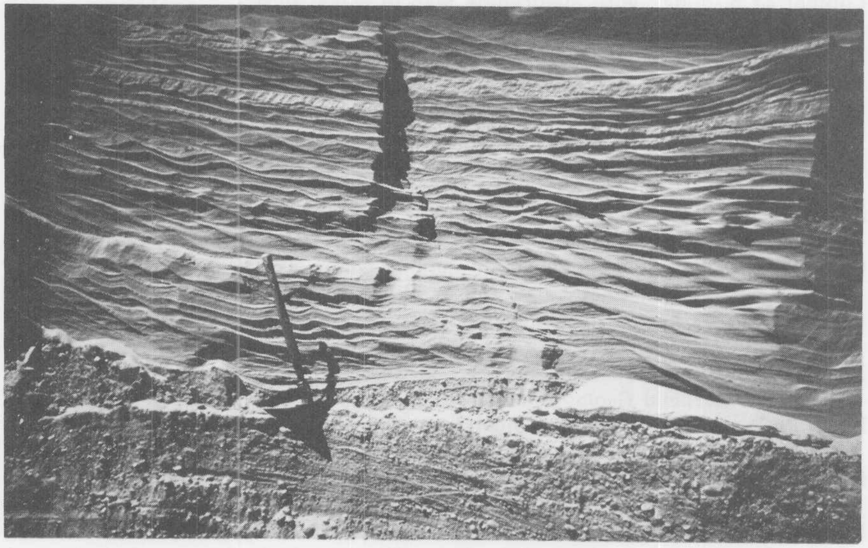
Plate 5. *Sediments of the Muddy River delta, Elm City Construction Co. pit, Montowese*

*A.* Ripple-laminated sand overlying diamicton.

*B.* Detail of ripple-laminated sand overlying pebbly sand. Tool handle is 20 in. long.

Plate 5.





## APPENDIX

A complete list of the publications of the State Geological and Natural History Survey of Connecticut is available from its Distribution and Exchange Agent, State Librarian, State Library, Hartford 15, Connecticut.

### *Quadrangle Report Series*

The quadrangle reports listed below will be sent postpaid at $1.00 each, the quadrangle map alone for 25¢ postpaid. Residents of Connecticut shall add 3½ percent sales tax. Payment must accompany order. Make checks or money orders payable to Connecticut State Library. Quadrangle reports, and all other publications of the State Geological and Natural History Survey of Connecticut, are available without charge to public officials, exchange libraries, scientists, and teachers, who indicate, under their official letterhead, that these publications are required in their professional work. Established book dealers shall receive a 20 percent discount.

Orders should be sent to the Survey's Distribution and Exchange Agent, State Librarian, State Library, Hartford 15, Connecticut.

1. The Bedrock Geology of the Litchfield Quadrangle, by Robert M. Gates, Ph.D.; 13 p., with quadrangle map in color, (Misc. Ser. 3), 1951.
2. The Geology of the New Preston Quadrangle: Part I. The Bedrock Geology, by Robert M. Gates, Ph.D.; Part II. The Glacial Geology, by William C. Bradley; 46 p., 14 pls., with charts and quadrangle map in color, (Misc. Ser. 5), 1952.
3. The Bedrock Geology of the Woodbury Quadrangle, by Robert M. Gates, Ph.D.; 32 p., 8 pls., 1 fig., with quadrangle map in color, 1954.
4. The Bedrock Geology of the Ellington Quadrangle, by Glendon E. Collins; 44 p., 1 fig., with quadrangle map in color, 1954.
5. The Bedrock Geology of the Glastonbury Quadrangle, by Norman Herz, Ph.D.; 22 p., 2 pls., 1 fig., with quadrangle map in color, 1955.
6. The Bedrock Geology of the Rockville Quadrangle, by Janet M. Aitken, Ph.D.; 55 p., 20 pls., 1 fig., with quadrangle map in color, 1955.
7. The Bedrock Geology of the Danbury Quadrangle, by James W. Clark, Ph.D.; 47 p., with quadrangle map in color, 1958.
8. The Bedrock Geology of the Middletown Quadrangle, by Elroy P. Lehmann, Ph.D.; 40 p., 7 figs., with quadrangle map in color, 1959.
9. The Bedrock Geology of the Naugatuck Quadrangle, by Michael H. Carr; 25 p., 5 figs., with quadrangle map in color, 1960.
10. The Surficial Geology of the Wallingford Quadrangle, by Stephen C. Porter; 42 p., 18 figs., with quadrangle map in color, 1960.
11. The Bedrock Geology of the Cornwall Quadrangle, by Robert M. Gates, Ph.D.; 35 p., 5 figs., with quadrangle map in color, 1961.
12. The Surficial Geology of the Mount Carmel Quadrangle, by Richard F. Flint, Ph.D.; 25 p., 3 figs., with quadrangle map in color, 1962.
13. The Bedrock Geology of the Deep River Quadrangle, by Lawrence Lundgren, Jr., Ph.D.; 40 p., 6 figs., with quadrangle map in color, 1963.
14. The Surficial Geology of the Branford Quadrangle, by Richard F. Flint, Ph.D.; 45 p., 4 pls., 7 figs., with quadrangle map in color, 1964.
15. The Bedrock Geology of the Essex Quadrangle, by Lawrence Lundgren, Jr., Ph.D.; 44 p., 9 figs., with quadrangle map in color, 1964.

## *Quadrangle Geologic Maps of Cooperative Program With U. S. Geological Survey*

These maps are published by the U. S. Geological Survey. The Connecticut State Library carries a stock for sale at $1.00 each, postpaid. Payment must accompany order. Make checks or money orders payable to Connecticut State Library. Connecticut residents must add 3½ percent sales tax. No free copies can be distributed.

Geologic Quadrangle No. 119. Surficial Geology of the New Britain Quadrangle, by Howard E. Simpson, 1959.

Geologic Quadrangle No. 121. Bedrock Geology of the Roxbury Quadrangle, by Robert M. Gates, 1959.

Geologic Quadrangle No. 134. Bedrock Geology of the Avon Quadrangle, by Robert Schnabel, 1960.

Geologic Quadrangle No. 137. Surficial Geology of the Windsor Locks Quadrangle, by Roger Colton, 1960.

Geologic Quadrangle No. 138. Surficial Geology of the Uncasville Quadrangle, by Richard Goldsmith, 1960.

Geologic Quadrangle No. 144. Bedrock Geology of the Norwich Quadrangle, by George Snyder, 1961.

Geologic Quadrangle No. 145. Surficial Geology of the Bristol Quadrangle, by Richard Goldsmith, 1961.

Geologic Quadrangle No. 146. Surficial Geology of the Southington Quadrangle, by Albert La Sala, 1961.

Geologic Quadrangle No. 147. Surficial Geology of the Avon Quadrangle, by Robert W. Schnabel, 1962.

Geologic Quadrangle No. 148. Surficial Geology of the Montville Quadrangle, by Richard Goldsmith, 1962.

Geologic Quadrangle No. 150. Surficial Geology of the Meriden Quadrangle, by Penelope M. Hanshaw, 1962.

Geologic Quadrangle No. 165. Surficial Geology of the Norwich Quadrangle, by Penelope M. Hanshaw and George L. Snyder, 1962.

Geologic Quadrangle No. 176. Surficial Geology of the New London Quadrangle, by Richard Goldsmith, 1962.

Geologic Quadrangle No. 199. Bedrock Geology of the Mount Carmel Quadrangle, by Crawford E. Fritts, 1963.

Geologic Quadrangle No. 200. Bedrock Geology of the Southington Quadrangle, by Crawford E. Fritts, 1963.

Geologic Quadrangle No. 223. Geology of the Hartford North Quadrangle, by Robert V. Cushman, 1963.