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THE SURFICIAL GEOLOGY OF THE MOUNT CARMEL QUADRANGLE

With Map

By

RICHARD FOSTER FLINT

QUADRANGLE REPORT NO. 12

1962

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Middletown

Printed by the State Geological and Natural History Survey

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State Geological and Natural History Survey of Connecticut

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Surficial Geology of the Mount Carmel Quadrangle by Richard Foster Flint

ABSTRACT

The Mount Carmel quadrangle, in southern Connecticut, lies mainly in the Central Lowland region. Features made by glacial erosion include striations and grooves, and streamline hills (drumlins). Till, a non-stratified mixture of rock particles of all sizes, covers much of the area with a variable thickness that averages 10 to 20 feet. At Lake Chamberlain two tills are present, a lower till deposited by ice that moved north-south, and an upper till indicating ice movement from northeast to southwest. The time elapsed between the two episodes of till deposition is not known. In addition to till, glacier ice deposited large boulders that now lie free on the surface.

Stratified sand and gravel cover many areas within the quadrangle. Deposited upon or against melting glacier ice, these bodies of sediment occur generally on the floors or sideslopes of valleys. The largest such body, the Mill River valley ice-contact fill, forms two distinct terraces in the valley segment south of Mount Carmel. Glacier ice was present while each of the terraces was taking form. Outwash sediments occur only locally.

Terrace alluvium (sand and pebbles) occurs on a Quinnipiac Valley terrace only. Postglacial sediments include alluvium, colluvium, swamp deposits, wind-blown sand and silt, and artificial fill.

Developed in the various glacial and postglacial sediments are five varieties of Brown Podzolic soils.

Substances of potential economic value include ground water, sand and gravel, and humus from swamps.

INTRODUCTION

The Mount Carmel quadrangle (pl. 1), with an area of about 56 square miles, lies in the central part of southern Connecticut (fig. 1). It is wholly within New Haven County and includes parts of the towns of Hamden, Woodbridge, Bethany, Prospect, Cheshire, Wallingford, and North Haven. Its chief centers of population are Hamden (Centerville) and Cheshire.

Mapping of the surficial geology, on the scale of 1:24,000, was done at various times in 1958, 1959, and 1960. Data for the map were obtained chiefly from observations in natural and artificial exposures, test holes made with shovel or hand auger, and analysis of land forms. Subsurface information was obtained from files of the U. S. Geological Survey and the Connecticut State Water Resources Commission. The bedrock outcrops plotted were taken, with some additions and other changes, from a manuscript map kindly supplied by C. E. Fritts of the U. S. Geological Survey, as were the locations of many glacial striations

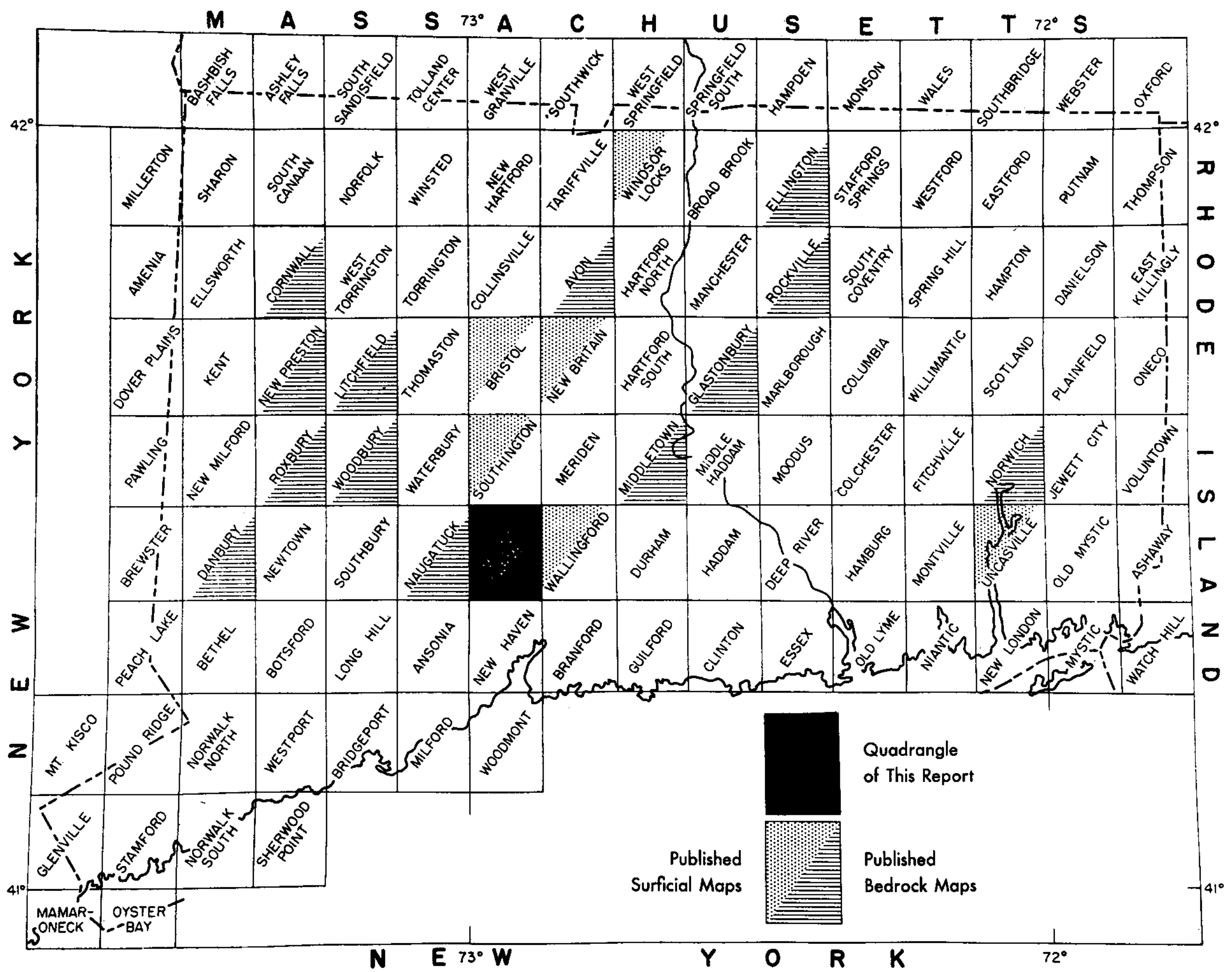

Fig. 1. Index map of Connecticut showing the location of the Mount Carmel quadrangle, and of other published quadrangle maps. For list of published maps see Appendix.

and erratic boulders. Discussions in the field with C. E. Fritts on the distribution of bedrock units, and with J. H. Hartshorn, have been very helpful. These two geologists also commented constructively on the manuscript. Roald J. Haestad of Malcolm Pirnie Engineers, Resident Engineer during construction of the Lake Chamberlain Dam, kindly facilitated study of temporary exposures at the dam site.

The fact that southern Connecticut had been glaciated was firmly established by J. D. Dana (1870, 1871). In later publications Dana (1875-1876, 1883, 1883-1884) contributed a considerable body of data on the glaciation of the district in and north of New Haven, including the Mount Carmel quadrangle. Ward (1920) made a more detailed study of the glacial features of an area of which this quadrangle constituted the northwest quarter, and mapped the general distribution of stratified drift in the area. Later papers of regional scope but touching on the glacial geology of the area include publications by Flint (1930, 1934).

TOPOGRAPHY AND DRAINAGE

The eastern two-thirds of the quadrangle falls within the Central Lowland of Connecticut, underlain by sedimentary and igneous rocks of Late Triassic age. The western third falls within the Western Highland, underlain by a variety of crystalline rocks of pre-Triassic age (fig. 1). Altitudes range from sea level along the Quinnipiac River in the southeast corner of the quadrangle to 900 feet near the northwest corner. In general the tops of the higher hills and ridges together approximate a gently undulating surface that in this part of Connecticut slopes southward at about 50 feet per mile. In the Mount Carmel quadrangle this surface is represented by (1) the high hilltops south of Prospect, at the Bethany Airport, west of Bethany Lake, and southwest of Lake Chamberlain, (2) the higher parts of West Rock Ridge and its northward continuation, and (3) Mount Carmel ("The Sleeping Giant"). The altitude of the surface decreases from 850-900 feet in the northwest part to 550-600 feet in the southwest part of the quadrangle.

Beneath this imaginary surface, altitude is rather consistently related to erodibility of the bedrock. The relatively high areas are underlain generally by gneisses, certain schists, and quartzites in the Western Highland. In the Central Lowland they are underlain by diabase, notably in Mount Carmel ("The Sleeping Giant") and in the long West Rock Ridge diabase sheet, segments of which are named West Rock Ridge, High Rock, Gaylord Mountain, and Mount Sanford. The lower areas are underlain by arkosic sandstones. Hilltops in the lower areas generally have altitudes of 250 to 350 feet.

The mantle of glacial drift that overlies the bedrock is generally so thin that it has not greatly altered this relationship, developed mainly before glaciation occurred. Locally, where the glacial drift is thicker than normal, individual hills and groups of hills exist by virtue of accumulations of drift, but this local relief is subordinate to the greater relief that depends on the bedrock. In valleys and in places on the slopes of higher lands relatively thick accumulations of stratified drift take the form of collapsed masses, kames, kame terraces, ice-channel fillings, and kettles.

Four watersheds are present within the quadrangle. Most of the eastern half drains south via Mill River. The southwest one-third drains south via West River. A northwest part drains west to the Naugatuck River, and small areas along the eastern and northwestern margins drain to the Quinnipiac River. Mill River, with a slope of about 15 feet per mile between Cheshire and Centerville, is the longest stream.

The drainage pattern as a whole is about what would be expected if the area had not been glaciated. Except for local segments of Mill River extending about two miles upstream and one mile downstream from Mount Carmel, most of the streams are adjusted to the local structure of the rocks, which in most places trends north-south or northeast-southwest. In detail, however, otherwise continuous streams are interrupted by swamps and ponds, most of them small. Most of these are believed to represent small basins created by the irregular deposition of glacial drift; as a result drainage is locally impeded. The presence of these small basins is one result of the recency of glaciation, since which there has been insufficient time for the establishment of uninterrupted stream flow.

At only one place does a distinct change in the position of a stream seem evident. About 1½ miles southeast of the center of the quadrangle, between Shepard Avenue and Hillfield Road, Hamden, the south branch of Jepp Brook turns abruptly north. Connecting the turn with Eatons Brook, 2000 feet farther south, is a channel about 300 feet wide, 15 feet deep, and open at both ends. The sides and floor of the channel, which parallels the strike of the sandstone bedrock, consist largely or wholly of till. Possibly the water of both branches of Jepp Brook formerly or temporarily drained through the channel into Eatons Brook, and was later diverted northward to its present route. As the till does ~~not~~ seem to have been stream cut, the inferred diversion is believed to have occurred before glacier ice passed over the locality for the last time. No clear evidence points to one particular cause of diversion.

A similar channel connects the west branch of Jepp Brook with a branch of Eatons Brook in the area between West Todd Street and West Woods School. This suggests that Jepp Brook drainage may have flowed into Eatons Brook at a former time, perhaps temporarily.

In addition to the natural basins mentioned, lakes and ponds have been created, as reservoirs and for industrial uses now abandoned, by the building of dams across many streams. Among the largest are Lakes Watrous and Chamberlain and Bethany Lake in the valley of West River, and the Naugatuck reservoirs in the northwestern part of the quadrangle. Most of the lakes shown on the map are man-made features.

BEDROCK GEOLOGY

The principal bedrock unit that underlies the eastern two-thirds of the quadrangle is the New Haven Arkose, of Late Triassic age. This consists of pinkish, gray, and red arkosic sandstone and conglomerate, with interbedded layers of red siltstone. These rocks are variably and irregularly stratified. They strike northeast and generally dip southeast at angles between 10° and 20°. This structure is reflected in the common NE-SW trend of individual hills and ridges that is clearly evident on the map.

Associated with the arkose are bodies of diabase and basalt, also of Late Triassic age, which constitute igneous intrusions in the sedimentary rocks. The intrusive rocks are greenish black to bluish black, and are massive, with well developed columnar jointing. The most massive is the West Rock Ridge diabase sheet. Another conspicuous unit is the stocklike body that constitutes Mount Carmel ("The Sleeping Giant"). Apart from these there are several narrow dikes, some of which are porphyritic. One of the dikes is clearly evident in the pattern of long, narrow bedrock outcrops that trends northeast through more than 3 miles, in the area north of Mount Carmel.

The western one-third of the quadrangle is underlain by a variety of crystalline rocks, most of which are metamorphic. These include the Waterbury gneiss complex (gneisses and mica schists), Hartland formation (garnetiferous mica schist), Orange phyllite (marble, quartzite, phyllite, and related rocks), Prospect gneiss (granodioritic gneiss), Ansonia gneiss (quartz-monzonitic gneiss), Woodbridge quartz-diorite, and small bodies of pegmatite. These rocks crop out in belts that trend generally northeast-southwest.

The identities and patterns of outcrop of the various kinds of rocks are of importance to the surficial geology of the quadrangle, in that the occurrence in the glacial drift of rock fragments having recognizable 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, except on the higher parts of the large intrusive bodies. There, recognizable glacial drift consists of little more than scattered boulders and cobbles mingled with fragments, commonly joint faced, of the local bedrock. Bare bedrock alternates with patches of loose rock fragments a few inches to 2 or 3 feet thick, in such a complex pattern that it was found impractical to show individual exposures. Accordingly the bedrock is shown as a unit, whether bare or covered with rubble and is differentiated from areas known or believed to have a cover of glacial drift or alluvium.

GLACIAL GEOLOGY

GLACIAL-EROSIONAL FEATURES

Striations and grooves, etched into the surface of bedrock by glacier ice carrying rock particles imbedded in its basal surface, are exposed sparingly in the quadrangle. The areal distribution of these features is very irregular. This results partly from the limited aggregate area of exposed bedrock and partly from the ease with which various kinds of bedrock yield to abrasion. Altogether, striations or grooves were recorded at 27 localities. Most of these are on phyllite or schist; none of them are on sandstone, despite the fact that sandstone underlies more than half the quadrangle. Probably the sandstone grains disaggregated as the rock was abraded, so that it would tend to retain few scratches. Furthermore, the cover of glacial drift is more nearly continuous on the sandstone than on other kinds of rock, thereby concealing striations once made. At 24 localities the striations trend NE-SW, ranging from N. 30° E. to N. 70° E. These fall into two groups. One, confined to the Western Highland, transects the structures in the bedrock and averages about N. 53° E. The other is confined to localities on or very close to the West Rock Ridge diabase sheet and "The Sleeping Giant," and averages about N. 30° E., essentially parallel with the trend of the local topography. As both groups appear to have been made during a single glaciation, the second group is probably attributable to local deflection of the ice by prominent hills and ridges.

Apart from these groups, different striations or grooves occur at two localities. At one, just north of the west end of the Lake Chamberlain Dam, the trend is N. 4° E. to N. 2° W. As the striated bedrock at this locality is directly overlain by till older than the till occurring at or near the other localities, the difference in trend is significant. That is, the striations near the west end of the dam were made by a glacier flowing in a different direction from that taken by the later ice. Similarly, on a large knob of diabase 2400 feet ENE of the summit of High Rock, several grooves trend between N. 5° W. and N. 18° W. Possibly these were made by the earlier glacier recorded at the Lake Chamberlain Dam site.

None of the NE-SW striations, in itself, indicates whether the effective movement of ice was southwest or northeast. However, at several places on the summit of West Rock Ridge, on High Rock, and at a point half a mile north of Old Naugatuck Reservoir, low bosses of bedrock are smooth on their NE sides and end in miniature cliffs, controlled by joints, at their SW ends. These stoss-and-lee forms indicate that movement of the glacier was toward the southwest. No such forms, having striations on their smoothed upstream surfaces, were seen; in all but a few localities the surface of the diabase has been roughened by weathering sufficiently to destroy shallow striations.

Generally throughout the quadrangle the surface has been molded by glacial action into streamline hills or drumlins (fig. 2). These are ovate in plan, and range from a few hundred feet to about a mile in length. The majority are elongate NE-SW, parallel or nearly parallel with the strike of the bedrock. Two, however, trend NW-SE. The northeast ends of many are slightly steeper than the southwest ends. The hills occur on every kind of bedrock that is exposed in the quadrangle. Some of them consist mainly or partly of bedrock, as indicated by rock exposures. Others expose no bedrock and may either be covered thinly with drift or consist of drift entirely. The hill north of the intersection of Candee Road with Bethany Mountain Road in Prospect probably consists wholly of till, at least in its southern part, because a well drilled in it penetrates 150 feet of till at a point where the hill itself is less than 150 feet high. A well in Talmadge Hill, Prospect, on Talmadge Hill Road 1000 feet south of Route 68, penetrated 38 feet of till before encountering rock. As the hill at this point is 60 to 100 feet

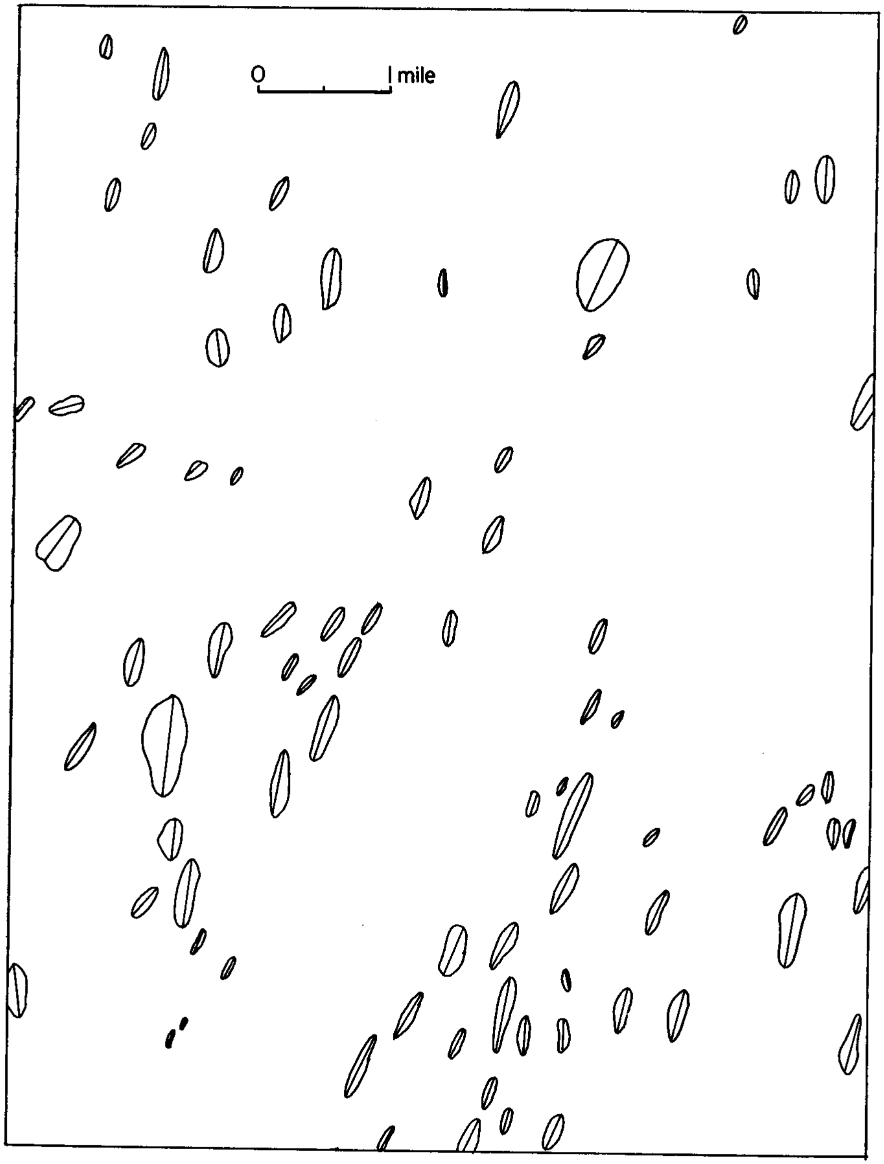

Fig. 2. Sketch map of Mount Carmel quadrangle showing positions and trends of streamline hills (drumlins).

high, the streamline form is evidently a combination of rock and drift. There is little if any difference in form between hills believed to consist mainly of bedrock and those believed to include a large amount of till. In this quadrangle the elongation of the streamline hills is determined mainly by the structure of the bedrock, as can be seen by comparing trends of long axes of hills with the strikes of bedrock structures exposed in the same hills. In the area of Triassic rocks the trends approximate N. 10° E. to N. 30° E., varying with local variation of strike. In the Western Highland the trends vary through a wider range, from slightly west of north to slightly north of east, but agreement with structure is good.

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 coming from melting glacier ice. Both kinds are present in the Mount Carmel quadrangle.

Till

GENERAL CHARACTER

Till, a nonsorted, nonstratified accumulation of rock particles of all sizes, is the most widespread of the surficial deposits in the area. It forms a nearly continuous mantle over the surface of the bedrock. Through an aggregate of about 10 per cent of the quadrangle the till is extremely thin and discontinuous or is absent altogether. Most of this aggregate area consists of outcrops of diabase, and of various crystalline rocks within the Western Highland. Such rocks are not easily erodible by glacier action, and evidently supplied little material from which till could be created. Where stratified drift is present, the general mantle of till commonly passes beneath it. This is confirmed by records of a few wells, which show that till occurs between bedrock and overlying stratified drift.

Thickness of the till mantle is variable. Except in some streamline hills, it is 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 thickest section seen exposed was 22 feet thick. The records of many wells indicate 20 to 30 feet of till, 13 indicate 50 feet or more, and two indicate more than 100 feet. Average thickness of till within the quadrangle is estimated at between 10 and 20 feet, but because of abrupt variations and the small number of well records available, the estimate can not be considered as a close one.

The till in the Mount Carmel quadrangle 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 many places exceeding 20 per cent of the total. Within the fine fraction, sand and coarse silt are abundant; hence the till is commonly rather friable.

The pebbles, cobbles, and boulders are generally angular or subangular in shape, but most of them show some degree of smoothing as a result of abrasion while they were being carried in the glacier. Corners and edges between facets are rounded, and the surfaces of some are marked with glacial striations. A very few pieces are well rounded; probably these had been carried in a stream or streams before being last picked up by glacier ice. The sand-size particles are mainly angular.

The composition of the till resembles that of the underlying bedrock. Where two kinds of bedrock crop out in adjacent areas, the character of the till changes, less abruptly but in a corresponding manner. Within the quadrangle the most conspicuous difference between bodies of bedrock is that between the Triassic sandstones and intrusives, and the gneisses, schists, phyllites and other crystalline rocks of the Western Highland. In the area of Triassic rocks till is conspicuously brown to reddish brown (color range, when dry, 10R 4/6 to 5YR 4/4),[1] approximating but less red than the color of the bedrock, and is composed predominantly of fragments of the bedrock and of minerals derived from it. In the area of crystalline rocks, on the other hand, till commonly ranges from olive brown to yellowish gray (5Y 4/4 to 5Y 7/2) and again consists chiefly of fragments of the local bedrock and its mineral constituents. Although some of the cobbles and boulders in the till of the Triassic area consist of sandstone, the larger fragments consist more commonly of diabase and basalt. Although such rocks occupy a far smaller area within the quadrangle than do the sandstones, the widely spaced joints that transect them caused the glacier to tear them away in large chunks that resisted subsequent crushing. In contrast, the sandstones, being weaker and more friable, were crushed and disaggregated more easily. In the area of crystalline rocks the number of boulders in till at any place is related to kind of bedrock. The Prospect and Waterbury gneisses, particularly, yielded large-size fragments to the ice that overrode them. These rocks are well jointed. Most of the schistose rocks are poorly jointed and were not easily torn out by the glacier.

Although the till is not stratified, in some places it has distinct fissility, consisting of closely spaced, subparallel partings approximately parallel with the ground surface. The origin of this structure is not fully understood.

It is generally known that at many localities the long axes of stones in till show a preferred orientation that imparts to the till a distinct fabric. A statisically 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. The fabrics of tills at the Lake Chamberlain Dam in Bethany, mentioned in table 1, constitute one kind of evidence that that area has been subjected to glaciation from more than one direction, as stated in the following section.

STRATIGRAPHY

Two different bodies of till occur within the quadrangle. The two occur in contact at the Lake Chamberlain Dam in Bethany, where they

[1]Colors are described according to the Munsell Rock Color System (Goddard, 1948).

TABLE 1. Characteristics of two bodies of till compared

Characteristics	Lake Chamberlain Till	Hamden Till (at this locality)
Color	Pale olive to yellowish gray (dry)	Dusky yellow to pale yellowish brown (dry)
Weathering	No visible alteration, even of upper part	Oxidized throughout
Thickness	Maximum continuous exposure 12 ft.; inferred thickness much greater	3 to 10 ft. exposed
Texture	Moderately stony	Stony; coarse fraction (est.) 30 per cent greater than that of Lake Chamberlain till
Structure	Fissile throughout most of exposed face; tough, blocky	Mostly not fissile; friable
Lithologic provenance	From W of N to slightly E of N	From NE (apart from elements reworked from Lake Chamberlain till)
Fabric	Preferred orientation of elongate pebbles N-S to slightly NW-SE	Preferred orientation of elongate pebbles NE-SW
Striations on immediately underlying bedrock	N. 2° W. to N. 4° E.	None at this locality. Elsewhere in vicinity NE-SW
Relations at the contact	Upper surface squeezed and dragged	Base contains pebbles of Lake Chamberlain till

were well exposed during reconstruction of the dam in 1959. The older of the two bodies is not known to be exposed elsewhere, and is referred to here as the Lake Chamberlain till. The younger body occurs generally throughout the area, and as it is exposed at many places within the town of Hamden it is called here the Hamden till. The two tills are compared in table 1, from which it is evident that the Lake Chamberlain till was deposited by a glacier that flowed across the locality from the north or northwest, and that the Hamden till was deposited later by a glacier that flowed from the northeast. The time elapsed between the two glacial episodes is not known, because the older till was decapitated by the later glacier, which eroded an unknown thickness of it and incorporated pebbles and cobbles derived from it and with matrix still adhering to them, into the accumulating younger till. If a soil ever developed in the surface of the older till, it was removed from the area of the Lake Chamberlain exposure. Hence there is no conclusive evidence that the locality was deglaciated between the two times of till deposition. However, had the sequence resulted from gradual change in direction of movement of a single glacier (through about 70°), a stratigraphic transition from the lower till to the upper could be expected, instead of a sharp contact with erosion of the lower till. Hence it is thought more likely that two distinct glaciations are indicated, however short the time that may have separated them.

Based on a variety of indirect evidence, 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. According to radiocarbon dates the events of that glaciation occurred between about 25,000 years ago and about 10,000 years ago. What part of that period of about 15,000 years is probably represented by the Hamden till is not known.

Erratic Boulders

Erratic boulders, lying on the surface and not imbedded or only partly imbedded in till, are numerous. Of those 10 feet or more in longest diameter 105 are shown on the map; those less than 10 feet long (not shown) are much more numerous. One of the two largest seen lies 0.6 mile west of Ives Corner in Cheshire. It is 50 feet long and is one of a group of eight boulders of diabase unlike the diabase occurring within the quadrangle. Some of the eight boulders formerly constituted part of a single boulder of even larger size, broken apart during deposition or through subsequent weathering.

The second large boulder lies 0.45 mile S. 82° E. of the intersection of Fenn Road with the College Highway, in Cheshire. It is 51 feet long, and also is diabase. Both large boulders were transported from points of origin outside the Mount Carmel quadrangle. Possibly they came from Triassic lava flows in the Meriden district; in places those flows have such widely spaced joints that boulders of this large size could have been torn from them.

Of the 105 large boulders mapped, 71 are diabase or basalt, 16 are Prospect gneiss, 5 are sandstone or conglomerate, 2 are Waterbury gneiss, 1 is Hartland formation, 1 is quartz, and 9 are unidentified. The preponderance of diabase and basalt reflects the influence of widely spaced joints in those rocks, which permitted glacier ice to tear them off in unusually large blocks.

The areal distribution of erratics of Triassic rock types (diabase, basalt, and sandstone) relative to the outcrop areas of those rocks is noteworthy. At least six of the large erratics shown on the map lie west of the area of Triassic rocks in which they occur in place, and many smaller erratics of the same kinds occur in similar positions. As all of them could have been brought to those positions by ice flowing from the northeast, their transport can be reasonably attributed to the glacier movement that deposited the Hamden till.

Conversely five of the large mapped boulders of Prospect gneiss, as well as a large number of smaller erratics, lie south, east, or southeast of the area of outcrop of that rock; indeed a number of them occur within the area of Triassic outcrop. The transport of these is reasonably explained as the work of the earlier glacier that deposited the Lake Chamberlain till, although any of them could have been picked up later by the Hamden glacier and moved toward the southwest.

The distribution of erratics is paralleled by the distribution of smaller size rock fragments. Fragments of Triassic rock are found west of the outcrop area of Triassic bedrock, and Prospect gneiss fragments occur east of the outcrop area of that rock type.

Of the 105 large boulders mapped, 30 occur on the eastern and northeastern slopes of the West Rock Ridge diabase sheet, despite the fact that the area of that slope constitutes less than 15 per cent of the area of the quadrangle. This concentration may have resulted from scraping off of drift from the base of the ice against the upstream side of a cleatlike obstacle. As only six boulders were mapped on the western slopes of the ridge, it can be reasoned that most of the boulders were deposited in their present positions by the southwesterly glacier movement that deposited the Hamden till.

High concentrations of surface boulders, mostly local but including erratics, and of all sizes, occur in some areas of the Western Highland. Some concentrations are several acres in individual extent. All overlie slopes. Probably their localization is of complex origin. Among probable factors are (1) presence of resistant bedrock with widely spaced joints; (2) factors in the movement and regimen of former glacier ice; and (3) postglacial eluviation of inclosing finer grained particles, leaving the boulder sizes as a lag concentrate.

Ice-Contact Stratified Drift

Ice-contact stratified sediments are deposited in streams and other bodies of water against, upon, beneath, or otherwise in immediate contact with melting glacier ice. They include sand, gravel, silt, and clay, and commonly possess one or more of these characteristics: great internal variability; poor sorting; large range and abrupt changes in grain size both vertically and horizontally; inclusion of small bodies of till, erratic boulders, or flowtill[2]; deformation of sedimentary laminae by subsidence or other displacement activated by the 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, features that reflect the presence of irregular bodies of melting ice during accumulation of the drift.

In the Mount Carmel quadrangle, drift of this kind consists mainly of sand, with subordinate gravel, very little silt, and even less clay. In the area of Triassic rocks its color is generally not far from moderate brown (5YR 3/4), and in the Western Highland it is light olive brown (5Y 5/6) to yellowish gray (5Y 7/2). The difference reflects differences in the kinds of rock and mineral grains of which the drift is composed.

Where its base is exposed, ice-contact stratified drift overlies till or bedrock. At only one place was it seen to be overlain by undoubted till. In April 1960, a temporary exposure at the intersection of Shepard Avenue with Apple Tree Lane, 1200 feet south of Northwest School, showed a wedge-shaped body of till overlain and underlain by stratified drift. The till body, 25 feet long, pinched out southward and thickened northward to a maximum of 3 feet, ending in an eroded face. The exposure was destroyed by building construction prior to October 1961. The wedge of till is believed to represent minor local movement of glacier ice, interrupting the general deposition of stratified drift during deglaciation.

Areal distribution of the ice-contact stratified drift is closely related to local topography. In general it occurs in valleys and in areas that would have been basins if they had been temporarily blocked by glacier ice along one side. Its abundance increases conspicuously with decreasing altitude. By far the most extensive continuous body of it occupies the comparatively broad valley of Mill River and its chief tributary, Willow Brook. The body of sediment enters the quadrangle from the north in the area of West Cheshire, crosses it without a break, and leaves it south of Centerville (Hamden) to continue through the adjacent New Haven quadrangle.

The prime condition responsible for the accumulation of ice-contact stratified drift is the production of so much meltwater, during the disappearance of a glacier, that much of the drift released from the ice is transported and deposited by running water flowing upon or adjacent to the ice itself. An example is the body of sand and gravel that extends from west of Cheshire Reservoir southward along Cook Road and Roaring Brook Road for more than 1.5 miles. The body forms an irregular double terrace (essentially a kame terrace), including a surface at 650 to 680 feet and a lower surface at about 600 feet. Both surfaces are marked by knolls and small basins; the largest basin in the lower surface is 50 feet deep. Probably the sediments were deposited while a

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

lobe of glacier ice projected southward into the valley of Mixville Brook. At that time a stream of meltwater flowed south along the western margin of the ice, first building the higher terrace and later, after considerable shrinkage of the ice lobe, the lower one. When the melting ice lost contact with the face of the lower terrace, building came to an end and the double terrace was left blocking the head of the valley.

Basically similar in origin to the body described above is the mass of drift lying along the east base of the West Rock Ridge diabase sheet through the segment between Brooksvale Stream and Roaring Brook. In places it too is double. Similar also are the three smaller masses in Hamden, respectively south of Westwood Cemetery, southwest of West Woods School, and south of Northwest School, in the central part of the quadrangle. Somewhat different in detail is the small mass near the northeast corner of Bethany, southeast of Cheshire Road. This mass has a very steep ice-contact face on its north side, with two narrow ridges projecting northward from it. The south side of the mass is a long slope, with an angle of about 15°; the component sand and gravel are exposed here and dip parallel with the surface. The body of sediment is a fan or delta built southward from a tongue of glacier ice and fed by two streams, perhaps successive, occupying tunnels or deep channels in the ice, represented by the two narrow ridges of sand and gravel.

The mass lying between High Rock and West Woods School in Hamden likewise includes a curving ridge, half a mile long, that may have been built in a tunnel within the base of the melting glacier.

In the valley of Mill River and that of its tributary, Willow Brook, there is a large mass of sand and gravel. Although it is here called the Mill River valley ice-contact fill, it consists of two or more depositional units. It extends north-south from end to end of the quadrangle, continuing from the Southington quadrangle on the north into the New Haven quadrangle on the south, with a single interruption at Mount Carmel. Downstream from the mouth of Willow Brook the body is generally about half a mile wide, except at the crossing of the large basalt intrusive at Mount Carmel, where the valley narrows to the width of the river channel and bedrock is exposed. Upstream from the mouth of Willow Brook the fill is separated into two parts by a massive hill of bedrock. North of Brooksvale it subdivides again, so that three prongs in all are formed. The profile (fig. 3) shows two of the prongs.

Despite much local irregularity, amounting in places to as much as 30 feet of relief, the fill as a whole slopes down valley. In cross profile as well the fill has a very irregular surface, but in the wider places there is a tendency for the surface to be somewhat lower in its central part than near its lateral margins. Possibly the difference has resulted from greater subsidence of the surface over the axis of the valley, where presumably the drift is thickest, than over the marginal parts where the drift should be least thick.

The topographic detail consists of knolls and basins occurring both singly and in clusters, with intervening areas that are subflat. Mill River occupies a shallow trench that extends from end to end of the mass. In many places the trench is erosional, having been cut by the river.

However, in some places along both Mill River and Willow Brook the trench widens and its sides appear to be of constructional rather than erosional origin. Probably these wide places are kettles, the sites of large masses of residual glacier ice that endured throughout the period of accumulation of the sand and gravel. Much of the course of Willow Brook and segments of the course of Mill River north of Ives Corner consist of chains of kettles connected by the postglacial streams.

As can be seen in figure 3, upstream from Mount Carmel the fill forms a single terrace-like unit. The part of this unit which constitutes the eastern, or Mill River, prong is labeled *Mill River terrace*. The part that constitutes the Willow Brook prong, farther west, is labeled *Willow Brook terrace*. The two parts are believed to have been deposited contemporaneously. The profiles of both are believed to have been originally smooth and similar, before the melting of residual glacier ice caused them to subside very unevenly. Measured from Wallingford Road to the Mount Carmel dike, the average slope of the surface of the unit is about 15 feet per mile.

Downstream from Mount Carmel the fill forms two units, a high terrace, and a second terrace about 30 feet lower. Both terraces have the same knoll-and-kettle character and both slope downstream more gently than does the terrace farther up the valley. Although the face of the higher terrace is erosional in some places, in others it is constructional, with kettles sunk into the lower terrace at its toe. From these facts it is apparent that residual glacier ice persisted in Mill River valley throughout the building of the terraces, which therefore are kame terraces by definition.

However, the fact that the two terraces downstream from the Mount Carmel dike are separated in places by a stream-cut scarp shows that the low terrace was formed at least in part by erosion of the high terrace. The knolls and kettles that separate them at other places show that the high terrace was abandoned as local masses melted, and that the spaces thereby opened up were partly filled by deposition of sediment, creating the low terrace.

Where Mill River crosses the Mount Carmel dike the continuity of the sand-and-gravel fill is interrupted. Because of the interruption, and because the surfaces of the terraces are very irregular and the character of their sediments is very similar, it is not certain which of the two terraces downstream from that point represents the continuation of the single terrace (with two prongs) upstream from it. It seems more likely to be the lower terrace. If that is the case the upper terrace was built while the valley upstream from the dike was completely covered with glacier ice.

Little is known of the thickness or subsurface form of this body of stratified drift. The thickest section exposed in 1959 was only 20 feet thick, and most of the recorded wells end at slight depths while still in the stratified drift. Of the deeper wells two, close to the western margin of the body, encountered bedrock at the base of the gravel at 30 feet and 33 feet, two others northwest of Brooksvale showed gravel on bedrock at 70 and 74 feet, and one, at the Meadowbrook Country Club, on the axis of the body 250 feet north of the southern edge of the quadrangle, penetrated 140 feet of sand before reaching bedrock. This is the thickest section known.

Internally, this body of sand and gravel as a whole possesses the characteristics of ice-contact stratified drift. However, despite abrupt local variations in grain size and stratification, there are rather systematic changes in the downstream direction. Sand, predominant over gravel, becomes preponderantly so downstream. Within the coarse fraction also, grain size decreases southward, and rounding of pebbles and cobbles increases. Although the sediment has not been analyzed in detail, both composition of the coarse fraction, where sampled, and the red color of the fines indicate that the material was derived largely if not entirely from the underlying Triassic rocks.

At only one locality are silt and clay known to predominate in the mass. Immediately northwest of Ives Corner, sand grades laterally westward into silt and clay, forming a strip of fine sediment, with scattered cobbles, at least 2000 feet long and 200 feet wide along the western margin of the body. Probably this was a shallow lake along the margin of the valley fill, a lake that existed only as long as the sand and gravel were accumulating.

The sediments constituting the fill are generally cross stratified. In many places the cross lamination is of cut-and-fill type, with foreset layers inclined commonly in the down-valley direction. The rather systematic nature of both stratification and changes in grain size and rounding downstream suggest that this body of sediment resembles a body of outwash in that it was built by a stream system under a series of hydraulic controls common to the entire valley. Such a condition is best explained by the hypothesis that during the deposition of at least that part of the fill which is exposed to view, a meltwater stream was flowing across and around a discontinuous chain of ice masses, earlier separated from the glacier and lying beyond the main glacier mass. A corollary of this concept is that the sediment accumulated rapidly, because the masses of ice, even though buried beneath gravel and sand in places, are not likely to have remained unmelted longer than a few tens or at most a few hundreds of years.

Outwash Sediments

A distinctive body of outwash sediments, confined to the Quinnipiac Valley and extensively present in the adjacent Wallingford quadrangle, occurs in the Mount Carmel quadrangle in a single small area of less than five acres, near the intersection of Old Hartford Turnpike with Kings Highway, at an altitude of about 60 feet. The sediments consist of sand with subordinate rounded pebbles. The sand is yellowish gray (5Y 7/2), and includes distinctive minerals derived, not from the Triassic rocks but from crystalline rocks of the Western Highland, occurring far north of this quadrangle (Krynine, 1937). The outwash possesses cut-and-fill stratification, with thinner courses than those in the ice-contact stratified drift and with foreset layers dipping south and west. It overlies till, and in the Wallingford quadrangle overlies ice-contact stratified drift.

This outwash body constitutes a valley train that occupies the Quinnipiac Valley through a north-south distance of about 36 miles. The erosion remnant in the Mount Carmel quadrangle lies at or close to the upper limit of the valley train at its latitude; possibly therefore it records the original top of the outwash body.

POSTGLACIAL SEDIMENTS

The time elapsed since the area was freed from its glacial cover constitutes postglacial time for the Mount Carmel quadrangle. During this time sediments have accumulated in places, and stream erosion, weathering, and soil development have occurred generally.

Sand and Gravel, Undifferentiated

Some bodies of sand, in places with a few pebbles and in others with small amounts of silt, are designated on the map as sand and gravel, undifferentiated, because the conditions under which they accumulated are not clearly evident.

One such body occupies the extreme headward part of the valley floor of Mill River, as well as the floor of a former meltwater channel, now dry, cut into bedrock and bisecting Hillside Cemetery, east of the Cheshire village green. Like the ice-contact stratified drift, the sediment is moderate brown in color, and was derived primarily from the local Triassic rocks. It is fairly well sorted and in places at least is indistinctly stratified. It is mainly alluvial and perhaps partly colluvial in origin.

In the northern part of its area of outcrop it is inferred to overlie bedrock at small depth; in the southern part it overlies or grades into ice-contact stratified drift. The contact between these bodies is not apparent from shallow borings, nor is there any topographic break. It is not known, therefore, how much if any of this sand and gravel, undifferentiated, is nearly contemporaneous with the ice-contact stratified drift and how much is postglacial. The unit is here treated arbitrarily as postglacial.

Immediately west of the occurrence described above, along Wallingford Road, is a much smaller body of sand and gravel, undifferentiated. It is coarser in grain size, but lacks distinctive form. Possibly it consists chiefly of ice-contact stratified drift.

Other occurrences of sand with pebbles, which do not clearly imply an origin either as outwash sediments or as postglacial alluvium, occupy the floor of West River valley between Lake Dawson and Lake Watrous, an area at the head of Lake Watrous, and a small area one-half mile west of Cheshire Reservoir.

Terrace Alluvium

Alluvium consisting chiefly of pebbly sand constitutes a thin veneer on the surface of a terrace, 20 to 30 feet above sea level, cut by the Quinnipiac River. It occupies a small area in the southeast corner of the quadrangle, but is more extensive in the adjacent Wallingford and New Haven quadrangles. It is one foot to more than 5 feet thick, and overlies bedrock where exposed in a railroad cut, and probably overlies ice-contact stratified drift also. In this area it consists of medium and coarse sand with small, subrounded pebbles, loose in texture, and moderate yellowish brown (10YR 5/4) in color. It appears to be a mixture of outwash sediments, ice-contact stratified drift, and possibly till, reworked by the postglacial Quinnipiac River. The sediment was deposited from the bed load of that stream as it meandered across its valley during gradual downcutting, during which part of the valley floor was left isolated as the terrace on which the sediment now lies.

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 occurs along small streams having steep gradients; the finest along streams of very gentle slope. Most of the occurrences that extend laterally beyond active stream channels are confined to floodplains, which today are inundated at times of high water. Along Mill River, however, the alluvium as mapped lies not only on the floodplain but on or in stream terraces standing a few feet higher. Whether these terraces are inundated during rare floods, under the existing regimen of the river, is not known. On small streams also the alluvium as mapped includes minor stream terraces.

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 no more than a few feet thick. In places, however, alluvium occurs as conspicuous fans built on flat areas at the bases of steep slopes. The fans are shown by symbols on the map. Although most of them are postglacial, one or more may have been built at least in part contemporaneously with ice-contact stratified drift with which they are associated. 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 not shown on the map as a separate unit, but is included either with alluvium or with bedrock.

The most conspicuous colluvial bodies within the quadrangle are taluses, no one of which is in contact with alluvium. These are aprons consisting of angular blocks of diabase or basalt that mantle parts of cliffs and that were formed after deglaciation. Examples are the taluses along the east side of Roaring Brook Road in Prospect, 0.4 mile south of its crossing of Roaring Brook; along the southeast base of Mt. Sanford; and along the Quinnipiac Trail where it intersects the mountain road 0.4 mile northeast of the main entrance to Sleeping Giant State Park.

Swamp Deposits

More than 50 swamps, large and small, lie wholly or partly within the quadrangle. Most of them are no more than a few hundred feet in maximum diameter. They are of three kinds. Most abundant are swamps that occupy shallow basins in till in upland areas. Next are swamps that occupy the floors of kettles associated with ice-contact stratified drift; most of these lie within the valleys of Mill River and Willow Brook. Least numerous are swamps that lie on valley floors but that do not occupy definite basins; probably many of these occur where drainage is impeded by variations in the permeability of underlying material, including plant matter. Probably some of them occupy the sites of former kettles that were breached and drained by streams.

The living vegetation of many of the swamps consists of herbs, rushes, and sedges, and the swamps are open. Some swamps, however, are forested. The swamp deposits beneath consist commonly of black or dark brown muck, a sediment composed of fine sand, silt, and clay with conspicuous amounts of residues produced by the decay of woody and herbaceous plants, rushes, and sedges. The thickness of the swamp deposits is not known. In small swamps it is probably no more than a few feet, but in the larger ones it is greater. A core boring made near the center of Bethany Bog, between Fairwood Road and Beacon Road in Bethany, shows that the swamp deposits there are at least 44 feet thick. Analysis of the fossil pollen at many levels in the core reflects 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 uncovered the site of the swamp, is believed on indirect evidence to have embraced at least the last 13,000 years and possibly a longer time. The succession of plants identified in the core indicates that over this period the climate became warmer and drier, but that it underwent intermediate fluctuations. (Deevey, 1943, p. 727-729)

The swamp shown in the extreme southeast corner of the quadrangle, on the floor of the Quinnipiac Valley, lies barely above high-tide level. It appears to be continuous with tidal marsh in the adjacent New Haven and Branford quadrangles, but in the Mount Carmel quadrangle it contains fresh-water vegetation.

Wind-Blown Sand and Silt

A cover of sand and silt believed to have been deposited by the wind is present discontinuously over parts of the quadrangle, mainly within the area of Triassic rocks. In most places it ranges in thickness from less than one foot to 2 feet, with a maximum observed thickness of 3 feet. The sediment is generally a sandy or silty loam, light brown (5YR 6/4) to moderate brown (5YR 4/4). Because of its small thickness and discontinuity of distribution it is not shown on the map. It occurs overlying both till and stratified drift, but has not been seen overlying alluvium or terrace alluvium. Therefore it is believed to antedate the latter sediments.

Probably this sediment was derived both from the outwash body in the Quinnipiac Valley and from the ice-contact stratified drift in the valley of Mill River, which must have been exposed to wind erosion during their accumulation and until the time when they became covered by vegetation. The presence of the loam west of the Quinnipiac River and west of Mill River as well as east of it implies that the effective winds had easterly as well as westerly components of movement. No sand dunes have been recognized within the quadrangle.

At several localities, ventifacts (pebbles, cobbles or boulders faceted and polished by the abrasive action of wind-blown sand and silt) are imbedded in the wind-blown sand and silt. Most of the ventifacts are pebbles of basalt, apparently derived from till. Probably they were abraded during the period of deposition of the inclosing sand and silt. The direction of the winds responsible for abading the pebbles cannot be learned from the orientation of the facets because the ventifacts have been disturbed, possibly by plowing, growth of tree roots, burrowing animals, or frost activity in the ground.

Soils

The Mount Carmel 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 inches thick. In the Mount Carmel quadrangle there are five chief soil types (Morgan, 1939): Wethersfield, Cheshire, Manchester, Woodbridge, and Pittsfield. As the area lies within a single zone of climate and vegetation, local differences among its soils must be the result mainly of differences in parent material, relief, and drainage.

Wethersfield soils are reddish to brownish, well drained upland soils developed in compact till derived from Triassic sedimentary rocks, diabase, and basalt. Cheshire soils are reddish to brownish, well drained soils developed in sandy till derived chiefly from sandstone. They are coarser in texture than Wethersfield soils. Manchester soils are thin, brownish soils developed in ice-contact stratified drift derived from Triassic rocks. These three soils occur only in the central and eastern parts of the quadrangle.

Woodbridge (dark gray to brown) and Pittsfield (yellowish brown) soils are well drained upland soils developed in till derived from crystalline rocks. These two soils occur only in the western part of the quadrangle.

Artificial Fill

Artificial fill consists of deposits made by human activity; these include railroad, highway, and building-construction fills and large accumulations of trash. Most of the fill material was obtained from areas immediately adjacent to the fill bodies. In densely populated areas within the quadrangle, most of the surface material (beneath streets, lawns, and driveways) is fill. However, fill is mapped only where it is at least 5 feet in thickness and large enough in individual area to be readily shown at the scale of the map.

GLACIAL AND POSTGLACIAL HISTORY

Before glaciation began in the Mount Carmel area, the principal valleys, ridges, and hills had already been developed by long-continued erosion and were broadly similar to those of today. Probably the surface was mantled with a thick residual soil. Whatever the number of glaciations of the Mount Carmel quadrangle, the result was removal of the preglacial soil, smoothing and streamlining of hilltops, destruction of many gullies and minor valleys by glacial erosion or filling with drift, and interruption of minor streams through the creation of small lakes and swamps.

When the glacier reached its maximum extent the quadrangle was completely buried, because evidence of glaciation is present on the highest hills as well as in the valleys. As the buried bedrock floor of the Quinnipiac Valley in the adjacent Wallingford quadrangle lies more than 200 feet below sea level, the glacier must have been well over 1000 feet thick; it may have exceeded that thickness by a wide margin.

The first glaciation clearly recorded in the quadrangle entered the area from the north or slightly west of north. In a subsequent glaciation or at a time later in the same glaciation the ice flowed over the area from the northeast. During final deglaciation the thickness of the glacier, at least in a wide belt near its margin, was so reduced by melting that the ice ceased to flow and became inert. Probably thinning of the glacier exposed first the highest hills and then progressively the lower hills and ridges. Streams of meltwater flowed between the margins of glacial tongues and adjacent valley sides, and built up high, embankment-like masses of sand and gravel. Further thinning resulted in the extensive separation of blocks of stagnant ice of various sizes from the main glacier body. It was in conjunction with these that the ice-contact stratified drift in Mill River valley was deposited. The presence of kettles and other ice-contact features from end to end of that mass of drift indicates that the belt of separated bodies of residual ice was 8 miles wide within this quadrangle alone. In a late phase of deposition of the drift mass, in the sector downstream from Mount Carmel, the lower terrace was fashioned partly by stream erosion and partly by collapse over melting, buried ice.

Considerably later, meltwater streams in the Quinnipiac Valley built up the large body of yellowish outwash sand that is represented by a single small occurrence in the Mount Carmel quadrangle. During the whole period of meltwater-stream activity, fine sand was blown from valley floors and was spread as a very thin, discontinuous blanket over the uplands. Probably this activity was brought to an end by the establishment of a cover of vegetation over valley floors, first in the valley of Mill River and later in that of the Quinnipiac.

With the disappearance of the extraordinary glacial source of abundant sediment, streams became relatively underloaded and began to dissect the glacial sediments. Dissection was accompanied by meandering; this resulted in terraces cut into ice-contact stratified drift or outwash, and covered with thin veneers of mixed sediment consisting mainly of sand deposited from the bed loads of the streams. In the Quinnipiac Valley the terrace veneers are wide and conspicuous, like the one lying partly in the Mount Carmel quadrangle. In the valley of Mill River the terraces are narrower and less conspicuous. Below the terraces, on the valley floors, narrow bodies of alluvium have developed.

During postglacial time the existing soils formed beneath the surface, under a cover of vegetation. The youngest soils are those on postglacial terraces and on alluvium bordering the streams. The accumulation of peat in swampy areas 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.

ECONOMIC GEOLOGY

SAND AND GRAVEL

Despite a large demand for concrete aggregate, the sand and gravel that constitute most of the ice-contact stratified drift within the quadrangle are not worked for this purpose on any large scale. This is because the sediments of Triassic origin are structurally rather weak, and because those of crystalline-rock origin are either too thin or too rich in large boulders to be attractive. These materials are extracted locally, from small pits, and are used principally as fill.

SWAMP DEPOSITS

Organic swamp deposits within the quadrangle are potential sources of garden humus. However, the swamp areas are small and it is doubtful that their commercial development would be economically feasible.

GROUND WATER

Various bodies of ice-contact stratified drift within the quadrangle are good potential sources of ground water for domestic use. However, as the sand and gravel of which they consist are very permeable, water tables are generally low, being adjusted to the nearest streams. In consequence, development of a reliable water supply from such material depends on its thickness below the water table; this is a matter for local investigation in each case.

Till is too thin and in many places too impermeable to be a source of water other than for shallow wells of low yield. Most of the water used within the map area is derived from surface reservoirs or from wells drilled into bedrock.

A discussion of the occurrence of ground water in the Mount Carmel area will be found in Brown (1928).

REFERENCES

Brown, J. S., 1928, Ground water in the New Haven area, Connecticut: U. S. Geol. Survey Water Supply Paper 540, 206 p.

Dana, J. D., 1870, On the geology of the New Haven region, with special reference to the origin of some of its topographic features: Connecticut Acad. Arts and Sciences Trans., v. 2, p. 45-112.

——— 1871, On the Quaternary, or post-Tertiary of the New Haven region: Am. Jour. Sci., v. 1, p. 1-5, 125-126.

——— 1875-76, On southern New England during the melting of the great glacier: Am. Jour. Sci., v. 10, p. 168-183, 280-282, 353-357, 409-438, 497-508; v. 11, p. 151; v. 12, p. 125-128.

——— 1883, On the western discharge of the flooded Connecticut, or that through the Farmington Valley to New Haven Bay: Am. Jour. Sci., v. 25, p. 440-448.

——— 1883-1884, Phenomena of the glacial and Champlain periods about the mouth of the Connecticut Valley – that is, in the New Haven region: Am. Jour. Sci., v. 26, p. 341-361; v. 27, p. 113-130.

Deevey, E. S., 1943, Additional pollen analyses from southern New England: Am. Jour. Sci., v. 241, p. 717-752.

Flint, R. F., 1930, The glacial geology of Connecticut: Connecticut Geol. Nat. History Survey Bull. 47, 294 p.

——— 1934, Late-glacial features of the Quinnipiac-Farmington lowland in Connecticut: Am. Jour. Sci., v. 227, p. 81-91.

Goddard, E. N., and others, 1948, Rock color chart: National Research Council, Washington, D. C., 6 p.

Krynine, P. D., 1937, Glacial sedimentology of the Quinnipiac-Pequabuck lowland in southern Connecticut: Am. Jour. Sci., v. 233, p. 111-139.

Morgan, M. F., 1939, The soil characteristics of Connecticut land types: Connecticut Agr. Expt. Sta. Bull. 423, 64 p.

Ward, Freeman, 1920, The Quaternary geology of the New Haven region: Connecticut Geol. Nat. History Survey Bull. 29, 78 p.

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