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LATE PLEISTOCENE AND RECENT GEOLOGY OF THE HOUSATONIC RIVER REGION IN NORTHWESTERN CONNECTICUT

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by

George C. Kelley

U. S. Geological Survey
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ABSTRACT

An investigation of Late Pleistocene and Recent surficial deposits in western Connecticut and adjacent areas was undertaken to determine characteristics of Wisconsin glaciation and the history and chronology of deglaciation in part of the finely dissected New England Uplands.

The study area lies along the midreach of the Housatonic River in western Connecticut, and has local relief exceeding 1,200 feet. Surface morphology and internal characteristics of glacial and glaciofluvial erosional and depositional features were examined and mapped in detail in the Kent and Ellsworth, Connecticut, U.S.G.S. 7-1/2 minute quadrangles, and by reconnaissance in the surrounding quadrangles. This study contributes to the expanding detailed knowledge of glaciation and geomorphology in western New England and eastern New York state.

Ice along the lateral east margin of the southward-waxing, Wisconsin-age, Hudson-Champlain Valley ice lobe successively overran ridges trending northeast-to-southwest. Late Wisconsin ice flow was consistently toward the southeast in the study area. Glacial erosion on the upland surfaces was weak, and several early or pre-Wisconsin melt-water channels persist, which evidence little late Wisconsin glacial or glaciofluvial modification. Deeply weathered

rock has been locally preserved beneath unweathered till. Till deposits are generally thin, averaging from 10 to 15 feet in thickness, but till deposits exceeding 200 feet in thickness have been observed. Direct evidence for two or more cycles of till deposition is lacking, although multiple glaciations can be inferred from drainage derangement of the Housatonic River and from anomalies in configuration of old, upland melt-water channels which were re-occupied and eroded by melt water during subsequent deglaciations.

The orientation of ridges and the local terrain relief exerted minor control on ice flow during waxing phases of glaciation. Local relief and ridges which were oriented transverse to ice flow became the dominant control factors for ice flow during late phases of deglaciation and ultimately initiated marginal stagnation zones.

Late Wisconsin deglaciation evolved in three stages. First, the active ice margin receded rapidly northwestward across, and almost transverse to, the upland ridge crests in response to factors of both backwasting and downwasting. Second, local terrain relief restricted active ice flow, initiated stagnation, diverted melt-water flow and controlled deposition of small active ice-marginal deposits on the northwest slopes of ridges. Third, melting and thinning of stagnant ice tongues in valleys with ice surfaces which were low gradient and southward-sloping caused rapid northward recession of the stagnant ice margin. Sequences of related outwash deposits have been correlated with inferred ice-marginal, recessional positions. In this region, the zone of stagnant ice distal to active ice ranged from 6 to 15 miles in average width.

Lacustrine sediments accumulated as stagnant ice blocks melted in isolated basins and other depressions where through-flowing melt-water drainage was restricted or absent. The paucity of ice-contact and outwash deposits in the isolated basins indicates that little entrained debris was present in the stagnant ice. Prograding outwash along the Housatonic River and other major drainage routes infilled glacially overdeepened rock basins and buried underlying lacustrine sediments beneath upward-coarsening sand and gravel.

Upland bogs, which have developed postglacially, contain as much as 22 feet of organic material mixed with silt and clay. An age of 12,750 ± 230 years B.P. was determined for materials immediately above three feet of older organic-rich clay layers. This dated material correlates with the upper part of the pollen T zone reported elsewhere in Connecticut and New York.

ACKNOWLEDGMENTS

Development of this project would have been impossible without the assistance of many people and several organizations. I offer my sincere appreciation and thanks. Any errors or misconceptions which may be included in this work, however, are solely the responsibility of the author.

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The multiple contributions of the Syracuse University Department of Geology, and advisor Ernest H. Muller, are recognized and appreciated. The provision of advice, work space, materials, support, much computer access, and a patient open ear have all contributed to the development of the geological concepts contained herein.

Recognition must also be given to the support of my family, and particularly to my wife who provided editorial assistance at critical stages in the evolution of the manuscript.

My deepest gratitude must go to Nancy M. Craft. Without her faith and unswerving assistance throughout the program development, numerous revisions, and defense, it would not have been possible to complete this manuscript. I, therefore, respectfully dedicate this work to:

The Secretary

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CHAPTER I

INTRODUCTION

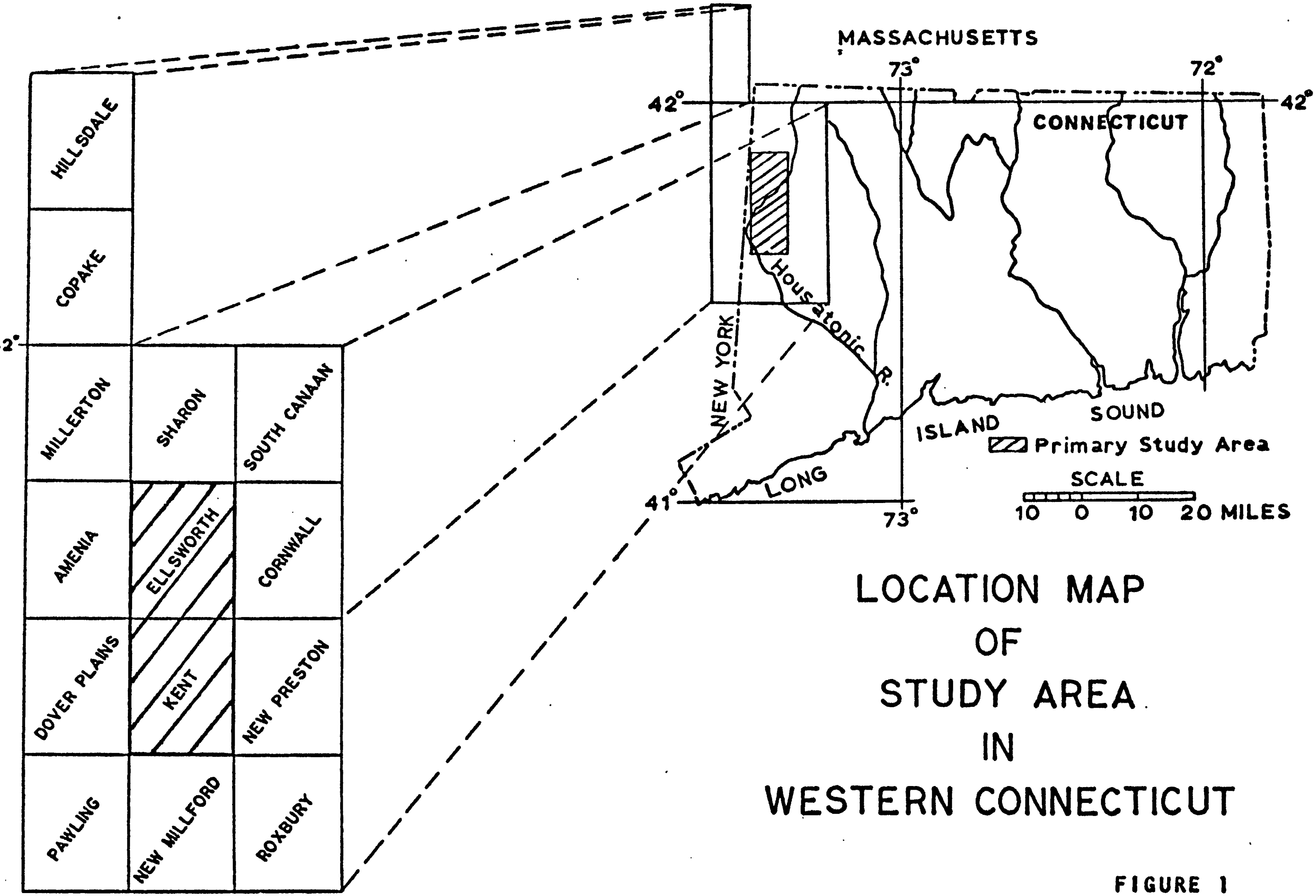
Objectives

This study was undertaken to determine the nature of glaciation, and the chronology of deglaciation along the Housatonic River in western Connecticut.

Physiography

Geographically, the study area is in central western Connecticut in the New England Upland province, and lies along the midreach of the generally southward-draining Housatonic River. The study area has a primary part which consists of the Kent and Ellsworth 7-1/2 minute topographic quadrangles, and a secondary part which includes portions of adjacent and nearby topographic quadrangle areas (Fig. 1).

Topographically, the hills, ridges and narrow valleys which dominate the landscape are controlled by bedrock lithology and structure, and were sculptured by preglacial weathering and erosional processes. These features exhibit only minor glacial modifications. The grain of the



LOCATION MAP
OF
STUDY AREA
IN
WESTERN CONNECTICUT

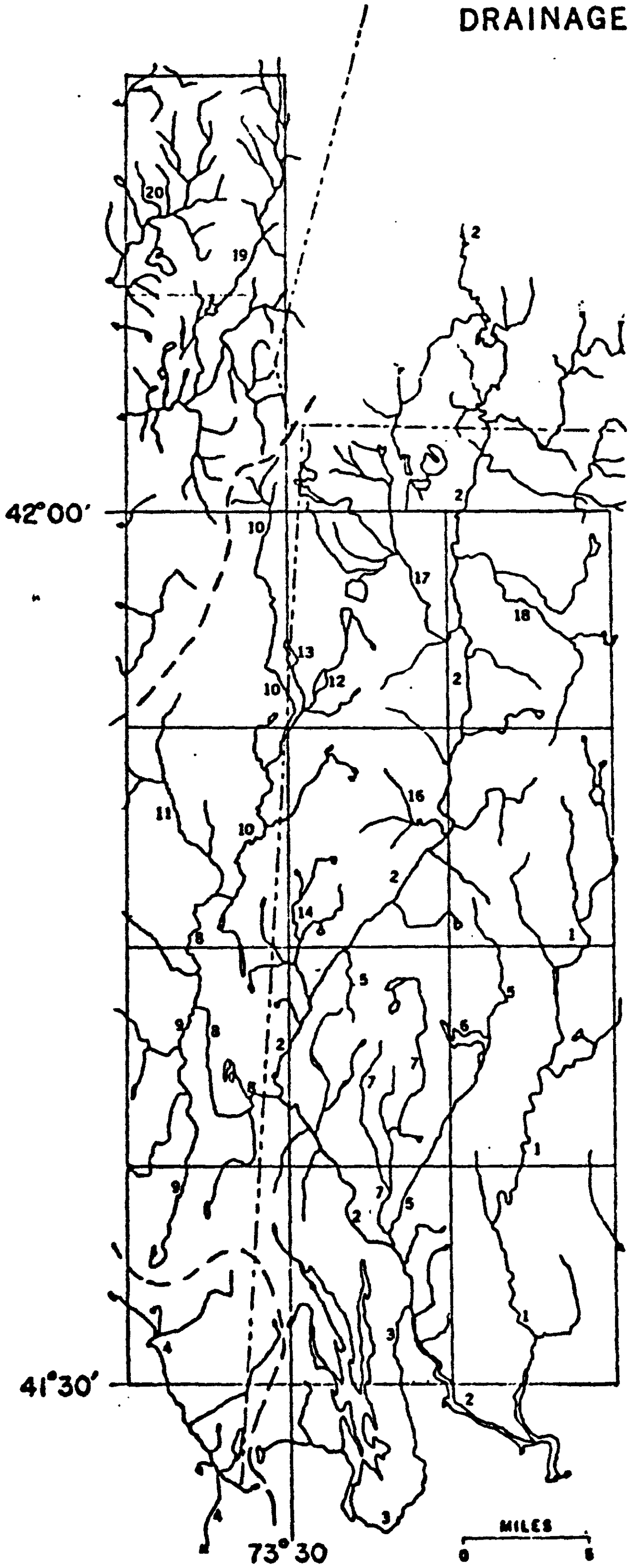
FIGURE 1

landscape reflects the trend and relative resistance of the underlying rocks. Valleys have developed in Stockbridge and Woodville marble formations. Ridges are formed of resistant materials, including the gneissic complex of the highlands, Danbury granitic gneiss, hornblende gneiss, Poughquag (Cheshire) quartzite, and schist of the Waramaug and Salisbury formations (Rogers and others, 1959). Severe deformation of the Waramaug formation has locally reduced resistance of these rocks to erosion, facilitating the development of isolated basins and interconnecting drainage.

Relief in the primary study area exceeds 1,300 feet, with altitudes ranging from less than 230 feet on the Housatonic River southeast of Gaylordsville to 1,441 feet in the Housatonic Highlands at Ellsworth Hill (Pl. II, III).

Hydrologically, the Housatonic River and its tributaries dominate the drainage in the study area (Fig. 2). Massachusetts, north of the primary study area, the Housatonic River follows a meandering course on a broad, lacustrine and alluvially floored valley between the Taconic Range on the west and the Berkshire Hills on the east. Near Falls Village, Connecticut, the river drops over falls which are only slightly incised in carbonate rock and then migrates southward through a narrow, steep-walled valley carved in the resistant gneissic rocks of the Housatonic Highlands. Along the stream reach between Cornwall Bridge

DRAINAGE NET IN WESTERN CONNECTICUT AND EASTERN NEW YORK



STREAMS AND LAKES

1. Shepaug River
2. Housatonic River
3. Still River
4. East Branch Croton River
5. East Aspetuck River
6. Lake Waramaug
7. West Aspetuck River
8. Tenmile River
9. Swamp River
10. Webatuck Creek
11. Wassaic Creek
12. Mudge Pond
13. Indian Lake
14. Macedonia Brook
15. Cobble Brook
16. Guinea Brook
17. Salmon Creek
18. Hollenbeck River
19. Roeliff Jansen Kill
20. Taghkanic Creek

Drainage divide

FIGURE 2

and Bulls Bridge the river is a southwest-trending, subsequent stream following weak carbonate rocks. At Bulls Bridge it again plunges over falls and quickly descends rapids in a vertically walled canyon carved in the severely folded Stockbridge carbonate rocks. From Bulls Bridge, the river's course trends southeastward, crosses the topographic grain obliquely, and passes through several narrow water gaps cut in resistant ridges. It continues southeastward and discharges into Long Island Sound. Tributaries entering the Housatonic River are lithologically controlled by the trend of the underlying bedrock. Some have north-flowing stream reaches for all or part of their courses before joining the Housatonic River.

Geologically, the primary study area contains part of the northeast-to-southwest-trending Housatonic Highlands which are formed of pre-Cambrian gneisses. These are flanked by complex and severely folded metasedimentary rocks of Cambrian to Ordovician age (Rogers and others, 1959). Small masses of intrusive felsic rock are exposed at scattered locations. Lithologies include phyllite, marble, schist, granite, pegmatite, felsic and mafic gneiss, and quartzite. Mapping of lithologic stratigraphy and structure has been completed by reconnaissance in the primary study area (Rogers and others, 1959) and by detailed mapping in the New Preston and Cornwall quadrangles of the secondary area (Gates and Bradley, 1952; Gates, 1961).

Background Information

The following discussion reviews significant references which focus on problems in western New England or are directly applicable to the study area.

Various attempts have been made to interpret and correlate Pleistocene stratigraphy and chronology within and between the Midwest, the northern Mid-Atlantic states, and New England. Efforts to trace and correlate drift sheets and to distinguish terminal and recessional ice-marginal positions have been based on areal relations of moraine segments, ice-contact deposits, drainage channels, drift pebble lithologies, heavy mineral variation, till fabric analyses, and proglacial lake fluctuations and deposits. Applications of these criteria to regional problems can be found in many references, notably Fairchild (1932a; 1932b), MacClintock and Richards (1936), Holmes (1939), Flint (1953), Muller (1965), Fullerton (1971), Connally and Sirkin (1970; 1971; 1973), Goldthwait, R.P. (1971), and Cadwell (1972).

Multiple glaciation in New York, New Jersey and Pennsylvania, possibly including Wisconsin, Illinoian and pre-Illinoian materials, has been inferred at several localities (Leverett, 1934; Peltier, 1949; Kaye, 1964b; Muller, 1965). Most drift in these states, however, is considered to be of Wisconsin age (Flint, 1971, Chapter 21). Several drift sheets exposed in coastal regions of southern New England and on offshore islands led Kaye (1964a) to infer multiple glaciations, each correlated with a glacial episode in the Mississippi Basin. Elsewhere, Wisconsin-age deposits dominate, although all or most parts of New England were presumably glacierized several times.

Delineating and correlating the general retreats and re-advances of the latest glacial ice and its associated drifts has been complicated by many factors. One factor is regional lithologic variation involving distinct differences in underyling bedrock composition, orientation, and exposure. These variations initially determined the amount, type, and region in which specific rock lithologies were entrained by the glacial ice, and subsequently influenced the extent of dispersion now evident in glacial drift (Holmes, 1939). Variation in observed lithologic percentages in glacial drift of south central New York is the primary factor in the persisting discussion of the Binghamton-Olean problem, initially identified by

MacClintock and Apfel (1944), complicated by Denny (1956), clarified by Moss and Ritter (1962), reviewed by Muller (1965), and elaborated further by Cadwell (1972).

Topographic effects also complicate correlations. Continental glaciers encountered greater local relief in the dissected Appalachian Plateau of Pennsylvania and New York than in the midwest. Tracing and correlating the often obscure moraines and other ice-marginal features across uplands are frequently impossible, and frustrate local as well as regional correlations. Tarr (1905) in central New York, and Muller (1965) in western and central New York, correlated elements of significant glacial marginal features such as the massive Valley Heads moraine system.

Von Engeln (1921) described and discussed the striking glacial features present in the Valley Heads moraine near Tully, New York, and called them a "glacial series" following a model originated by Penck and Bruckner. Clarifying the meaning of the term, von Engeln stated:

> "By this phrase it is meant to characterize the typical succession and association in which the various evidences of the occupation of an area by glacial ice will be encountered after the ice has melted away." (p. 40)

Both erosional and depositional features indicate the ice-marginal relationships associated with distal outwash, the marginal loop, and the proximal loop trough extending up-ice through the drumlin belt. Describing the materials which form an outwash plain-valley train, he stated:

> "...more material was probably carried forward and southward by the waters released at the melting end of the ice and those which flowed along its lateral margins; for all the valley to the south of the morainic front is deeply filled with stream-sorted gravels, sands and clays..." (p. 57)

Thus he recognized an associated group of related glaciofluvial deposits extending through the ice-marginal zone and beyond. He also considered the probable effect of ice-marginal retreat distal to the obvious morainal deposits evident today, stating:

> " It must not be conceived that this outwash deposit was necessarily all built up from streams issuing from the ice immediately at the points where the morainic front is now seen. This morainic mass probably continues under the outwash for considerable distances southward and may indeed be made up of a number of ridges marking earlier halts in this section, as the visible mass marks the last stand. These possible and probable earlier corrugations of morainic material are, however, now all veneered over and buried under outwash. They must of course have been lower in elevation than the visible morainic mass at Tully, else they could not have been buried completely. But during the existence of each halt an apron of outwash was deposited along the moraine front, and as a succeeding, more northerly ridge was built up its outwash in turn filled in behind and built up over the deposits of both morainic and outwash material made previously." (p. 57)

Von Engeln also noted gradation in textural distribution within the aggrading outwash. He stated:

"Accordingly, the coarsest materials, boulders and pebbles, were deposited first, and as the streams spread over their own accumulations, their flow was progressively less deep and more feeble so that successively finer deposits were laid down southward." (p. 57)

He visulaized the stagnation and isolation of ice masses distal to the active ice margin, and considered their probable effects.

"As the moraine accumulated, deposit along the front of the ice was frequently much more rapid than the melting of the ice of a particular area. Hence it commonly happened that a block of ice was buried deeply under the gravelly debris. In such position it was effectively protected from melting as quickly as did the exposed ice areas adjacent to it. In time the buried block was completely detached from the ice tongue and persisted, unmelted, while additional masses of deposit were piled around and over it. When the detached ice blocks finally melted away completely the deposits over it must have sunk down to fill the cavity thus created. Such burial, melting and slumping must have constantly occurred while the moraine was forming, but the resulting hollows were then almost at once slushed full of other sediment. But during the very last period of the maintenance of the ice front at the moraine, the buried ice blocks apparently persisted until after deposit had ceased..." (p. 54-55)

Two factors are significant in von Engeln's (1921) concept of deposition. First, the outwash prograded from the ice front, simultaneously lengthening and aggrading vertically, and obliterating underlying features. Second, an active ice margin gradually retreated, developing a distal zone of stagnant ice. Rapid ice retreat from this position precluded development of thick accumulations behind the morainal loop. He inferred that the source material for the moraine and outwash plain was active ice, stating;

> " While vast quantities of the glacial debris brought forward by the Onondaga valley lobe were deposited in the moraine ...still more material was probably carried forward and southward by the waters...for all the valley to the south of the morainic front is deeply filled with stream-sorted gravels, sands and clay..." (p. 57)

Details of the deglaciation history and chronology for numerous, less distinct recessional positions lying in the uplands and through valleys of central New York between the Valley Heads moraines and older terminal moraines have been only recently presented by Cadwell (1972). The 5 general criteria he used to delineate 25 ice-marginal positions in 6 zones include surface morphology, upland outflow channels, upland melt-water deposits, configuration of deposits around umlaufbergs, and "valley-deposits mosaic" (a distinctive sequence of related deposits). As Muller (1965) has aptly pointed out:

> "Consistent stratigraphic relations and continuous tracing of moraines are the most widely reliable criteria for correlation of glacial deposits. Both are particularly difficult to apply in areas of moderate to high relief such as the Appalachian Uplands."

The dissected Catskill Uplands and the Adirondack Highlands have even greater local relief than the

Appalachian Uplands, which further complicates extending correlations of deposits and deglaciational events eastward in New York State. Ice of Valley Heads age which was encircling the Adirondacks subsequently divided south of the Adirondacks into a western Oneida-Black River lobe and an eastern Mohawk-Champlain lobe (Muller, 1965). Correlation of the eastern ice-marginal deposits of the Mohawk-Champlain lobe with deposits in New England is uncertain, and numerous interpretations prevail in the literature (Schafer and Hartshorn, 1965; Connally and Sirkin, 1970; 1971; 1973; Flint, 1971; Fullerton, 1971).

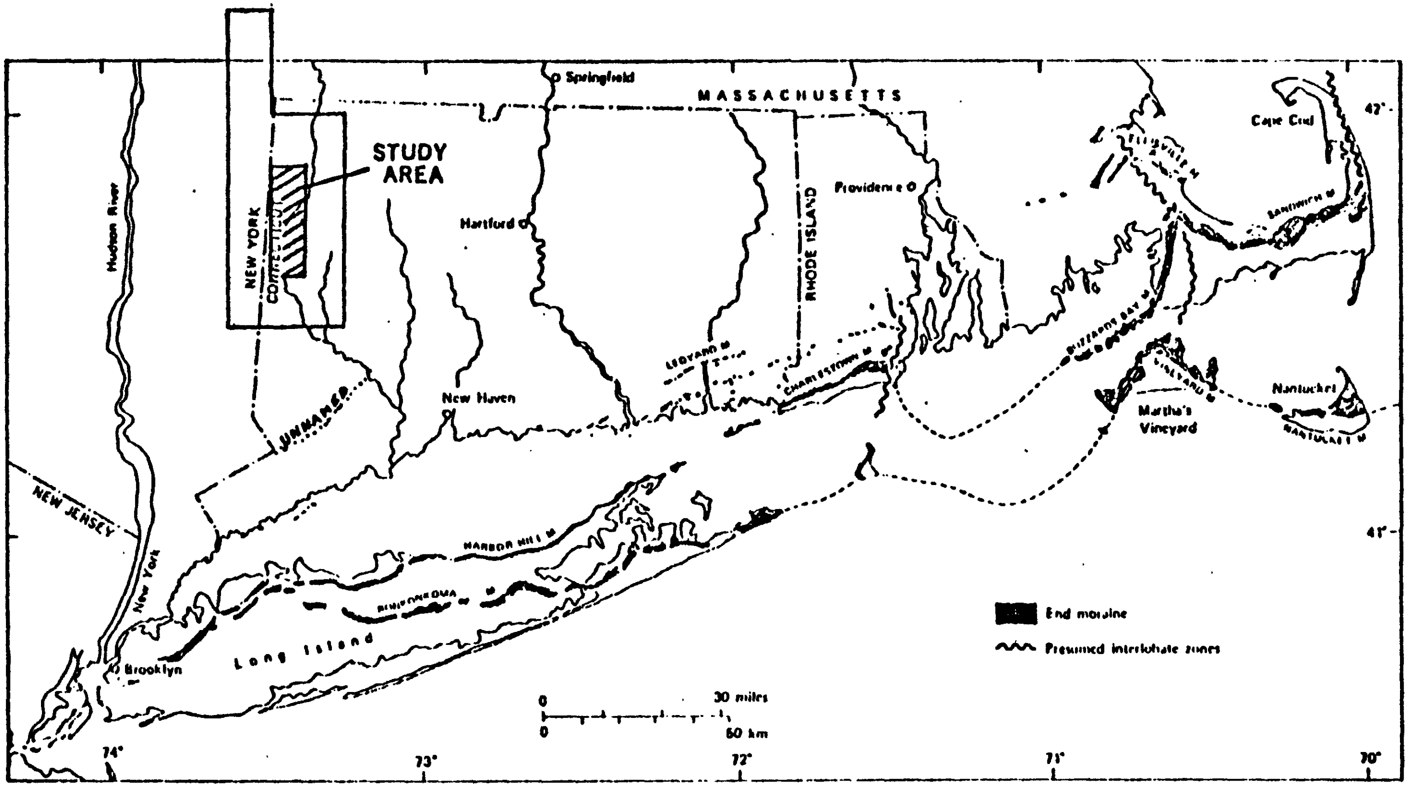
With the advent of radiocarbon dating, correlation of deposits and events throughout the northern United States seemed possible, and this technique has been valuable in some places (Flint, 1971). Problems today appear to result from too many dates, as exemplified by dates associated with moraines of the Valley Heads system in sections of New York State. Ages as old as 12,600 years B.P. are reported for deposits in central and western New York, believed to immediately post-date the youngest Valley Heads position (Muller, 1965). Cadwell (1972) reported an age of 16,500 years B.P. at a location near Binghamton, approximately 80 miles south of the Valley Heads position. This date shows that recession from the Woodfordian maximum approached the Valley Heads position prior to 16,000 years B.P. Fullerton

(1971, Pt. I, p. 55) reported a 12,900 ± 100 years B.P. age in material associated with Valley Heads deposits in the Mohawk Valley. Calkin (1970) obtained dates of 14,900 ± 450 years B.P. (I-4216) and 13,800 ± 250 years B.P. (I-4043) on overlying outwash deposits distal to the Lake Escarpment moraine, a Valley Heads equivalent in western New York (Muller, 1965). To account for the age discrepancies in apparently correlative units, Fullerton (1971) envisioned re-occupancy of some older Valley Heads positions by ice during a younger re-advance.

Connally and Sirkin (1973) recognized these late Woodfordian dates (Late Cary-Port Huron age) when they summarized the deglaciation of the Hudson-Champlain Valley. In addition, Sirkin and others (1970) proposed 26,800 years B.P. as an age for maximum Woodfordian glaciation based on interglacial peat (Farmdalian). Schafer and Hartshorn (1965), however, reported a date of 21,200 ± 1,000 years B.P. for the horn core of an extinct bison found near Harvard, Massachusetts. This age is old, but is consistent with the maximum age for the Woodfordian stage in the midwest and elsewhere (Flint, 1963; Frye and Willman, 1963; Schafer and Hartshorn, 1965). These dates indicate that a maximum Woodfordian ice position in the eastern United States was achieved approximately 20,000 years B.P.

In the Hudson River valley, recession of the Woodfordian ice commenced by 17,000 years B.P. By 15,000 years B.P., it occupied a stillstand position north of the Hudson Highlands, as recorded by the Wallkill moraine (Connally and Sirkin, 1970). By 12,600 years B.P., after several re-advances in the Hudson-Champlain Valley, the ice receded from the Highland Front moraine along the southern edge of the St. Lawrence Lowlands by 12,600 years B.P. (Connally and Sirkin, 1971; McDonald and Shilts, 1971). Connally and Sirkin (1971) believed that the Valley Heads morainal system delineates a relatively stable ice-marginal position in central New York which correlates with separated recessional positions in both western New York and the Hudson-Champlain Valley. Fullerton's (1971) concept of re-occupied Valley Heads positions is compatible with the Connally-Sirkin (1971) thesis, at least for the final waning phases of ice retreat. These events of Cary-to-Late Port Huron-age range from about 15,000 to 12,600 years B.P.

Flint (1971) stated that the paucity of useful dates in New England has prevented adequate correlation in that region. Deglaciation of southwestern and south central New England was initiated by ice retreat from terminal positions on Long Island prior to 15,000 years B.P. (Schafer and Hartshorn, 1965) (Fig. 3). Connally and Sirkin (1971) inferred that Woodfordian recession began by 17,000 years



END MORAINES OF SOUTHERN NEW ENGLAND AND SOUTHEASTERN NEW YORK

(AFTER FLINT 1971)

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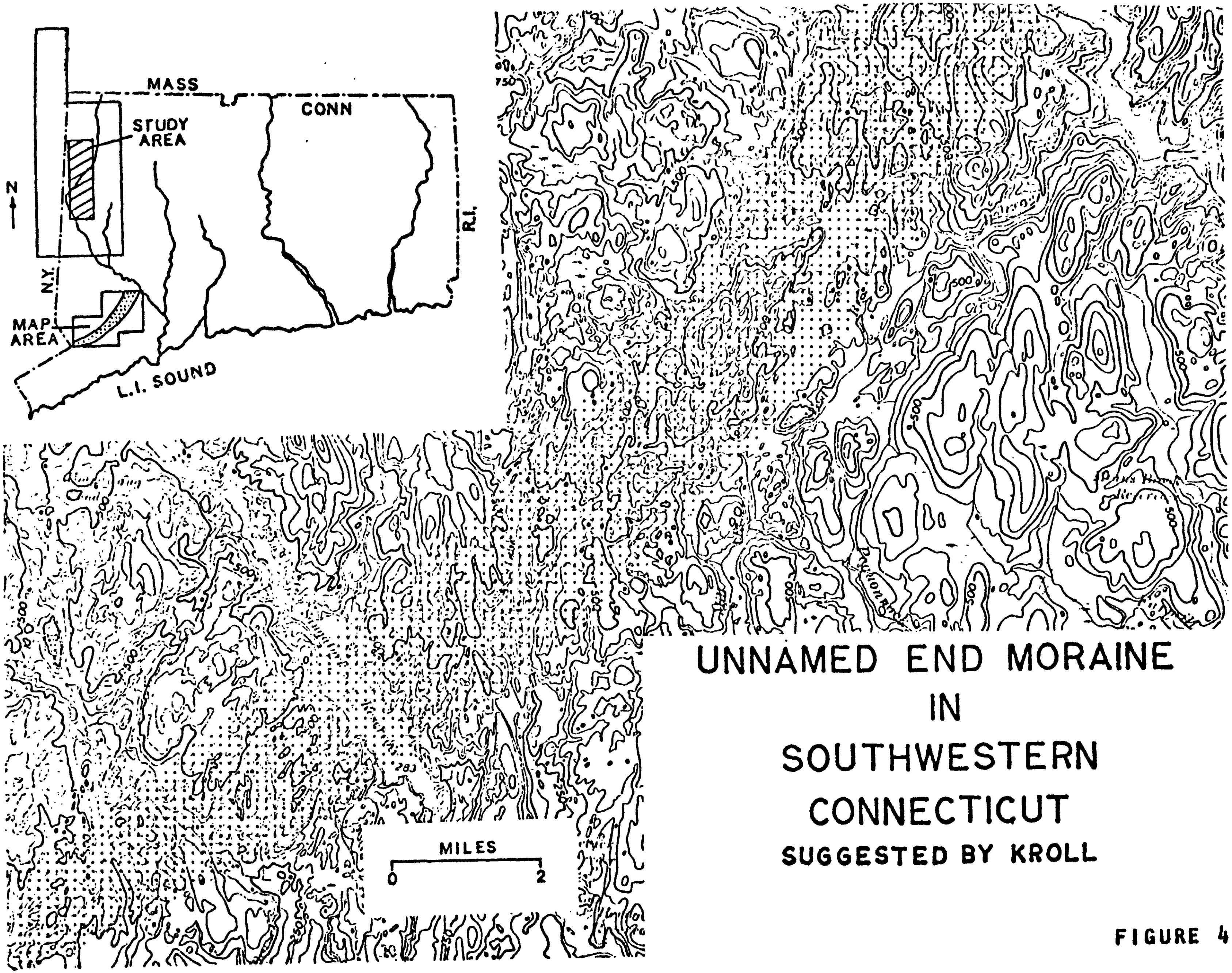
FIGURE 3

B.P. on western Long Island, or perhaps slightly prior to initiation of ice recession in central and eastern parts of Long Island. Northward, Schafer and Hartshorn (1965) indicated that by 14,000 years B.P. the present southern coast of Connecticut was free of ice.

As the active ice receded from terminal moraines on Long Island, minor recessional moraines were deposited along the southern New England coast in a zone extending 50 kilometers (31 miles) behind the terminal moraine (Flint, 1971). This zone is dominated, however, by stagnant ice deposits, and the minor terminal moraines may have developed along shear zones between actively flowing ice and stagnating dead ice (Schafer and Hartshorn, 1965). In southeastern Connecticut, this zone includes the Ledyard moraine which is chiefly a linear concentration of boulders (Goldsmith, 1960a; 1960b; 1962). A feature trending northeast-to-southwest in southwestern Connecticut (Fig. 4) was first identified as a moraine by Kroll (1971 personal communication) from observations he made while mapping the bedrock geology of the Norwalk North quadrangle. Newman (1973 personal communication) is currently attempting to evaluate Kroll's unnamed moraine in terms of a late Port Huron re-advance extending as far south as western Long Island, perhaps occurring around 13,000 years B.P. Local relief increases



UNNAMED END MORAINE
IN
SOUTHWESTERN
CONNECTICUT
SUGGESTED BY KROLL

FIGURE 4

northward from this moraine, and morainal features are absent or obscure.

Due to the general absence of "classical" moraines in most of New England, previous workers have sought to establish criteria by which recessional positions and the mode of local deglaciation could be determined in the moderate- to high-relief regions. Outwash heads, kame delta sequences, and other glaciofluvial constructional landforms were correlated between adjacent valleys. Attempts to reconstruct sequential events for local and regional deglaciation histories from inferred recessional ice positions are found in several reports including Woodworth (1898), Taylor (1903), Alden (1924), and Loughee (1940). These articles illustrate the persistence and dominance of the concept of active ice-marginal retreat in New England comparable to prevailing concepts for deglaciation in the midwest where morainal deposits reflect periodic stillstands and re-advances of waning but still active ice.

Inconsistencies within the deglaciation chronology have been indicated by Schafer and Hartshorn (1965). For example, Flint (1956) reported a minor re-advance near Middletown in central Connecticut dated at just prior to 13,000 years B.P. By 12,600 years B.P. the margin of active ice was at the Highland Front moraine in southeastern Canada (McDonald and Shilts, 1971). This time sequence allows only

400 years for deglaciation of the major part of New England. Antev's (1922) varve chronology, however, required at least 4,100 years for deposition of silts and clays in the proglacial lakes ponded between the receding ice and the damming deposits emplaced by the Middletown re-advance in the Connecticut River valley. His analysis requires that proglacial lakes persisted until approximately 8,900 years B.P. Flint (1956), however, believed that these proglacial lakes drained by at least 10,650 years B.P., a discrepancy of 1750 years.

The lack of classical moraines, dominance of stagnant ice features, varves, and radiocarbon ages suggest a rapid but conflicting deglaciation chronology throughout central and western New England. Debates regarding details of glaciations and the mode and chronology of deglaciation in New England began more than 100 years ago and continue today.

Even before the turn of this century, a viable alternative to the active ice-marginal retreat concept emerged (Woodworth, 1898). This alternative model sought to explain the nature of deposits and the mode of deglaciation in New England and eastern New York. It had two variations. One emphasized ice stagnation as regional in extent with most of the formerly active ice which was covering New England stagnating, downwasting, and eventually developing extensive areas which contained isolated blocks and tongues of dead ice (Cook, 1924; Flint, 1929). The second variation was a modification of the regional stagnation concept and assumed that ice thicknesses were significantly greater to the north. In this model, widespread stagnation and downwasting caused the thin, southern margin to retreat northward. Ice blocks and tongues became isolated only in a narrow local zone distal to the main mass of stagnant ice.

Other investigators, working in the dissected New England terrain, came to believe that stagnation occurred only in a limited marginal zone distal to active or weakly active ice. Stagnation was controlled chiefly by the topographic relief of the terrain (Currier, 1941; Rich, 1943; Koteff, 1974). Utilizing this concept, deglaciation sequences have been identified in some places by careful examination of distinctive stagnation features deposited in this presumed marginal stagnation zone (Jahns, 1941; 1953; Jahns and Willard, 1942; Koteff, 1974). Koteff (1974) reviewed the sequence model of Jahns (1941), clarified depositional details, and redefined the concept in terms of "morphological sequences" based on the possible assemblage of associated features. These are considered applicable to most areas of New England.

Flint (1971) has suggested, possibly as a compromise between currently prevailing views, that an initial period of deglaciation was dominated by backwasting with active ice-marginal retreat, during which stillstands and minor recessional moraines developed. Widespread stagnation and downwasting subsequently became dominant, with an attendant increase in melt water and sediments, and isolation of stagnating dead ice tongues and blocks. Cook (1924) also advocated a general stagnation with downwasting of the continental ice tongue in the Hudson-Champlain Valley. LaFleur (1961; 1965) favored a gradual northward retreat of the ice margin, but did not clarify whether the ice was active or stagnant behind a zone of marginal stagnation 2 miles wide. Other references in the literature (Connally and Sirkin, 1971; 1973) to ice "recession and re-advance" emphasize an active ice marginal retreat for this region. The southern margin of the Hudson-Champlain Valley ice lobe terminated in the northward-expanding proglacial Lakes Albany and Vermont. Stillstands or re-advances in that region are spaced far apart, such as those evident at Kingston and Glens Falls (Connally and Sirkin, 1971).

Muller (1965), in reference to the dissected Appalachian Uplands, stated:

> "Perceptive interpretation of combinations of textural, compositional, directional, pedologic and geomorphic criteria, as derived from detailed quadrangle-by-quadrangle mapping, should ultimately make possible the correlation of stratigraphic units and the tracing of moraines from one valley to the next."

This statement is equally applicable to New England.

Proglacial lake levels, shorelines, lacustrine deposits, and overflow outlets have provided important information in developing local and regional chronological interpretations in areas extending from the Great Lakes to New England. In central and western New York, Muller (1965) noted the close association of lacustrine and morainal deposits as ice receded from the Valley Heads moraine. Critical ice-marginal positions have been defined where erosional and depositional features indicate ponding which required blockage of drainage routes by impermeable ice. Two of these positions are at Covey Hill for Lake Iroquois and at the Hoosick River for Lake Bascomb. Details for lake chronology in the eastern Mohawk-north Hudson Valley region have been presented by LaFleur (1965).

Eastward in New England, proglacial lakes ranged in size from minor ponds to large, expanding, and persisting lakes such as Lake Hitchcock and its successors in the valley of the Connecticut River, and Lake Bascomb in the northwestern Massachusetts-southern Vermont area. In western Connecticut, south of the primary study area, receding ice dammed the

Still River, a north-flowing tributary of the Housatonic River (Hobbs, 1901; Harvey, 1920; Hokans, 1952). This area has been recently restudied by Thompson (1971), who concluded that the receding ice margin uncovered a series of overflow outlets at successively lower altitudes. Lacustrine deposits north of the study area consist of deltas, sands, and thick silts and clays, indicating the possibility of an extensive lake or chain of lakes along the Housatonic River in northwestern Connecticut and western Massachusetts. These lacustrine materials extend from south of Falls Village, Connecticut northward to the vicinity of Pittsfield, Massachusetts. Evidence from reconnaissance investigations suggests a possible continuation and direct connection between this hypothesized lake and a high level of glacial Lake Bascomb (Holmes, 1968 personal communication). Subsequent investigation and reports indicate that a series of less extensive lakes best accounts for the presence of these lake deposits (Holmes and Newman, 1971).

Definition of Problem

The complexity of deposits, paucity of useful radiocarbon dates, conflicting opinions regarding mode of deglaciation, and recurring problems of correlation and age of ice-marginal positions necessitate continued, detailed investigations in many parts of New England. Such investigations are necessary to identify and describe deposits, clarify details of glaciation, delineate characteristics of deglaciation, and facilitate regional correlations. Since unresolved problems remain in western New England today, this investigation initially sought to:

1. establish the location, mode of formation, and effects of a possible damming plug in the Housatonic River valley, perhaps situated in the primary study area and responsible for an hypothesized high-altitude lake of northwestern Connecticut and western Massachusetts;
2. map the surficial materials in the Kent and Ellsworth quadrangles in western Connecticut in detail;
3. investigate, evaluate, and interpret Late Wisconsin and Holocene deposits chiefly in the primary study area;
4. examine and evaluate data reported by geologists investigating nearby areas;

5. determine the regional mode of deglaciation;
6. apply a deglaciation model and delineate depositional sequences and chronology of late Pleistocene-Recent history for the Housatonic River region in northwestern Connecticut; and
7. make lateral correlations between the primary study area and adjacent areas.

Previous Work Applicable to Study Area

Studies about glaciation in the primary and secondary study areas are limited in number. Taylor (1903), developed criteria for identifying deglaciation by active ice-marginal retreat in Berkshire County in western Massachusetts. He extended his work southward to include features near Sharon, Connecticut in and immediately north of the current primary study area. He classified features in three groups:

1. ice-deposited moraines;
2. glacial and glaciofluvial deposits of ice-contact stratified drift; and
3. extra-marginal, melt-water erosional and depositional features.

Taylor (1903) identified and mapped ice-marginal deposits in the region extending more than 50 miles north of the primary study area, and correlated a series of recessional positions between valleys. He indicated that the distances between subsequent halts averaged only 3.5 miles.

Flint (1930) described glacial materials and suggested modes of deposition throughout the state of Connecticut. In western Connecticut, he indicated the presence of till and scattered, isolated, high-altitude glaciofluvial deposits in addition to stratified drift and alluvial deposits in the river valleys. He considered deglaciation to have been dominated by processes of downwasting of stagnant ice during which ponds and lakes formed between the ice and exposed portions of the adjacent terrain. Surfaces of ponds and lakes were water planes which are marked today by glaciofluvial materials originally deposited as fillings in these water bodies. In 1930 he emphasized regional stagnation and a north-to-south uncovering of the terrain, but he later (Flint, 1932) modified his view and omitted the north-to-south deglaciation.

Hokans (1952), investigated deposits along the Housatonic River and concluded that most deposits had a deltaic origin. He believed these materials were deposited by melt water into ephemeral, proglacial lakes associated with tributaries, or into estuarine waters extending northward in the river valley to the Massachusetts-Connecticut border. He believed that the unusual extension northward of estuarine water resulted from slow regional isostatic recovery after the glacier melted entirely by "normal retreat" from western Connecticut. The resulting isostatic recovery exceeded 600 feet in Connecticut alone.

Quadrangle mapping for the State Geologic and Natural History Survey of Connecticut, and as part of cooperative projects with the United States Geological Survey, has been actively pursued in western Connecticut. Various investigations have been recently conducted in the primary study area and in adjacent quadrangles. This work and its pertinence is summarized in Table 1.

Techniques

Field Investigations

Geologic investigations were conducted in the study area during the summers of 1968 and 1969 and summer-fall of 1970. Aerial photographs and preliminary field sheets for a then-pending soils map for Litchfield County, Connecticut (Gonick and others, 1970), were utilized to:

TABLE 1

SUMMARY OF MAPPING AND OTHER PROJECTS IN WESTERN CONNECTICUT PERTINENT TO THIS STUDY

Contributors and Areas	Contribution	Pertinence to the study
Gates and Bradley (1952) New Preston Quadrangle	Bedrock mapping; interpretation of surficial materials	Description of bedrock units; glacial direction indicators; and glacial deposits
Colton (1969) New Preston Quadrangle	Detailed surficial mapping	
Rogers & others (1959) State of Connecticut	Generalized bedrock map of Connecticut	Description of rock lithologies near study area
Gates (1961) Cornwall Quadrangle	Detailed bedrock mapping	Description of rock lithologies near study area
Malde (1967) Roxbury Quadrangle	Detailed surficial mapping	Surface materials
Pessl & Schafer (1968) Western Connecticut	Till studies	Till relationships
Melvin (1970) Western Connecticut	Logs of wells and test holes	Subsurface data
Holmes & Newman (1971) Ashley Falls Quadrangle	Detailed surficial mapping	Location of lacustrine deposits; extent of Falls Village Lake
Pessl (1971) Western Connecticut	Till Studies	Till relationships
Thompson (1971) Danbury and New Milford	Still River lakes investigation	Active ice recession inferred
Warren (1971) West Cornwall	Pre-Wisconsin diversion of Housatonic River	Evidence for multiple glaciation
Holmes & others (1971) South Canaan Quadrangle	Detailed surficial mapping	Lacustrine deposits and a possible Housatonic Valley plug location
Holmes & others (in prep.) Sharon Quadrangle	Detailed surficial mapping	Ice-marginal deposits and major melt-water drainage channels
Warren (in press) Cornwall Quadrangle	Detailed surficial mapping	Thick till; high-altitude drainage routes; ice-marginal deposits

1. facilitate terrain analysis;
2. identify peculiar and potentially significant features;
3. delineate bedrock exposures; and
4. locate potential exposures of surficial materials.

A reconnaissance survey was undertaken along roads in the secondary study area to locate, examine and tentatively identify glacial and glaciofluvial deposits based on morphology and internal characteristics. Detailed geologic investigations were carried out in the primary study area, and walking traverses were utilized to study, locate, and examine morphology and internal characteristics of surficial materials. These were then mapped at a 1:24,000 scale. Auger samples and shoveled pits augmented surface observations in areas where exposures were scarce.

A survey and a textural description were made of all borrow pits, gravel extraction sites, construction excavations, artifical grading, and stream bank exposures available during the field seasons. Samples were collected for later laboratory analysis from 47 glacial and glaciofluvial deposits. Sketches or photographs, and descriptions, were made at each sample site. Samples included 50 random pebbles larger than half an inch, where practical, and a grab or a selected material sample. Water well records, road test borings and power auger logs were obtained from the Water Resources Division of the United States Geological Survey (Melvin, 1968 personal communication; 1970) and were used to determine the composition and thickness of subsurface materials.

A general paucity of till exposures prevails in the primary study area. To supplement other ice flow directional data, and to differentiate possible multiple tills (Flint, 1961), samples for fabric analyses (Holmes, 1939) were taken at ten localities where undisturbed till was exposed, and fabric analyses were made on the orientation of 50 elongate pebbles with a length-to-width ratio of at least 2 to 1.

Extensive walking traverses were made in the wooded upland areas to study and interpret questionable terrain features identified on topographic maps or aerial photographs, to obtain ice-flow directional data including striations and stoss-and-lee topography, to identify and examine abandoned melt-water channels, and to examine potential glaciofluvial deposits suggested by previous workers (Taylor, 1903; Flint, 1930).

Four swamp deposits were initially examined by making probe traverses at 12-foot intervals to determine basin bottom configuration. A Davis corer was then used to retrieve continuous-core samples in the deepest part of each swamp for use in later laboratory analyses. The basal zone at one location was subsequently resampled to retrieve approximately 1.76 ounces (50 grams) of organic material for radiocarbon analysis, and to concurrently obtain additional organic material for pollen extraction, analysis, and correlation with material previously examined from this site. All samples collected were extruded directly from the core sampler onto plastic film, rolled and sealed, further protected with an outer wrap of aluminum foil, and refrigerated until pollen extraction could be undertaken in the laboratory.

Laboratory Investigations

Pebble lithologies were identified and counted at the field base camp or in the laboratory. Seventeen bulk samples were selected for mechanical analysis to delineate possible lacustrine and fluvial deposition environments in the study area. Each sample was split to obtain approximately 3.52 ounces (100 grams) and was then sieved through screens at half phi intervals ranging from between -5 and -2 phi to +4.5 phi. Sieving was accomplished by shaking two screen sets for 15 minutes on a Ro-Tap. Accumulated fractions from each screen were weighed, and both weight percentages and cumulative weight percentages were calculated and graphed. Characteristics of mean, median, and standard deviation, skewness, and kurtosis were calculated utilizing the graphic methods of Folk (1968). Samples containing a high percentage of silts and clays smaller than +4 phi size were subjected to pipette analysis through +9 phi, regraphed, and graphic characteristics were recalculated.

Approximately 1/32 cubic inch (1/2 cubic centimeter) of organic material was selected for palynological analysis from the central part of dominantly peaty core samples. Each sample was treated with a 10 percent potassium hydroxide solution. Hydrofluoric acid was added where high inorganic content was observed and acetolysis procedures were applied (Faegri and Iversen, 1964). Pollen extractions obtained were mixed with approximately twice their volume of glycerine jelly. Slides were prepared and pollen grains identified and counted. Counts of approximately 200 AP grains, where practical, were sought per core interval analyzed. Pollen identification and counts were made with a Bausch & Lomb phase-contrast, zoom-equipped microscope at magnifications between 400X and 800X. Problem grains were examined by oil immersion and phase-contrast techniques at magnifications between 1000X and 2000X. Pollen percentages were calculated for lower core intervals to identify the pollen zones present in the basal parts of the cores.

CHAPTER II

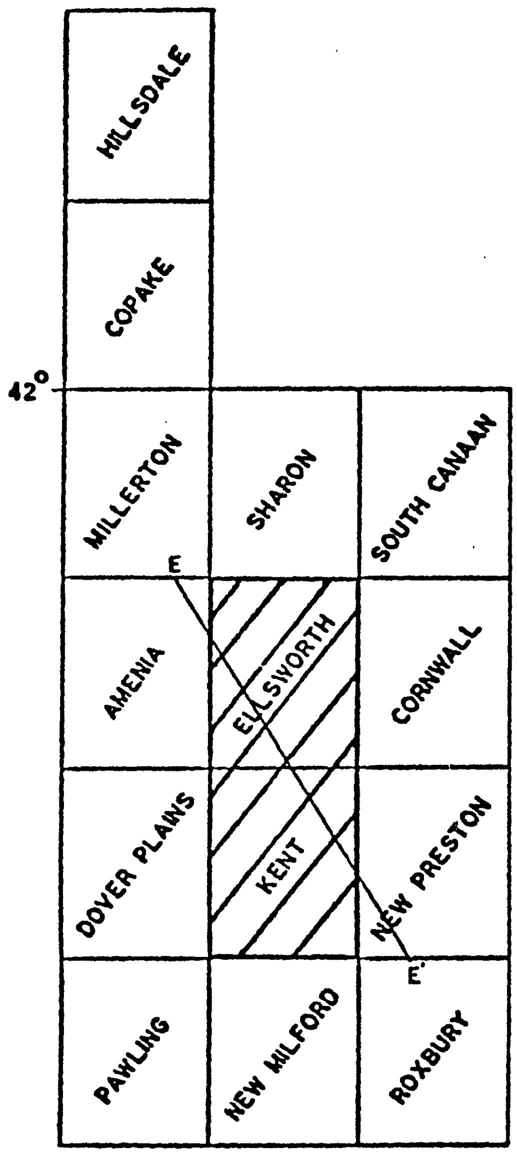
GLACIATION EVIDENCE

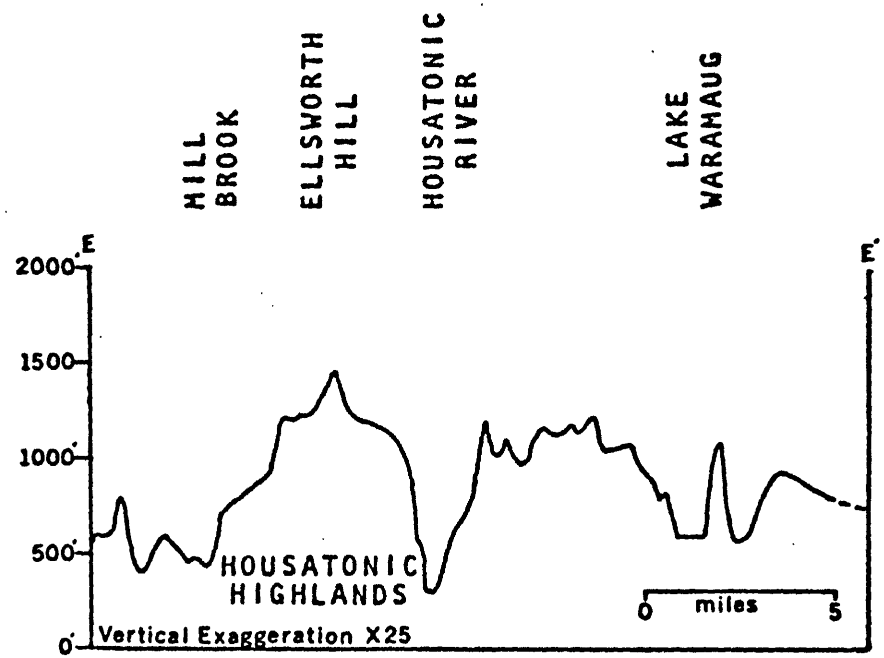
Introduction

The topography in New England basically reflects the fluvially sculptured, Tertiary landscape initially encountered by the Pleistocene ice sheets (Fig. 5). Terrain modification in New England due to Pleistocene glacial erosion and deposition is believed to have been minor (Flint, 1930; Schafer and Hartshorn, 1965, p. 114). Evidence of glacierization is ubiquitous in the study area, and includes striations, polished surfaces, roche moutonnees, rock basins, craggy lee slopes, drumlins, erratics, and ground moraine. Data derived from these evidences illustrate the behavior of at least the last active ice sheet in this region.

Ice-Flow Directional Indicators

Glacial ice flowed across this region from northwest to southeast. Striations and grooves scoured on upland rock surfaces in the primary study area have bearings ranging





CROSS-RIDGE PROFILE PARALLEL TO ICE FLOW

FIGURE 5

from S.8°E. to S.80°E., with a mean bearing of S.36°E. Bearings are strongly concentrated between S.25°E. and S.40°E. Bradley (Gates and Bradley, 1952) reported that four-fifths of the striations found in the New Preston quadrangle had an average trend of S.21°E., while the remaining striations trended S.40°E. He did not observe striations which were gradational betweeen these two directions. In the primary study area, however, striations range through these modal points without a comparable bimodal distribution (Fig. 6, 7). The upper half of Figure 7 is a summary of striation data for the primary study area. In the region east and southeast of this area, Pessl (1971) found a comparable striation divergence.

Ice movement toward the southeast is indicated by crescentic and lunate fractures associated with striations on the surface of quartzite in an abandoned quarry near Beaman Pond south of the hamlet of East Kent (K43, Pl. IV). [NOTE: Sites are designated by abbreviations and index numbers (Appendix A). Letters refer to U.S.G.S. 7-1/2 minute quadrangle maps. Numbers are consecutive from south to north within each quadrangle and are retained throughout the report.] These fractures penetrate the rock surface and dip gently toward the southeast. The southwest part of Bull Mountain (K34, Pl. IV), near South Kent, is a large roche moutonnee with a smooth stoss surface on the northwest and a

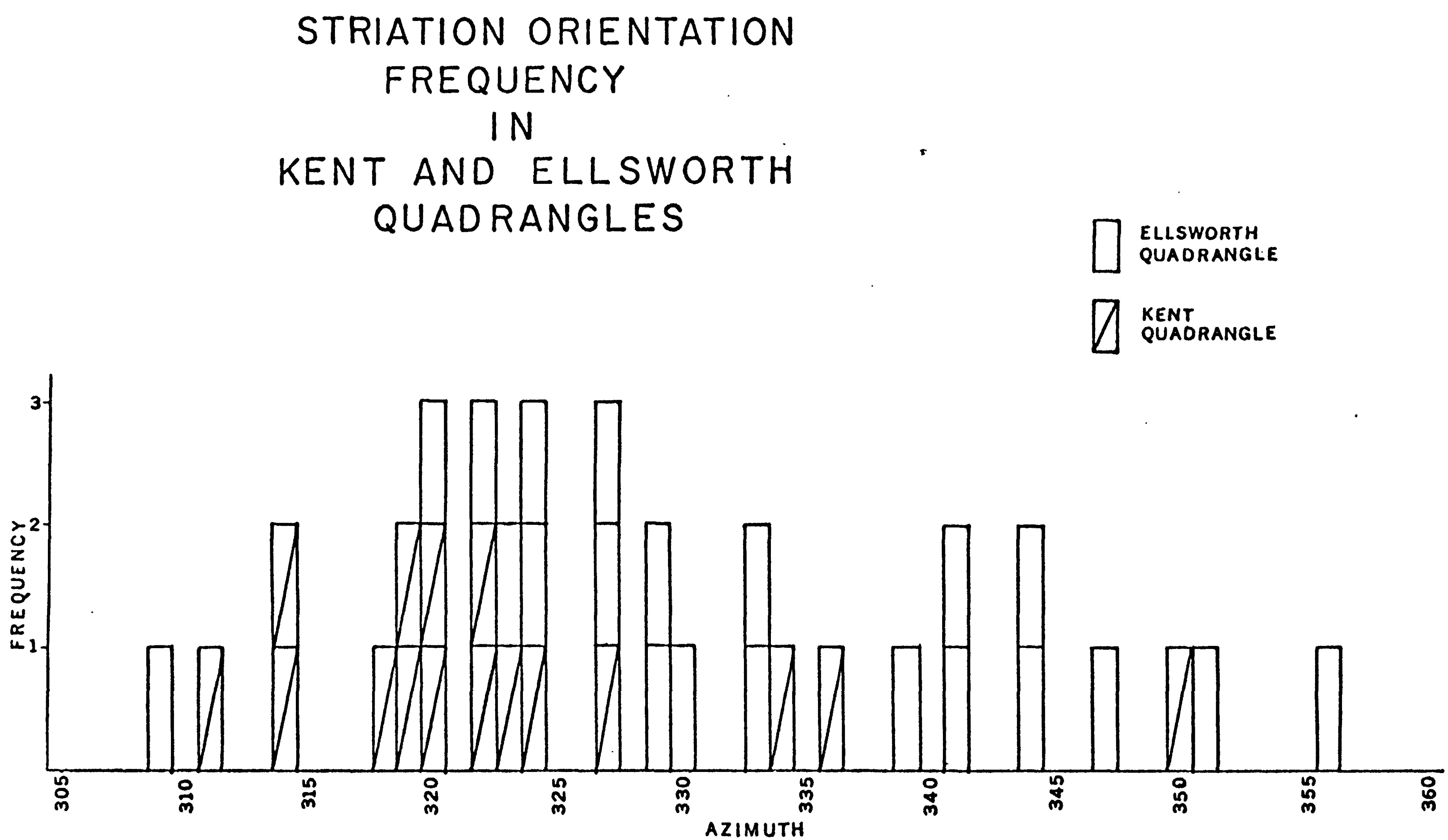
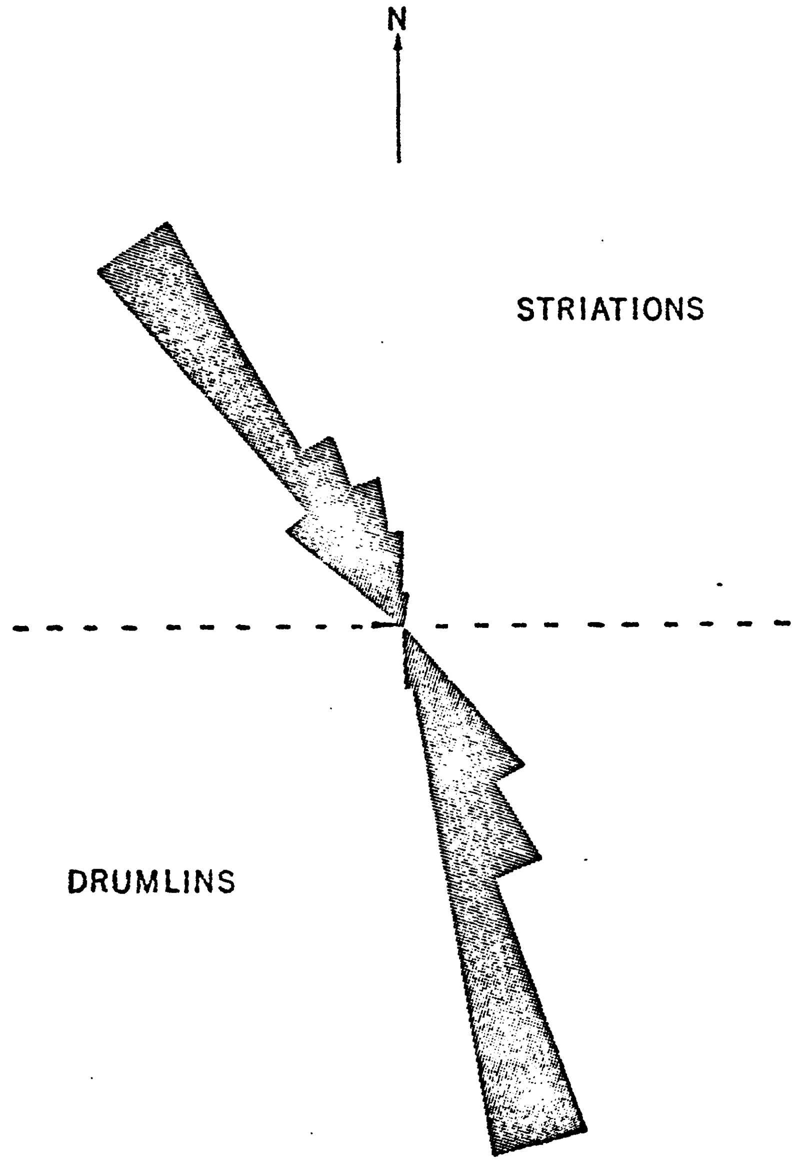

STRIATION ORIENTATION
FREQUENCY
IN
KENT AND ELLSWORTH
QUADRANGLES
ELLSWORTH QUADRANGLE
KENT QUADRANGLE
FREQUENCY
1
2
3
305
310
315
320
325
330
335
340
345
350
355
360
AZIMUTH

FIGURE 6

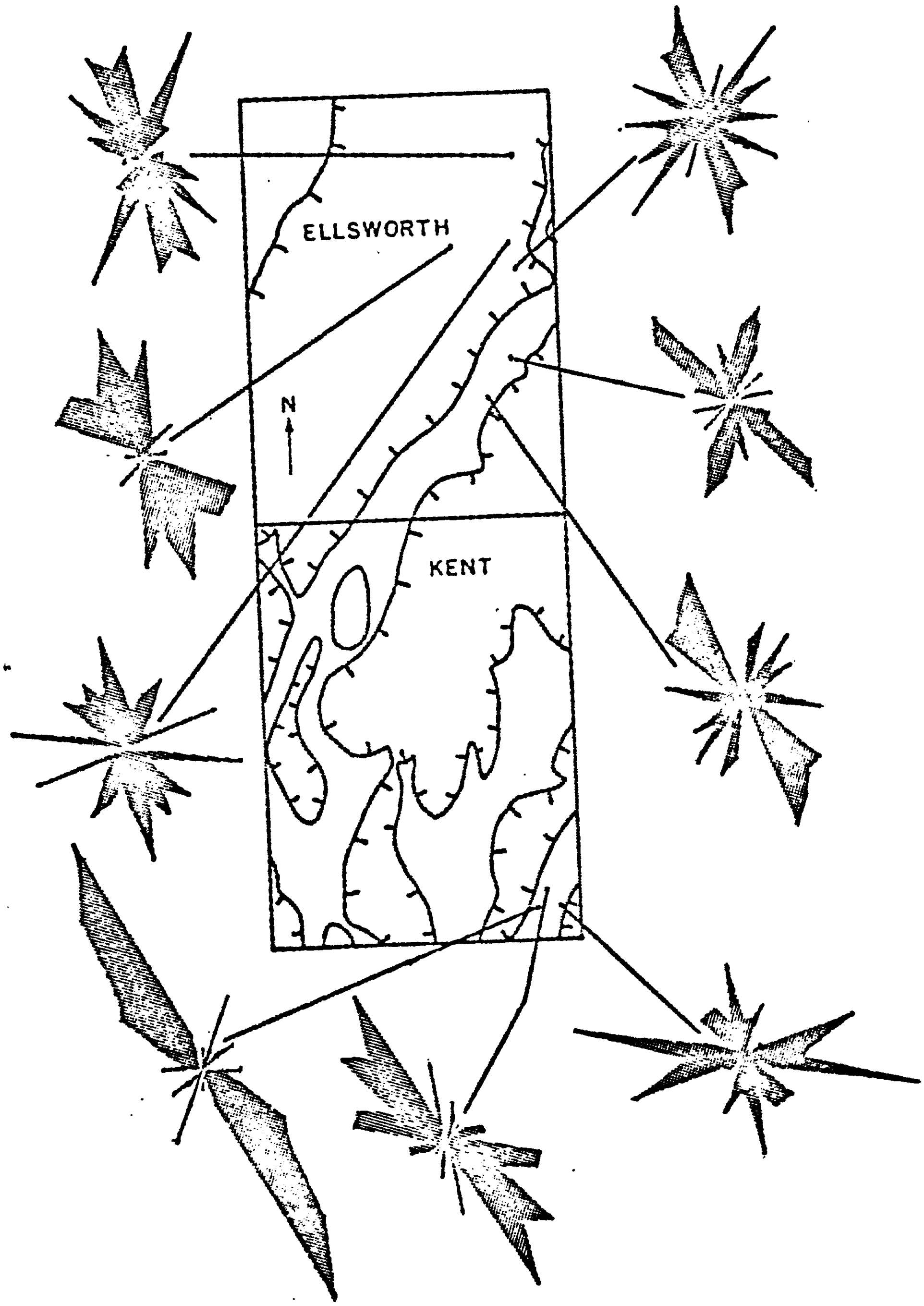


STRIATION AND DRUMLIN AXIS
ORIENTATIONS

FIGURE 7

craggy, plucked, lee face toward the southeast. Other roche moutonnees have been reported by Bradley (Gates and Bradley, 1952) and Colton (1969) in the adjacent New Preston quadrangle.

Streamlined forms include a variety of drumlinoid features ranging from rock drumlins through rock-cored drumlins, crag-and-tail topography, and till heads or till ramps, to true drumlins. Each of these features provides direct evidence of glacial erosion and deposition, and also indicates direction of ice movement. The lower half of Figure 7 shows the distribution of drumlin axis orientations in the primary study area. Most drumlins trend between S.18°E. and S.20°E. A few trend more easterly. This northwest-to-southeast direction conforms with most drumlin orientations and other streamlined forms observed by Bradley (Gates and Bradley, 1952) in the New Preston quadrangle, and by Warren (in press) in the Cornwall quadrangle. Bradley (Gates and Bradley, 1952), however, also reported the presence of secondary drumlin tails which trend nearly north-south. These data are consistent with the orientation of other ice-flow directional indicators which include drumlin axes, boulder trains, and indicator fans in the western third of Connecticut (Colton, 1969; 1969 personal communication). Figure 8 shows sampling locations in the primary study area and the results of individual till fabric



TILL FABRICS
IN
ELLSWORTH AND KENT
QUADRANGLES, CONNECTICUT

FIGURE 8

analyses. An interpretation of the significance of these directional data is presented in the discussion at the end of this chapter.

Glacial Erosion

Only small exposures of glacially polished rock have been observed, and these occur most frequently in upland areas where protective overlying drift has recently been removed. Granitic gneiss and schist dominate in this area and weather rapidly, causing glacially polished surfaces and striations to be quickly destroyed. Resistant quartz stringers provide small polished surfaces on which striations and polish have persisted as the enclosing country rock surface has been postglacially weathered and removed to depths of a quarter to half an inch. Along the unnamed road south of Whitcomb Hill (Pl. III; E5, Pl. V) hornblende gneiss has retained glacial grooves 2 inches wide, although the exposed rock surface has lost any evidence of glacial polish. Similar weathered surfaces have been observed during reconnaissance investigations in the Cornwall quadrangle, and have been reported in the New Preston quadrangle (Gates and Bradley, 1952).

The extent to which glacial abrasion, scour and plucking have eroded this terrain cannot be definitively established. Schafer and Hartshorn (1965) estimated erosion in excess of 20 meters (22 yards) throughout New England, based on average drift thicknesses and presumed deposits now obscured beneath ocean waters off the New England coast. Connecticut, with thin drift, presumably averaged less erosion than the estimated 20 meters.

Weathered rock beneath unweathered glacial drift has been reported from several places in New England (Schafer and Hartshorn, 1965), This rock, which is occasionally 8 meters thick, may be pre-Pleistocene weathered regolith, comparable to the weathered regolith which commonly exceeds 20 meters (22 yards) thickness in regions beyond the glacial limit. While New England was being repeatedly glaciated and eroded, weathering in extra-marginal areas may have been climatically accelerated or retarded. This possibility makes it imprudent to attempt comparison of weathering rates and soil development between regions, or to make direct estimates of glacial erosion in glaciated regions. Wells drilled in valley slopes in the primary study area have occasionally penetrated weak, deeply weathered, iron-stained marble beneath unweathered till (App. B, No. K29U, No. NM30U). Thompson (1971) reported exposures of glaciated marble with surfaces weathered to depths exceeding 12 inches. This presumably reflects weathering during Recent time, but its precise nature is currently under investigation (Thompson, 1973 personal communication). The results of his investigation may aid in evaluating the significance of weathered rock encountered elsewhere in southern New England in terms of the effect of preglacial, interglacial or postglacial weathering. It can conservatively be assumed at this time that saprolite beneath unweathered drift indicates the relative inability of the glacier responsible for the overlying material to everywhere erode weak, weathered rock.

Well logs, test borings, and bedrock outcrops along the Housatonic River and tributary valleys indicate that rock basins have been eroded by glacial ice moving in the preglacial valleys. Each inferred rock basin location and configuration is illustrated on the geologic sections and maps (Pl. I; Pl.IIA; Pl. IIIA). These basins exceed 50 feet in depth below their rock lip (riegel). The existence of some rock basins is equivocal, because till deposits may have diverted the early postglacial Housatonic River, forcing it to cross a rock threshold somewhat higher than the ancestral river bed. An example of this type of till diversion is found southwest of West Cornwall (C10, Pl. VI) (Warren, 1971), and west of Calhoun Corners (E8, Pl. V).

Unfortunately, wells which might clarify the problem do not penetrate the appropriate till deposits.

Warren (1971) reported a well southwest of West Cornwall (C10, Pl. VI) which penetrated till more than 55 feet beneath the level of the adjacent Housatonic River. From this and other geomorphic evidence, he inferred multiple cycles of fluvial and glacial activity without postulating a glacially eroded rock basin. The inferred closure of rock basins elsewhere is probably reasonable. For example, along Macedonia Brook (K44, Pl. IV) northwest of the village of Kent, closure is inferred. A graded channel would require a rock canyon less than 20 feet wide and more than 50 feet deep southwest of the Kent School.

Although glacially eroded rock basins do occur along some valleys, valley walls generally do not exhibit either a glacial origin or major glacial modification, and U-shaped troughs are not common in the study area. An exception may occur on the northeast slope of Long Mountain (K26, Pl. IV), which appears to be a truncated spur when viewed from the vicinity of Geer Mountain looking southward. In adjacent and nearby areas of western Connecticut, other workers have found few glacially modified stream valleys (Flint, 1930; Gates and Bradley, 1952).

Large bedrock blocks, some exceeding 20 feet in length, are found at distances ranging from a few feet to a few miles southeast from their source. These indicate that the glacial ice entrained and transported particles of considerable magnitude. Particles of local lithologies, ranging in size from cobbles through boulders to house-sized blocks, are frequently encountered on the upland surfaces and in the drift. Their frequency supports glacial plucking as the major mechanism of glacial erosion in this region. A band of boulders ranging from less than 3 feet to more than 8 feet in major dimension is conspicuous near Flanders (Pl. II; K47, Pl. IV). "Pebble" counts taken among these particles reveal only rocks of local lithologies, including granite, gneiss, and quartzite (App. D, No. 9B1). Each of these lithologies in this region has characteristics favoring the formation of blocks and erosion by plucking.

Bradley (Gates and Bradley, 1952) found that effectiveness of plucking in the New Preston quadrangle was directly related to local variations in rock lithologies and structures. Since these rock units extend into the primary study area, lithologic control on glacial erosion is presumably comparable. Periglacial frost-riven debris is usually of insufficient volume to account for the craggy appearance of cliffs. Therefore, the craggy surfaces of roche moutonnees and other lee features were caused by the removal of blocks excavated and entrained by glacial ice.

Deposition

The most extensive surficial deposit in the primary study area is till (Qt). [NOTE: Unit designations refer to deposits in areas of the Kent and Ellsworth quadrangles under discussion. Unit descriptions for Plates II and III are in the map Explanation (Pl. IIB-IIIB).] The till occurs chiefly as a discontinuous ground moraine blanket, and consists of glacially eroded rock debris emplaced directly by ice. It ranges in thickness from thin patches around upland rock exposures to thick deposits in valleys and along the flanks of some hills. Two water wells, one north of Northville (K2, Pl. IV; App. B, No. NM30U) and another near Good Hill Cemetery north of Flanders (K51, Pl. IV; App. B, No. K34U) have till thicknesses of 70 feet. More than 60 feet of till overlies possible preglacial fluvial or lacustrine deposits in a well at South Kent (Pl. II; K31, Pl. IV; App. B, No. K30U). The greatest till thickness in the study area is recorded in a well west of Hatch Pond (E18, Pl. V; App. B, No. S11W), where 200 feet of till overlies sand and gravel. Greater thicknesses have been reported in the adjacent Cornwall quadrangle (Warren, in press), where till between 400 and 650 feet thick underlies Dean Hill (C10, Pl. VI), and 225 feet of till occurs south of West Cornwall (C4, Pl. VI) (Warren, 1971).

Ground moraine in western Connecticut often consists of one or more compact lodgment tills formed by deposition beneath glacial ice, and a loose ablation till superposed on underlying surfaces by melting, stagnant ice. The two different lodgment tills commonly found in New England are referred to as upper and lower tills (Pessl and Schafer, 1968; Pessl, 1971), or in somewhat earlier literature as new and old tills (White, 1947; Flint, 1961; Schafer and Hartshorn, 1965). These have been described for nearby areas by Pessl and Schafer (1968), Pessl (1971), and Thompson (1971). Both tills are believed to be present in the primary study area, but small, infrequent, and slumped or otherwise poorly exposed excavations preclude their delineation and they have not been observed here exposed in superposition. One lodgment till is generally a poorly sorted, compact mixture of particles of clay-to-boulder size with clay and silt dominant in the matrix. Colors range from dark gray (5Y 3.5/1) (Munsell, 1954) to olive gray and olive brown (5Y 4/2 to 2.5Y 5/5). Excavation in this "lower till" is extremely difficult. The second, "upper till" has a more sandy matrix, is generally loose and friable, and tends to disintegrate easily. Colors of this till range from olive gray and light olive gray to olive (5Y 4/2 to 5Y 6/2). Iron staining is common in this till. Fresh exposures are generally more easily excavated in this "upper till".

The upper till is usually thin, ranging from less than 10 feet to rarely more than 30 feet. The lower till is frequently found to be more than 10 feet thick, and often exceeds 100 feet in thickness. Exceptions, in terms of characteristic color, thickness, texture, and composition have been observed, suggesting that distinguishing characteristics overlap between these tills. Occasionally exposures have been found in western Connecticut which exhibit both tills in superposition; they can then be distinguished with certainty (Pessl, 1971).

Fabric analysis of elongate pebbles in several till exposures in the primary study area was undertaken to help identify and distinguish between possible upper and lower tills. Pessl (1971) observed that lower tills have a constant northwest-to-southeast fabric orientation, but upper tills may have some fabrics oriented slightly east of due north. Multiple fabrics obtained by Pessl (1971) demonstrated a gradual shift in fabric orientation, changing upward in section from northwest to northeast, revealing that northeast orientations may be confined only to the higher parts of the upper till. Unfortunately, comparable results have not been found in the primary study area. The fabric orientations shown in Figure 8 are best interpreted as only vague indicators of ice directional movement. The variability of these fabrics presumably shows only ice-flow characteristics for the ice which deposited the tills at each site at the level sampled, and does not establish two distinct till sheets in this area. Local topographic deflection of basal ice flow which was depositing the till may account for the unexpected orientation evident in some fabrics (Pl. III; Fig. 8).

In this study, reliance has not been placed on till fabrics for either differentiating between tills or as indicators of ice-flow direction, because:

1. exposures for analysis were limited in number;
2. sampling in at least one location may have been carried out in the frost-activated zone;
3. minor colluvial slope processes may have re-oriented elongate pebbles;
4. single fabric samples taken in small exposures may not accurately represent the site;
5. some samples may represent super-glacially derived ablation materials in which preferred orientation is a fluvial remnant; and

6. disorientation in two samples may reflect original lee slope deposition (Boulton, 1971, p. 64).

Excavation in pits between Bear Hill and Northville Cemetery (K16; Pl. IV) revealed deposits containing quantities of weakly to moderately stratified, poorly to well-sorted material intermixed with till (Qtm). This exposure is interpreted as ablation till typical for this region, and indicates the presence of copious melt water during late stages of deglaciation. Similar material has been found in the Gaylordsville area.

Discussion and Interpretation

Multiple glaciations have been inferred for this region based on a variety of evidence (Schafer and Hartshorn, 1965; Pessl, 1971), but definitive glacial evidence for multiple glaciation, or an ice re-advance, is lacking in the primary study area. Here, ice flow was consistently from the northwest, superposed multiple tills have not been found, and the limited till fabric data provide evidence for only one glaciation. Variation in till color alone between different sites is a questionable criterion for inferring multiple till deposition unless two tills are exposed in superposition. Thick, dark, compact, lower till is found in drumlins in various parts of New England. Upper till tends to be sandy, generally less than 30 feet thick, light in color, and often exhibits upward changes in fabric orientation. It is seldom a drumlin-forming deposit.

Thick till deposits near Sharon, and thick tills on the southeast side of the East Aspetuck River valley, may be thickening of till during the last ice retreat at or beneath the margin of active ice. If formed beneath the ice margin at these locations, then perhaps the rest of the study area has only a thin mantle of younger "upper" till. Elsewhere, thick till present in Dean Hill near Cornwall Bridge (C4, Pl. VI), and till present in the buried channel of the Housatonic River near West Cornwall (C10, Pl. VI), cannot be accounted for in terms of ice-marginal activity. These deposits support the presence of older, thicker till. Deep till exposures are lacking and well log reports omit changes which occur in tills. Present data are insufficient to clarify relationships of till deposits in the primary study area.

South of Sharon (Pl. III; E18, Pl. V), and at South Kent (Pl. II; K31, Pl. IV), tills overlying gravels have been reported in wells. The presence of buried gravel can be explained in several ways including:

1. poor well log reports in which ground-up, weathered rock or other material has been misinterpreted;
2. ice-marginal fluvial deposits from advancing ice subsequently overrun and buried beneath till;
3. ice-marginal, fluvial deposits formed during glacial retreat and subsequently buried by re-advance, with the intervening time of either short-term or interglacial duration;
4. interstratified lenses of gravel which are typically formed in tills; and
5. wells penetrating till and weathered rock to enter karst chambers.

The presence of gravel beneath the till does not independently establish multiple glaciations or even a re-advance. Additional evidence regarding glaciation in the study area derived from deglacial phenomena is discussed in Chapter IV.

More than one interpretation may be possible for the changes to northerly ice-flow sources evident in the till fabric of a series of analyses in upper till (Pessl, 1971), for the south- and southwesterly oriented striations associated with the dominantly southeast striations, and for the small deflection of drumlin tails to a more north-south direction. Bradley (Gates and Bradley, 1952) believed a minor, northerly rejuvenation of ice after an initial stagnation was responsible. Pessl (1971) suggested a gradual shift in ice-flow centers to a more northerly position. Each line of evidence, however, may simply reflect the increasing influence of topography on active ice flow as the glacier thinned.

Glaciation of the western half of Connecticut is associated with ice lobes in either the Hudson-Champlain Valley or the Connecticut River valley. Southwesterly oriented, regional ice-flow directional data (Pessl, 1971; Colton, 1969 personal communication) indicate the eastern limb of the Hudson-Champlain Valley lobe was responsible for glaciation in this extreme western part of the state. Thickening of the elongate ice tongue forced ice through low-altitude cols in the Hudson, Housatonic and Taconic Highlands (Fig. 9), and ultimately caused the mountains and highlands along the western New England border to be overtopped (Taylor, 1903) (Fig. 10). Evidence on active glaciers today indicates that ice margins tend to lie approximately normal to the local direction of ice flow (Flint, 1971, p. 92). Thus, the trend of the advancing ice

LOCATION MAP FOR STUDY AREA SUB-AREAS

KEY

1. Ridge Southeast of the East Aspetuck River
2. East Aspetuck River Valley
3. Semi-isolated Basins
4. Uplands Southeast of the Housatonic River
5. South Kent Trough and Cobble Brook Valley
6. Housatonic River Valley
7. Housatonic Highlands
8. Sharon Area
9. Valley West of the Housatonic Highlands
10. Taconic Range
11. Hudson Highlands

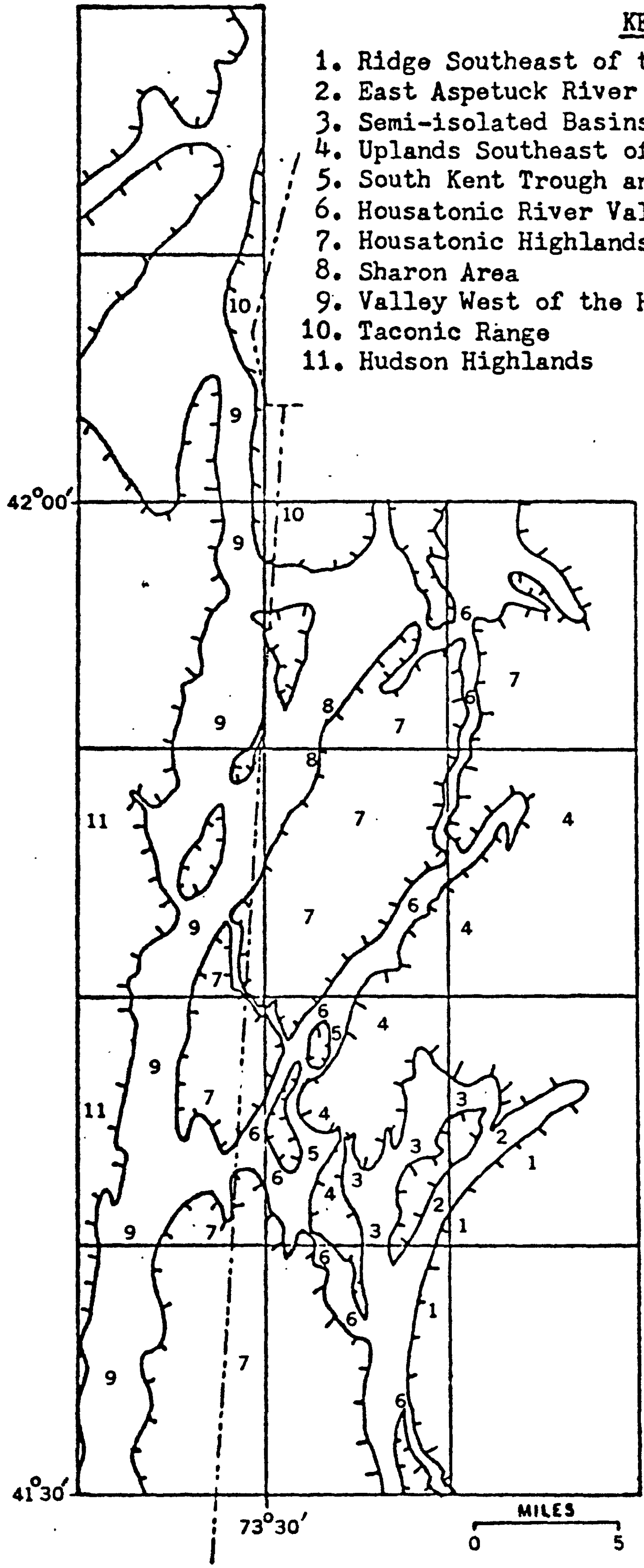
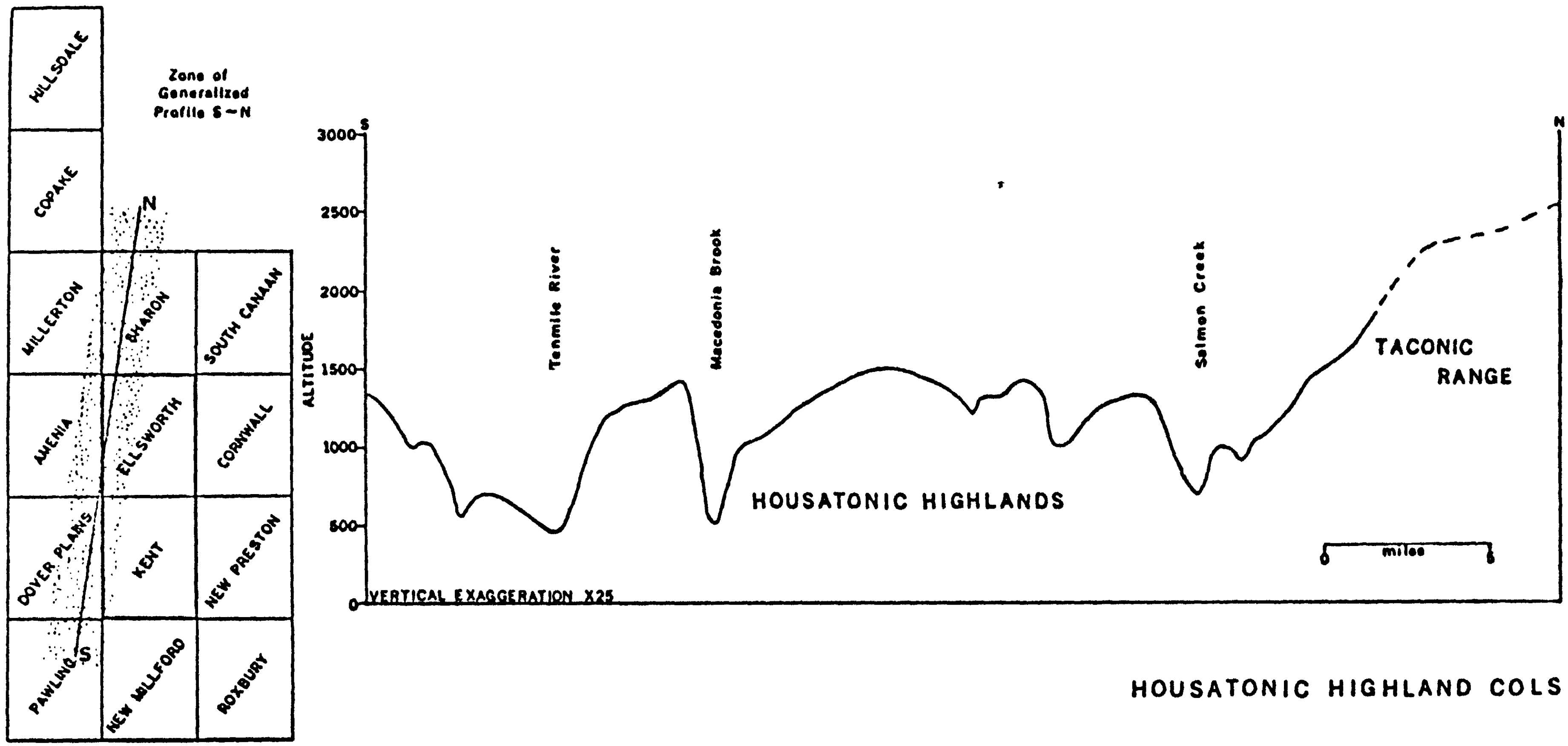


FIGURE 9



HOUSATONIC HIGHLAND COLS

FIGURE 10

margin in northwestern Connecticut was northeast to southwest. Late glacial ice flow indicators reveal that the northeast-to-southwest marginal trend also persisted during deglaciation, at least across the uplands. However, major and minor relief features effectively altered and partly obscured this trend.

Upland ridges and valleys oriented approximately transverse to ice flow differentially affected the margin by restricting or favoring ice flow, which in turn caused proturberances and a markedly sinuous ice margin, chiefly during thinning and deglaciation. A high-altitude observation of this region at that time probably would have revealed a strongly ragged, lobate, and serrated ice margin, similar to small-scale maps and high-altitude photographs depicting margins of ice fields in Alaska and other moderate-to-high relief regions today. Two elements prevailed during deglaciation. First, the ice margin probably retreated northwestward normal to the indicated direction of ice flow. Secondly, the ice margin at any given time, or at any stillstand, was irregular and delicately adjusted to the local topography.

The Taconic range north of the study area rises rapidly to altitudes higher than the Housatonic Highlands and adjacent ridges to the east and west (Fig. 10). Ice from the Hudson-Champlain Valley lobe, penetrating through cols near Bulls Bridge (Connecticut), Lakeville (Connecticut) and State Line (Massachusetts), presumably encountered the lateral ice margin of the Connecticut River valley lobe on the intervening upland between these major valleys. As the active ice thinned, "shadow zones" of reduced pressure may have developed in the lee of the high Taconic ridges, gradually causing a southward deflection of ice flow through western Massachusetts and western Connecticut. South of the high Taconic range, lower altitude uplands permitted ice flow to actively cross the study area. This prevented southward deflections of ice flow until the ice penetrated farther to the southeast. The various ice-flow directional indicators are thus interpreted as sensitively reflecting the subtle changes caused by topographic features which controlled basal ice flow.

CHAPTER III

DEGLACIATION CRITERIA

Introduction

Several hypotheses concerning deglaciation in New England and eastern New York were reviewed in Chapter I. Concepts in these hypotheses centered on two basic deglaciation modes - active ice and stagnant ice. Gradations between these classifications range from regional stagnation through ice-marginal zone stagnation near active ice, and active ice-marginal retreat with stillstands and re-advances, to gradual but continuous active ice-marginal retreat. Each environment produces associated erosional and depositional features, with morphologies indicative of ice characteristics, underlying topography, available melt water, and the amount and distribution of entrained debris. Because the control factors can be significantly different, kaleidoscopic morphological effects are possible along an ice margin.

In this chapter, criteria have been adapted to evaluate deposits and erosional features formed by active ice, stagnant ice, and related ice-marginal melt-water activity to identify ice-marginal conditions which may have prevailed.

Deposition

Taylor's (1903) study applied chiefly to the region immediately north of the primary study area, and identified a diverse group of features, some requiring active ice-marginal flow and others more clearly reflecting deposition associated with stagnant ice margins. Table 2 summarizes the salient aspects of Taylor's criteria. His descriptions, however, do not preclude active ice lying immediately adjacent to a zone of stagnant ice. Through this mechanism, shear plane activity near the active ice margin may produce moraine ridges and linear boulder concentrations similar to those in the vicinity of the Ledyard moraine in southeastern Connecticut (Goldsmith, 1960a; Shafer and Hartshorn, 1965, p. 120) or the Charleston moraine in Rhode Island (Kaye, 1960).

Taylor (1903), from observation of ice-marginal terraces, concluded that the ice-surface gradient near the ice margin was typically 100 to 110 feet per mile, including postglacial isostatic adjustment. He applied this gradient to interpreting ice-marginal positions across uplands

TABLE 2

MORAINES AND BORDER DRAINAGE FEATURES
(after Taylor, 1903)

Type	Composition	Morphology	Typical Localities
Frontal or marginal moraines (like moraines of Great Lakes lobes)	Till, frequently high in clay content	Sag and swell, knob and kettle	Plain country or broad valleys
Terminal moraines of ice tongues	Generally coarse, low clay-high gravel content. Generally coarser material than in typical kames. Boulders and cobbles often dominate	Fragmentary and limited in areal extent. Knob-and-basin topography with relatively less relief than kames. May plug narrow valleys	Deep, narrow valleys where free drainage is generally present
Lateral moraines of ice tongues	Till with some associated sands and gravels where marginal drainage is evident	Fragmentary and indistinct. Best identified when associated with other marginal features such as ground moraine, gravel kames, and low knobs. Adjacent hill slopes often bare or with thin drift. Sometimes identified by change from thin to thick drift on a slope. Often associated with melt-water drainage channels	On hill sides, often where valley slopes are steep
Stoss moraines	Till, usually without associated sands and gravels	Similar to lateral moraines, but seldom well developed. Lack evidence of marginal or submarginal drainage*	Stoss slopes of hills which acted as re-entrants in ice front

*(Taylor indicates that stoss slopes behind the ice margin are usually swept clean, and retain till only on lower hill flanks, unless an active ice margin persisted for some time against the hill flanks during general ice-marginal retreat. Then submarginal deposits of thick till will persist.)

between presumably correlative ice-marginal valley deposits. Results obtained were reasonable where relief was moderate to low. Taylor (1903, p. 353) did not, however, apply this technique across higher mountains such as the Taconics. He indicated that ice-tongue gradients in narrow valleys are steeper due to flow-resisting stress afforded by the interaction of ice and valley wall.

Taylor (1903) recognized that variations in ice regimes at the terminus permitted concurrent deposition of active or stagnant ice deposits at different localities. He calculated that in the region studied, ice-marginal features representing retreatal halts occurred on the average of every 3.5 miles throughout a north-south distance of 50 miles. This interval contrasts sharply with the 15 to 20 miles between retreatal positions determined by Cadwell (1972) south of the Valley Heads moraine system in New York State. Taylor (1903, p. 345-346) further emphasized that the frequency and diminutive size of marginal deposits in New England, along with their highly intermittent form, frustrated attempts at correlation.

Details regarding ice-marginal deposits were also presented by Flint (1971, Ch. 8) in his discussion of the morphology of various glacial drift features. These descriptions served to supplement and extend Taylor's (1903) earlier concepts. Table 3 provides an adapted summary of

TABLE 3

SUMMARY OF ICE-MARGINAL FEATURES
(after Flint, 1971)

Features	Definition and Description	Deglaciation Significance
I.ACTIVE ICE		
End moraine,terminal	Essentially a constructional ice-marginal feature. Initial form due to (1)drift in ice; (2)ice movement; (3)ablation rates; and, (4)melt water. Ultimate form depends on post-depositional erosion and mass-wasting processes which, in turn, are determined by (1)composition; (2)slope; (3)permeability; and, (4)climate. Topography ranges from smooth,inconspicuous,undulating thickened drift sheet to irregular knob-and-basin configuration in generally discontinuous ridge form, seldom exceeding 15 meters in height	Indicates stillstand or re-advance of active ice at a terminal or marginal position
End moraine, lateral	Lateral extension of terminal moraines, similar in form and materials	
II.ICE DISINTEGRATION		
Ice contacts	A group of constructional features deposited against ice which slumped as the ice melted. Larger ice-sediment interface features are often preserved, reflecting re-entrants and proturberances. Highly permeable sediments facilitate preservation of ice contacts. Internal collapse of sediments and external deformed terrain reflect subsequent ice melting	Indicates thin, sometimes stagnant, dead ice. Interpretation depends on location and areal relationship of features
Kame terraces	Stratified drift deposited by braided melt-water streams between glacial ice and valley wall. A generally narrow, constructional terrace of limited length. Must be distinguished from stream terraces eroded in valley fills. Sometimes occurs in series at successively lower altitudes. Often extends downstream into outwash deposits at a gradient somewhat greater than modern stream	Adjacent ice apparently stagnant, but ice near valley center may still be weakly active
Outwash head	Stratified drift built on or against thin, terminal ice from which valley train outwash material extends. Kame terrace may extend upstream from this position. Collapse surface may or may not be present	Ice-marginal position of essentially stagnant ice

TABLE 3 (continued)

Features	Definition and Description	Deglaciation Significance
Kames	Mound-like hill composed of ice-contact, stratified materials deposited in openings on the ice surface or adjacent to ice (kame delta) by melt water or runoff from adjacent slopes. Form is related to and may grade into kame terraces, collapsed masses, ablation drift, eskers, and parts of some end moraines	Usually associated with kettles, and thus indicates stagnating, dead, disintegrating ice
Kettles	Generally circular basin in drift (chiefly in stratified drift; occasionally in till), due to the melting of incorporated ice. Occurrences range from a single, isolated basin to groups of basins. Size range from small to 2 km diameter. Depth may be as much as 45 meters	Indicates stagnant, dead ice
Collapse sediments	Stratified materials let down on underlying terrain after initial deposition on ice. Differential melting and sedimentation cause internal folds and faults and external unsymmetrical, undulatory upper surface, typically appearing as low mounds and shallow basins. Stratification approximates upper surface	Indicates thin, stagnant, or near-stagnant ice conditions
Ice-channel fillings	Group consisting of eskers, fracture fillings and other ice-channel fillings. May be long, narrow, continuous or interrupted ice-contact ridges of stratified drift of superglacial,englacial,or subglacial origin. Eskers trend in direction of local ice flow or follow valley trend. Fracture fillings may lie transverse or oblique to valley trend	Indicates thin, stagnant ice. Forms are well preserved only if ice was dead or weakly active and not buried by subsequent deposition

(Note: Material in active ice features -till tends to dominate; stratified drift locally significant.
Material in stagnant ice features -stratified drift dominant, but till may occur, especially ablation and flow till.
Materials in collapsed ice features -contact deposits grade into ablation till reflecting initial differences between thick drift on thin ice and thin drift on thick ice.
Paucity of stratified deposits may indicate a lack of melt water or a limited amount of material greater than silt size. Lacustrine materials indicate ponding ranging from small, local, marginal and ephemeral pools to large, more persistent impoundments.)

Flint's (1971) descriptions of moraines and ice-disintegration features, including the possible significance of deposits for evaluating ice regimes at the time of deposition. Flint noted, as Taylor did, that high subglacial relief causes marginal lobation during glacial thinning, affecting the location and nature of marginal deposits. Taylor (1903; 1914) believed that active ice-marginal retreat dominated during deglaciation in western New England. Flint, however, (1929; 1930; 1942; 1971) has consistently argued for extensive ice stagnation throughout New England.

Flint's 1971 text clearly emphasized his concept of glacial retreat by stagnation in New England. Initially:

> "The terminal part of the glacier separates into many blocks or 'pieces,' throughout a zone that may be 10km in width or even more." (p. 207)

Later, regarding the regional thinning of the ice sheet:

> "Within such belts local sequential relations establish the former existence of stagnant terminal ice through widths of as much as 20 to 30km." (p. 224)

and finally, in discussing the Laurentide Ice Sheet for the eastern region of the United States:

> "The implication is that the ice between the St. Lawrence Valley and the Atlantic Coast finally thinned and disappeared by downwasting while the main ice sheet farther northwest continued with active flow and a moraine-building habit." (p. 496)

Descriptions for glacial deposits in Table 3 are strongly influenced by Flint's concept of regional ice stagnation in New England. Careful consideration must be given these criteria when applying them to specific areas for evaluating the ice regimes and interpreting the mode of deglaciation.

Flint (1942) and Demorest (1942) present a discussion, later extended by Rich (1943), describing the isolation of thinning, terminal, stagnant valley ice by burial and insulation beneath outwash materials. Behind the buried segments, separation and recession of an active ice margin may occur without forming any moraine segments. Exposed, uninsulated blocks of stagnant ice may melt more quickly than the buried ice. In either case, collapsed ablation topography will result at the site of the buried stagnant ice. In narrow valleys, this structure may constitute a drainage-blocking valley plug. Taylor (1903) reported drainage derangement of the Westfield River in Massachusetts by glaciofluvially deposited materials which block the valley.

Valley plugs, ice-cored or not, can produce a variety of effects. Where drainage cannot be directed to other valleys or channels, ephemeral ponds develop in the fosse between the plug and the retreating ice margin or around stranded, separated, clean ice blocks lying behind the plug. Ponds thus formed are partially or completely infilled with sediments, depending on a variety of factors including retreatal rates, amount and rate of sedimentation, rate of distal sapping by outflowing melt water, and rate of ablation of any ice core present. Deposits, including lacustrine materials, through kames, kame terraces and inundating outwash valley trains, mark these locations. Subsequent melting of buried ice present in narrow valley ice plugs may have quickly restored through-drainage, prevented excavation of remnant deposits along the valley slopes, and left at least meager evidence of the former ice plug's existence. Stream and valley gradients, material textural changes, and remnants of kame terrace and outwash deposits facilitate interpretation of these valley ice-terminal positions.

Arguments persist about the relative significance of various deposits as defining indicators of stagnant or active ice regimes. End moraines are usually accepted as indicators of deposition by active ice, although some non-moraine till ridges lie subparallel to parallel to known end moraines. These deposits may have been formed as ice-pressed features associated with disintegrating stagnant ice. Stagnant, dead ice is best inferred from kettles, related kames, and short crevasse fillings. Other features in various combinations also indicate stagnant, dead ice.

These include kame deltas, collapse masses, ablation drift, and some eskers. The absence of end moraines alone does not indicate stagnant ice. Flint (1942) indicated that end moraines may not develop due to:

1. continuous marginal retreat without pause;
2. paucity of glacial drift; or
3. melt-water debris flush.

The absence of distinctive, identifiable moraines to mark recessional ice stillstands in many parts of New England prompted the development of another conceptual model. Jahns (1941) proposed, and later applied (Jahns and Willard, 1942; Jahns, 1953), a sequence model in which outwash material, graded to a specific base level, was deposited against dissipating ice in a zone adjacent to active ice. As ice downwasted, lower base level controls became exposed, initiating the deposition of successive sequences at lower altitudes. In this model, the marginal and distal elements of Penck and Bruckner's "glacial series" (as cited in von Engeln, 1921) were expanded and emphasized to include depositional details within an extended stagnant ice zone related to rapid ice-marginal retreat.

Since the initial model was proposed (Jahns, 1941), several variations in base level controls and depositional environments have been identified during detailed mapping in

New England. Koteff (1974) classified eight morphological sequences which may evolve in a zone distal to the elusive ice margin. These are summarized in Table 4. He indicated that morphological sequences have certain common aspects. Materials consist generally of melt-water gravels, sands, silt clays, and occasionally flowtill, which were emplaced in fluvial, lacustrine, or marine environments. Bedrock, till, ponds, moraines, sand and gravel accumulations, and stagnant ice blocks may serve as specific base levels to which materials in each sequence are graded. Deposits include severely collapsed ice-contact features near the stagnant ice margin, non-collapsed, more distal outwash plains, and valley trains. Textural gradation within deposits generally becomes finer downstream from the ice source area. To the extent that the duration of deposition in each sequence was brief, perhaps only a few years, materials in each sequence are considered time equivalent.

Koteff (1974) emphasized that the source of materials for the sequences is the "nearby" active ice, stating:

> "The still moving ice is thus viewed as a conveyor belt, or 'dirt machine', constantly replenishing the supply of material to be reworked and eventually laid down as meltwater deposits." (p. 141)

Several characteristics of Koteff's (1974) morphological sequences are strikingly similar to aspects of the "glacial series" of Penck and Bruckner as described by von Engeln (1921) for the Valley Heads moraine at Tully, New York.

TABLE 4

MORPHOLOGICAL SEQUENCES
(after Koteff, 1974)

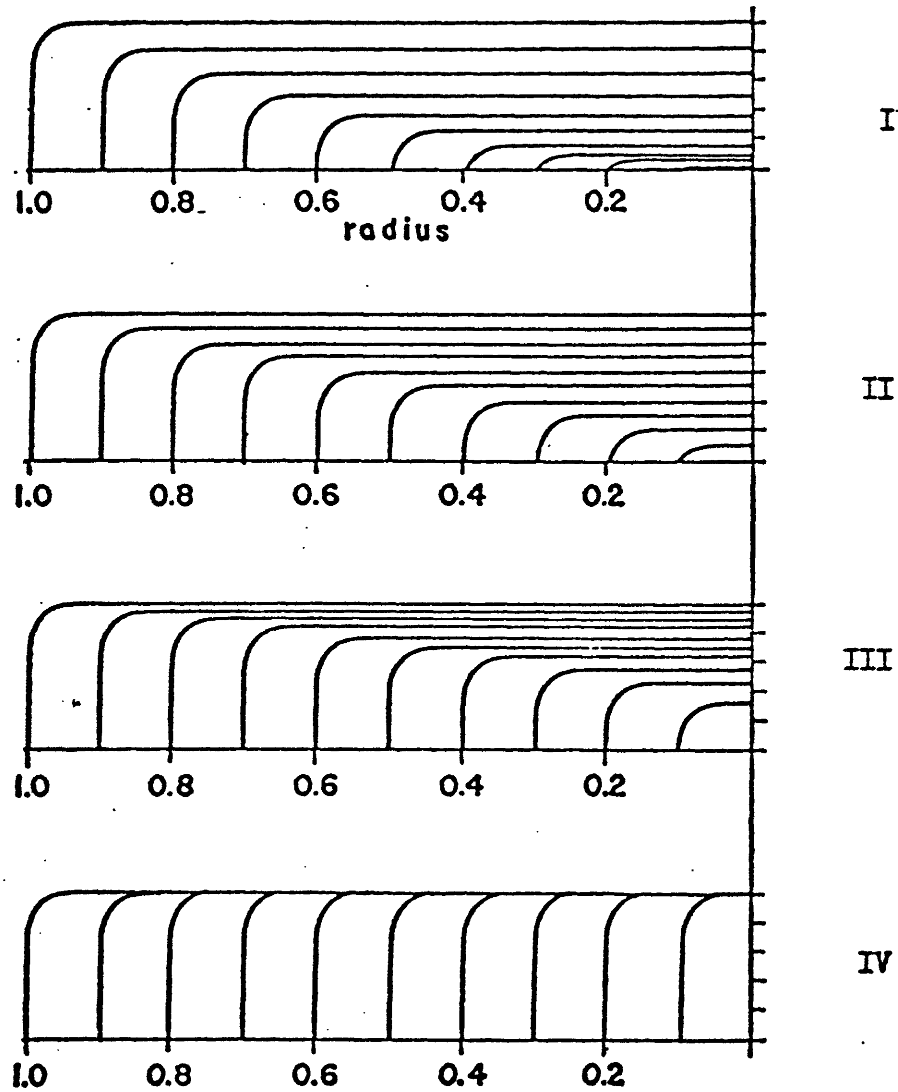
Sequence Type	Depositional Environment	Characteristic Features	Base Level Control
Fluvial ice-contact (FC)	Aggrading fluvial extending from stagnant ice edge through and beyond isolated ice zone	Head of outwash at edge of stagnant ice zone; channel fillings, kames, kame terraces, and outwash plans or valley trains	Bedrock, till, sand and gravel or ice blocks
Fluvial non-ice-contact (FNC)	Aggrading fluvial from an initial isolated point distal from stagnant ice zone through and beyond isolated ice zone	Same as sequence FC except channel fillings absent or rare. Initial deposition separated from stagnant ice along divides or on slopes with gradients greater than 40 ft/mi	Bedrock, till, Sand and gravel, or ice blocks
Lacustrine ice-contact (LC)	Direct deposition into impoundments contiguous to the stagnant ice zone	Delta and lake bottom sediments	Lake level
Fluvial-lacustrine ice-contact (FLC)	Aggrading streams extending from stagnant ice zone edge through isolated ice zone into impoundments	Head of outwash, channel fillings kames, kame terraces, outwash delta, and lake bottom sediments	Lake level
Fluvial-lacustrine non-ice-contact (FLNC)	Aggrading stream from isolated distal point to the stagnant ice zone through isolated ice zone into impoundments	Same as sequence FLC except head of outwash absent and channel fillings absent or rare	Lake level
Lacustrine-fluvial ice-contact (LFC)	Direct deposition into impoundments with overlying aggrading fluvial extending to threshold	Prograded kame delta with aggraded fluvial cap	Lake level, then lake spillway
End moraine and associated outwash (EMO)	Active ice margin and distal aggrading fluvial	Morainal ridge, head of outwash, and outwash plain-valley train	Fluvial gradient threshold
Glaciomarine deposits (M)	Similar to sequences above	Similar to sequences above	Sea

NOTE: Stagnant ice zone = ice contiguous with active ice
Isolated ice zone = ice blocks and tongues separated from contiguous active and stagnant ice

Erosion

Implicit in the discussion of ice-marginal features, particularly those associated with stagnating ice, is the concept of melt-water deposition. Melt water also erodes distinctive features which are of diagnostic value for interpreting deglaciation modes.

It is generally assumed that waxing glaciers produce significantly less melt water than waning glaciers (Flint, 1971, p. 190). Bloom (1971) discussed the theoretical effects of different deglaciation modes on the release of melt waters returned to the ocean basins, and pointed out that deglaciation is a function of backwasting versus downwasting. Figure 11 schematically represents the profiles of ice caps in various deglacial ice regimes. Water volume, positions of melt-water stream discharge, and the amount and volume of glacial debris transported are partly controlled by the temperature conditions which prevail in the ice. Backwasting tends to dominate at the marginal edge in polar ice, and downwasting tends to dominate in the marginal zone of temperate ice. Polar ice, with ice temperatures below freezing throughout, tends to have a restricted volume of melt water which is derived chiefly from its edge, and only short periods of englacial and subglacial melt-water flow. This polar ice condition



Vertical Exaggeration X100

I. Rapid initial downwasting relative to backwasting
II. Downwasting proportional to backwasting
III. Rapid initial backwasting relative to downwasting
IV. Backwasting exclusively

DIAGRAMMATIC PROFILES OF GLACIAL
BACKWASTING VERSUS DOWNWASTING
(after Bloom 1971)

FIGURE 11

inhibits the production of glacial or glaciofluvial ice-marginal deposits. Temperate ice however, with temperatures at or above the pressure-melting point throughout, tends to have large quantities of melt water passing englacially and subglacially through the ice zones which contain large amounts of glacially entrained debris. Copious melt water enhances formation of glacial and glaciofluvial ice-marginal deposits. If an initially circular ice mass of uniform thickness is assumed, it seems probable that the discharge of melt water released during local deglaciation as backwasting prevailed would be nearly constant during equal increments of marginal retreat. The total water volume released during equal increments of marginal retreat around the entire periphery of the shrinking ice mass must actually decrease, however, because there would be less ice volume in each concentric band. By contrast, when downwasting prevailed, particularly during a transition from a backwasting polar ice regime to a downwasting temperate ice regime, the discharge of melt water would be initially large and would decrease with time as the margin retreated at a constant rate. Variations between the extremes in available amounts of melt water occur, but volume changes may not be discerned from the preserved melt-water features. Erosion and deposition effects caused by melt water may be similar or distinctly different from place to place depending on the nature of the ice and on the underlying and adjacent terrain.

Derbyshire (1961; 1962) described and classified the characteristics of melt-water erosional channels and related deposits. He distinguished between features produced subaerially, submarginally, and subglacially. Ice competence and permeability change as ice thins, influencing changes in hydrostatic pressure, marginal and submarginal stream flow, and the development of slope chutes and other avenues by which water can descend to lower levels in the ice. A zone of saturation exists in the seasonally melting and permeable upper glacial ice. The water table in this zone tends to be inclined down ice, with gradient sufficient to cause water movement and erosion where the saturated water surface intersects the underlying terrain. As the ice thins, the seasonal melt level and water table drop, initiating subglacial erosion and deposition at lower altitudes. The directional tendencies for moving submarginal and extra-marginal melt water are indicated today by the overall pattern of the remnant channels. Factors in the local terrain cause divergence of individual channels. Unlike Kendall (1902), Derbyshire (1961) did not generally invoke the presence of lakes or lakelets at the heads of channels, but recognized that some channels serve as overflow outlets for lakes. His study classified three forms of channels developed on ridges and hill slopes, including:

1. those which occupy pre-existing cols in the upland;
2. a variety of channels and chutes running downhill across contours; and
3. channels which tend subparallel to slope contours.

Subglacially eroded channels, the erosional equivalent of eskers, may be formed by debris-deficient streams driven by hydrostatic pressure. These channels typically have undulating long profiles and seldom follow the gradient of the surface slope with which they are associated today.

Channels and ponds receive sediments when melt-water streams which are heavily charged with rock debris change gradients. Deposits associated with erosional channels, if present, vary from poorly sorted, poorly graded torrential materials (Derbyshire, 1961) to ice-contact deposits such as ice-channel fillings, kames, kame terraces, and more distal outwash materials. Shallow melt-water channels on the surface of outwash materials record the position of abandoned braided stream channels which remain today because outwash deposition terminated before the channels were obliterated by subsequent deposition.

Retreat of the ice from an outwash head position associated with a valley train may cause ponding between the ice and the outwash which serves as a sediment trap from which escaping debris-deficient melt water may quickly trench older deposits. This trenching usually forms distinctive paired terraces as the melt-water stream seeks to re-establish a graded condition. Eventually, younger, meandering, postglacial streams slowly excavate the outwash sediments, and may produce non-paired terraces (Flint, 1971, p. 189-190). In extremely narrow valleys, remnants of older paired terraces may be completely destroyed by postglacial stream activity. This destruction complicates the interpretation of Late Wisconsin and Holocene events. Krall (1966) modified Derbyshire's (1962) channel classification while studying drainage features in Central New York. Table 5 includes both Krall's proposed classification and brief descriptions, and the comparable terminology originally used by Derbyshire.

Flint (1971, p. 203) suggested that some series of fluvial channels on hill slopes reflect annual increments of downwasting. This erosional concept may be consistent with a depositional concept held by Taylor (1903). He observed that secondary ridges are frequently present within ice-marginal deposits which span a width of a mile or more. These ridges indicate minor recessional activities of

TABLE 5

CLASSIFICATION OF MELT-WATER DRAINAGE CHANNELS
(after Krall, 1966)

Krall (1966)	Derbyshire (1962)	Control	Channel Description
I. SUBGLACIAL CHANNELS			
Hydrostatic pressure channels	Subglacial col gullies	Stagnant or active ice	Channels with undulating or reversed gradient. May be associated with depositional eskers
Subglacial outflow channels		Stagnant or active ice	Channels found beneath glacier margin on terrain sloping in the direction of glacial movement
Moulin channels		Stagnant ice	Amphitheater-shaped channel with vertical head and open mouth. May end abruptly where melt waters became englacial
Subglacial channel systems	Subglacial channel system	Stagnant ice	Main subglacial channel with at least one subglacial tributary
Subglacial chutes	Subglacial chutes	Slight ice activity	Channels decending slopes nearly normal to contours. May end abruptly where melt waters became englacial
II. EXTRA-MARGINAL CHANNELS			
Subglacial chutes		Slight ice activity	Channels descending slopes nearly normal to contours. May end where melt waters became englacial
Single-walled submarginal channels	Submarginal benches (subglacial drainage)	Increasing ice activity	Formed under ice margin. One wall composed of ice; the other wall of bedrock or till. Ice impermeable to melt water
Double-walled submarginal channels	Submarginal channels (subglacial drainage)	Increasing ice activity	Formed under ice margin. Two walls composed of till or bedrock. Ice impermeable to melt water
Composite submarginal channels		Increasing ice activity	Channels with both conditions (ice-bedrock/till walled; bedrock/till-bedrock/till walled) at different parts of their courses

TABLE 5 (continued)

Krall (1966)	Derbyshire (1962)	Control	Channel Description
Single-walled marginal channels	Strictly marginal benches	Active ice	Formed along contact of ice and land surface; one wall ice
Double-walled marginal channels	Strictly marginal channels	Active ice	Two-walled; composed of bedrock or till
Composite marginal channels		Active ice	Channels with both conditions (ice-land walled; bedrock/till-bedrock/till walled) at different parts of their courses
Semi-marginal channels	Extra-marginal channels	Active ice	Formed beyond glacial margin. Controlled by topography of morainal deposition at some places
III. PROGLACIAL CHANNELS			
Subaerial outflow channels	Terminal channels or col gullies	Stagnant or active ice	Formed by water moving away directly beyond the ice front, or through passes beyond the ice front
Overflow channels	Overflow channels	Stagnant or active ice	Channels draining proglacial lakes

perhaps annual duration, during the longer, larger depositional episode. In addition to providing an indication of possible annual melting rates, melt-water channels may also provide evidence of ice-marginal surface gradients (Taylor, 1903; Embleton and King, 1968).

To utilize either erosional or depositional melt-water features in the analysis of regional deglaciation, factors such as the actual and relative altitudes of features and the volume and potential routes of escaping melt water, as well as the morphological and internal characteristics of deposits must be considered. Within limits, vague indications of ice condition in terms of permeability, temperature regime, and possible motion can be deduced from channel-filling deposits or high-level erosional drainage features. Unfortunately, erosional channels seldom demonstrate clearly the time of their initial formation, or of their possible re-occupancy by melt water, or by ice of prior or subsequent glaciations. Most upland notches probably were occupied at least briefly by melt-water streams during waning of the last glacier.

CHAPTER IV

APPLICATION OF DEGLACIATION CRITERIA TO STUDY AREA

Introduction

In this chapter, erosional and depositional criteria are applied to evaluate deposits and morphological features in the study area. A comparison of events during glaciation and deglaciation can be made to clarify the general conditions which developed in western Connecticut.

During glaciation, thickening ice in the Hudson-Champlain Valley presumably inundated the area by sending stringers of active ice through broad, low-altitude cols (Fig. 10). As the ice thickened, it overtopped the highland ridges which trended athwart the direction of ice flow. The slope of the advancing ice margin was probably steep, perhaps averaging 150 to 300 or more feet per mile. Valleys, such as the Housatonic Valley, began to receive active ice flow as ice thickness increased, maintaining flow across the upland ridges. Ridges and lowlands to the southeast were successively overrun. Perhaps the deteriorating climate in the proglacial region caused snow and ice to accumulate and locally persist prior to the arrival of active ice. The study area ultimately lay beneath an undetermined thickness of ice far behind the steep marginal zone. Above the study area, the ice surface presumably had a gentle slope.

With climatic amelioration, ablation soon exceeded accumulation. The still-active ice on this terrain thinned, and the distant ice margin receded. Melt waters flowing on this ice and in the upper zone of seasonal melting and saturation eventually lowered onto higher ridges, eroding numerous channels in the till and bedrock surfaces. A complex and varied pattern of erosion and deposition evolved during subsequent stages of deglaciation which can best be considered by separately discussing specific sub-areas within the study area (Fig. 9). These sub-areas include:

1. Ridge southeast of East Aspetuck River (Pl. II).
2. The East Aspetuck Valley and Marble Dale-Northville area in the southeastern part of the Kent quadrangle (Pl. I, Kent Profile D-D'; Pl. II).
3. Semi-isolated basins chiefly in the West Aspetuck drainage system, situated in the south and central part of the Kent quadrangle (Pl. II).

4. The upland southeast of the Housatonic Valley, trending northeast from the southwest part of the Kent quadrangle to the southeast part of the Ellsworth quadrangle (Pl. II, III).
5. The South Kent trough and Cobble Brook Valley in the western part of the Kent quadrangle (Pl. I, Kent Section B-B'; Pl. IA, Kent Profile B-B';, Pl. II).
6. The Housatonic River valley located in the southwestern and northwestern part of the Kent quadrangle and in the south, east, and northeast parts of the Ellsworth quadrangle (Pl. I, Ellsworth and Kent Sections A-A'; Pl. IA, Kent and Ellsworth Profiles A-A'; Pl. II; Pl. III).
7. The Housatonic Highlands from the northwest part of the Kent quadrangle, northeastward to the northeast part of the Ellsworth quadrangle (Fig. 5).
8. The Sharon area in the northwestern part of the Ellsworth quadrangle (Pl. IA, Profile C-C'; Pl. III).
9. The valley west of the Housatonic Highlands.

Significant features related to each of these areas, but lying in the secondary study area of adjacent quadrangles, will be identified and discussed as appropriate.

Ridge Southeast of East Aspetuck River, and East Aspetuck Valley Areas

The East Aspetuck Valley (Fig. 9, Sub-areas 1,2) trends generally northeast to southwest, and only a small portion lies in the southeastern part of the primary study area. This valley is underlain by Woodville marble (Gates and Bradley, 1952; Rogers and others, 1959). Southeast of the valley, the terrain rises gently and is covered with molded till overlying bedrock. Relatively thick till patches, roughly paralleling the trend of the valley, have been mapped in the New Preston quadrangle to the northeast (Colton, 1969) and in the Litchfield quadrangle (Warren, 1970).

As the glacier thinned, high ridges and hills to the northwest emerged as nunataks. Melt water, flowing partly on relatively clean ice and partly on exposed upland surfaces, formed minor erosional channels and patchy gravel deposits. Eventually melt water occupied two channels between Sawyer Hill and Bear Hill (K19, Pl. IV), with thresholds at 745 and 705 feet respectively, and entered the East Aspetuck Valley. Related deposits (K16, Pl. IV) are believed to be washed or modified till (Qtm; Pl. II), the highest level of which is associated with a 745-foot channel. These materials consist of poorly sorted lenses of stratified gravel interlayered with till and are evidence of the partial fluvial removal of fine materials. Their irregular morphology and composition suggest an ablation till origin. Materials characteristic of flowtill (Hartshorn, 1958) were not found.

High-level channels and erosion surfaces near Camp Ella Fohs (K9, Pl. IV) indicate that melt water flowed southwest and was held against Bear Hill and Mount Tom by impermeable ice. Ice west of this camp contributed melt water flowing towards the east, but blocked passage of water toward the west until melting ice in the East Aspetuck Valley lowered the altitude of the marginal drainage stream. The channel entering from the west is weakly incised, and contains weakly imbricated boulders with long axes dipping away from the pond.

Boulders, concentrated in a boulder field and fences (K6, Pl. IV) 2,000 feet east of the 380-foot bench mark (Pl. II), suggest a drainage route along the east side of the valley at altitudes ranging between 560 and 600 feet. Additional minor, low-altitude channels and erosion surfaces developed as the valley ice melted (Pl. I, Kent Profile D-D'; Pl. II). Based on surface morphology and internal deformation of strata, glaciofluvial deposits in the valley are interpreted as ice-contact sediments. Materials south and southeast of the Northville Cemetery (K12, Pl. IV; Qcd1) are hummocky knob-and-kettle terrain containing deformed strata composed chiefly of sand and pebble sand. These materials may have accumulated on thick ice and been later emplaced on the underlying terrain as the ice melted. Related deposits along the west hillside have ice-contact slopes facing the valley and a discontinuous terrace sloping southward from an altitude of 590 feet north of the cemetery to around 560 feet farther south (Pl. II; App. C, No. 71K15; App. D, Nos. 9K11, 71K15). Internally, these materials are deformed below a zone of horizontally stratified pebble gravel 6 feet thick. This relationship suggests that a kame terrace lateral to an ice tongue terminated in a valley plug of related ice-contact materials (K12, Pl. IV; Qcd1), and melt water depositing these materials moved along the East Aspetuck Valley from the northeast (FC; Koteff, 1974). Melt water and debris, however, may have been derived, in part, from the cross-ridge channels (K19, Pl. IV) between Sawyer Hill and Bear Hill before these channels were abandoned. This is evidenced by a gully descending the slope from those channels to the kame terrace.

East of Northville (K3, Pl. IV), collapsed topography composed of stratified pebble sands has maximum altitudes of about 460 feet adjacent to the hill slope. If it is assumed that deposition of these materials was contemporaneous with deposition of the valley plug materials (K12, Pl. IV) near the Northville Cemetery, a steep stream gradient of about 100 feet per mile would be required. This gradient is much too steep for deposition of this relatively fine-grained material, and erosion, rather than deposition, would have occurred. These sands and pebble sands, indicative of a low-energy environment of deposition, required either a relatively low-gradient stream or the infilling of ponds. Pebble sands south of Marble Dale (K15, Pl. IV; Qcd2) range in altitude from 515 to 500 feet, and are correlated with the materials northeast of Northville (K3, Pl. IV; Qcd2). Presumably, the same melt-water stream deposited the materials concurrently at both locations. This stream, however, must have flowed through the older, higher materials (Qcd1) at an altitude between 470 and 490 feet (K12, Pl. IV). This altitude range is lower than the small breach located immediately southeast of the cemetery, and it is also lower than the upper part of the rock canyon east of the valley plug (K12, Pl. IV; Qcd1). If the stream initially depositing these materials flowed over the pebble sands south of the cemetery, it is unlikely that it later occupied the rock canyon which the East Aspetuck now occupies. This narrow rock canyon extends for about 800 feet and is incised more than 60 feet deep. At Great Falls (SC4, Pl. VI), near Falls Village, Connecticut, the Housatonic River has incised only 15 to 20 feet in Stockbridge marble during Holocene time (Warren, 1971; Holmes and others, 1971). If, however, the canyon along the East Aspetuck River formed prior to the last glaciation, melt water may have excavated only a few feet of till or stratified drift from this canyon as the younger lower materials (Qcd2) were deposited. Subsequent excavation of the remaining unconsolidated materials could have occurred during the Holocene. Another preglacial East Aspetuck River channel, consistent in size with the dimensions of the rest of this valley, probably lies beneath the valley plug (Qcd1) west of the rock canyon (K12, Pl. IV).

In the nearby secondary study area, northeast of Marble Dale and east of New Preston, Bradley (Gates and Bradley, 1952) described drainage derangement by till which involved diversion of the headwaters of the East Aspetuck southward into the Shepquag River (NP2, Pl. VI). Colton (1969) mapped a channel incised in rock and till in the village of New Preston (NP1, Pl. VI) which has a threshold altitude of about 690 feet. This channel is now occupied by the underfit outlet stream draining Lake Waramaug. The volume of water derived from the Lake Waramaug watershed today is meager, even during times of high precipitation. Bradley (Gates and Bradley, 1952) believed the lake to be in a glacially overdeepened rock basin. Melting of the ice block in this basin augmented the volume of water derived from the watershed during deglaciation. However, even their combined discharge was probably insufficient to cut the New Preston channel in rock (NP1, Pl. VI). The size of the channel and the patchy presence of till along parts of the channel walls suggest that this channel was formed prior to the last glaciation, and was only re-excavated by glacial melt water and later Holocene erosion.

Channels which directed melt water towards the southeast originate near the crest of the till-covered upland southeast of the East Aspetuck Valley. These subaerial outflow channels can be traced to lower altitudes, suggesting that some differences in the ice surface altitude occurred on each side of this low ridge.

In the northeast and east central part of the adjacent New Milford quadrangle, comparable high altitude cols lead to distinct drainage channels, including several in the vicinity of New Milford Reservoirs No. 3 and No. 4, and those entering the northern part of Town Farm Brook (NM1, Pl. VI). These channels served as subaerial outflow routes although they may have formed initially as semi-marginal channels. Several channels cross or flank Aspetuck Hill (NM2, Pl. VI), south of Park Lane, at different altitudes, but each directed water towards the southeast and required impermeable ice to maintain their position. Channels were also found along the hill flank (NM3, Pl. VI) east of Route 25, northeast of Park Lane. Thin till ranging from 3 to 10 feet in thickness, overlies the marble in this area, and the arcuate topographic terrain apparently reflects the partly subdued, preglacial erosional form of the underlying rock rather than melt-water sculpturing of the till.

A large, flat-bottomed subaerial outflow channel starts abruptly at an altitude of about 385 feet, 0.9 mile northeast of Park Lane, and today contains the underfit Great Brook (NM4, Pl. VI). The width of this channel, and the anomalous bend in Great Brook, suggest that today's headward branches were originally tributaries to a stream comparable to today's Housatonic River. This channel headed at an ice margin and was occupied by a melt-water stream while drainage along Paper Mill Road was blocked. Boulder gravels half a mile north of Great Brook channel indicate a high-energy depositional environment. The cross-valley gravel ridge at Hickory Haven (NM6, Pl. VI), north of Paper Mill Road, lacks internal exposures, but has the morphology of an ice-channel filling.

Collectively, the deposits and drainage features southeast of the Aspetuck Valley suggest a brief interval of active ice-marginal, till moraine development with distal terrain erosion, followed by stagnation, and by deposition of the dead-ice features now dominant within the valley.

Semi-isolated Basins

Several basins of irregular size and shape occur in the southern part of the primary study area (Fig. 9, Sub-area 3). All but one are drained by the West Aspetuck River or its tributaries. Relatively few ice-contact deposits occur, but the pattern of deglaciation may be generally inferred from melt-water activity and a variety of associated features. A power auger test boring made along Merryall Brook (K5, Pl. IV), has 3 feet of alluvium above 53 feet of varved lake sediments (App. B, No. NM36th). Hand auger sampling and probing in the other basins revealed lacustrine sediments with varying thicknesses of overlying alluvial or swamp deposits.

A deeply incised West Aspetuck tributary (K40, Pl. IV) delivers water to the northern end of Kent Hollow from the upland areas around the Spectacle Ponds, and from the small swamp east of East Kent. This swamp occupies an abandoned melt-water channel (K46, Pl. IV) (hereafter referred to as the East Kent channel) which has a 1,155-foot threshold altitude, the lowest altitude for several miles along this ridge. Only small fan deposits enter Kent Hollow at the base of this slope (K38, Pl. IV). The fans suggest that stagnant ice remained after melt-water flow through the East Kent channel terminated. Bouldery ice-contact deposits (Qcd1) are present at an altitude of 770 feet west of this stream (K40, Pl. IV), however, and a corresponding eroded till surface occurs against the east hillside. The stream channel is deeply incised above this altitude. These features collectively suggest that fluvial activity continued in the stream as ice in Kent Hollow thinned, but major drainage terminated before the ice completely melted. The erosional competence of the stream has been weak during Holocene time.

A melt-water channel, armored with imbricated boulders and incised less than 3 feet into till, is present near the northwestern end of Lake Waramaug (K37, Pl. IV). This channel carried melt waters from Kent Hollow into the Lake Waramaug depression. Another channel, southwest of Ash Swamp (K33, Pl. IV), carried melt water from Lake Waramaug southwestward back toward Kent Hollow. These subaerial outflow or semi-marginal channels have threshold altitudes of 765 and 745 feet respectively.

The lower end of the northern channel (K37, Pl. IV) bifurcates and the higher, less deeply incised branch is directed southward along the base of the ridge towards Ash Swamp. The other branch is directed southeastward toward the lake. Glaciofluvial deposits are notably lacking here and elsewhere around the Lake Waramaug basin. These channels, and the lack of deposits, indicate ice was present in the basin at least while melt waters utilized the western channels. Initially, the melt waters entering from the northwest were directed along the east slope of Golf Course Hill, eroding unconsolidated material and exposing the underlying rock in Lake Waramaug State Park. These waters then moved on ice occupying Ash Swamp, through the 745-foot channel, and thence south past Sugar Loaf Hill. Thinning, a change in permeability, melting, or other changes in the ice of Lake Waramaug terminated flow to the southwest. When this channel was abandoned, water entering the Lake Waramaug basin exited through the 690-foot altitude New Preston channel (NP1, Pl. VI), and entered the East Aspetuck Valley (p. 81). Ice to an altitude of 765 feet was required in the northern part of Kent Hollow while melt waters entered Lake Waramaug through the northwestern channel (K37, Pl. IV). As the ice thinned in Kent Hollow, melt-water flow was diverted to the west side of Golf Course Hill. Apparently melt waters continued to enter the northwestern part of Lake

Waramaug after the Ash Swamp outlet ceased to function, because the channel of this northern outlet is incised down to altitudes of 720 or 710 feet, much lower than the 745-foot altitude of the Ash Swamp outlet (K33, Pl. IV). During this interval, water flowed from the Lake Waramaug basin through the New Preston channel.

Melt waters flowing along the hill flank toward the 705-foot Sawyer Hill-Bear Hill channel (K19, Pl. IV) washed and cut shallow channels in till at altitudes between 700 and 710 feet east of Kent Hollow Road (K27, Pl. IV) near the south end of Kent Hollow. The nearby sandy kames (Qcd2), and a sheet of pebbly sand, were deposited in a quiet pond on thinning ice. This pond was initially dammed by ice and later by a small valley plug of coarse cobble and boulder gravels (Qcd2) which blocked drainage in the West Aspetuck River from Kent Hollow. Sand deposits to a 690-foot altitude (Qcd1) (FLNC; Koteff, 1974), 2,000 feet northwest of the Sawyer Hill-Bear Hill channel (K19, Pl. IV), approximate the pond's surface altitude. Other materials may have been deposited on ice at the same time and emplaced on the underlying terrain when the ice melted.

The Sawyer Hill-Bear Hill channel (K19, Pl. IV) persisted as an overflow channel only while drainage to the southwest through the West Aspetuck River (K24, Pl. IV) remained blocked by ice to an altitude of at least 710 feet.

Ponding north of the Sawyer Hill-Bear Hill overflow channel served as a sediment trap, and sediment-deficient melt waters incised the distal till slope. This incision can only be traced to an altitude of 550 feet, and indicates that thinning, low-altitude ice remained in the East Aspetuck Valley until after the Sawyer Hill-Bear Hill channel ceased to function (p. 83). Ice in Kent Hollow and the East Aspetuck River valley developed a maximum altitude difference of 160 feet while the Sawyer Hill-Bear Hill channel carried melt water.

Two cols east and north of the Upper Merryall Cemetery (K25, Pl. IV), with threshold altitudes of about 725 and 695 feet respectively, are not clearly related to fluvial drainage. The higher one hangs as an abandoned channel almost 200 feet above the nearby West Aspetuck River (K24, Pl. IV). A distinct channel configuration is evident, although this channel slopes to the northwest and its surface contains only a few boulders. This channel may represent a glacially molded form developed on an obscure preglacial topography, or it may be a hydrostatic pressure channel formed by melt waters under pressure flowing beneath glacial ice. The latter hypothesis requires water to be under hydrostatic pressure in order to erode a reversed stream gradient toward the southeast (Derbyshire, 1962; Krall, 1966). A third hypothesis would require the presence of thick ice in the West Aspetuck Valley (K24, Pl. IV) northwest of Bear Hill, which would direct surface melt waters across the col from southeast to northwest. This flow would be in direct opposition to the evidence for most melt-water drainage trends in the study area. The direction of boulder-axis orientation is indecisive regarding melt-water flow direction.

The lower, 690-foot altitude col (K25, Pl. IV) may have served briefly as the outlet for Kent Hollow drainage when thinning ice opened this channel and terminated flow through the higher Sawyer Hill-Bear Hill channel (K19, Pl. IV). Flow through this 690-foot channel was short-lived, because ice melting in the West Aspetuck Valley northwest of Bear Hill provided a lower altitude escape route. A small, bouldery, ice-contact deposit (Qcd2) at the north end of Bear Hill which blocked this valley was truncated by waters flowing from Kent Hollow. Lack of erosion in this reach of the West Aspetuck (K24, Pl. IV) indicates that through melt-water flow terminated prior to complete melting of ice in this valley. While ice remained in the valley north of Lower Merryall (K14, Pl. IV), melt-water flow was diverted briefly through the area now occupied by Strastrom Pond (K11, Pl. IV), and thence southward where small, ice-contact deposits remain today to record this brief episode.

After melt water was diverted from the East Kent channel (K46, Pl. IV), it flowed at least partly on ice, and partly against exposed hill slopes, occupying successively lower routes southwestward along Kent Mountain, Seger Mountain and Bull Mountain (Pl. II). This water then returned to the semi-isolated basin by moving southeastward around the southern flank of Bull Mountain onto ice in the Mud Pond area (K29, Pl. IV; App. D, No. 9K44), through the gap between Long Mountain and Ore Hill (K30, Pl. IV), and thence southward where it crossed a low ridge to enter the Tamarack Swamp area. Ice in Tamarack Swamp may have redirected melt water back toward the Merryall Brook Valley through channels south of the West Meetinghouse Cemetery (K13, Pl. IV). Collapse sediments are sparse in these basins, and contain materials derived from both melting ice and from nearby slopes (Qcd, Qg, Qcd3, Qcd4) (FC; Koteff, 1974). Deposits are poorly exposed, pebble-to-cobble gravels and sands. Surface altitudes and morphology indicate that most features were initially deposited as kame terraces (K17, Pl. IV) between the ice and the valley slope. Other materials deposited on ice were subsequently let down to form kames and sheet sands (K21, Pl. IV). Many blocks and large boulders of local lithology are scattered over certain parts of the basins (Pl. II; K18, Pl. IV).

Uplands Southeast of the Housatonic Valley

Thinning of glacial ice subjected upland surfaces (Fig. 9, Sub-area 4) to the zone of seasonal melting, and to erosion by channelized englacial, subglacial, and extramarginal melt water. Numerous small channels on the uplands, higher than the main ridge-crossing cols, indicate places where concentrations of melt water were able to erode, perhaps briefly, before further ice thinning diverted melt waters to lower routes. Typical channels thus formed are north of North Spectacle Pond on Bromica Mountain (Pl. II; K45, Pl. IV), where straight-walled, flat-bottomed channels are incised about 15 feet into rock, and range from 20 to 40 feet in width. Some probably represent melt-water erosion of minor, high-altitude, glacially sculptured cols (subaerial or subglacial outflow channels).

As melting of the ice continued, and drainage changes evolved, some waters plunged downslope beneath the edge of the ice in subglacial chutes to flow beneath the ice or re-enter it at lower altitudes. The channel west of Bald Hill (K41, Pl. IV) is weakly cut in till, and has boulder imbrication indicating flow to the south, although its gradient is north. This channel was probably formed in a subglacial environment by water under hydrostatic pressure. The variety of channels present in this upland area conform to the classifications of Derbyshire (1962) and Krall (1966) (Table 5).

Melt water occupying the high-altitude channels had several routes across the highland ridge. Ice thinning reduced the number of routes and caused water to be concentrated in the few lower altitude cols through subaerial outflow and overflow channels until these were also abandoned. Numerous small channels, eroded surfaces, and minor fluvial deposits along the northwest-facing hill slopes are remnants of the drainage system which flowed partly on ice and partly on the adjacent terrain as the melt waters sought new escape routes to the southwest.

The East Kent channel (Pl. II; K46, Pl. IV), with a threshold altitude of about 1,155 feet, carried melt waters to the southeast, as ice-contact deposits east near Wilson Road were emplaced to altitudes as high as 1,190 feet. These materials, in the northeastern part of the Kent quadrangle (Pl. II; K49, Pl. IV; Qcd1), and the southeastern part of the Ellsworth quadrangle (Pl. III; E1, Pl. V; Qcd1), were partly deposited in ponded water surrounding ice blocks, and partly deposited as kame terraces between the ice blocks and the valley wall (FC, LC; Koteff, 1974). Thick impermeable ice in the Housatonic Valley directed melt waters across this divide. Initially, the melt water moved across the ridge west of Wilson Road (K49, Pl. IV) near the unnamed road entering the gravel pits. Water to the east and the northeast was ponded to about 1,190 feet in altitude, and deltaic gravels and sand were deposited in the southeast part of the Ellsworth quadrangle. As the ice thinned, melt-water drainage west of the gravel pits (K50, Pl. IV) graded deposits to the threshold outlet of this divide (K46, Pl. IV) and formed kame terraces with highest altitudes of 1,170 feet.

Average heights along this upland ridge rise toward the northeast. Numerous high-level, cross-ridge channels were occupied briefly by melt water prior to the opening and occupancy of the lowest available cols. Warren (in press) shows numerous drainage channels and melt-water routes. One cross-divide channel, at The Hogback (C2, Pl. VI), has a threshold altitude of about 1,105 feet. Farther to the northeast, east and southeast of Red Mountain (C8, Pl. VI), drainage crossed two thresholds at altitudes of about 1,395 feet and 1,415 feet respectively, without incising significantly. Downstream from these thresholds, the channel is incised vertically in rock to depths ranging from 10 to 20 feet. Ice-contact deposits 1 mile to the south, east of the Mohawk State Forest (C3, Pl. VI), were at least partly derived from drainage crossing the ridge. They were apparently formed in contact with thin ice to altitudes of

1,150 feet, approximately 250 feet lower than the affiliated melt-water channel.

At West Goshen (C5, Pl. VI), Milton (C1, Pl. VI), and East Street (C6, Pl. VI), fluvially sculptured channels are anomalous. Drainage from Tyler Lake, north of West Goshen (C5, Pl. VI), flows in a channel weakly incised in till. South of State Route 4 in West Goshen, this stream is in an incised rock channel. Downstream at Milton (C1, Pl. VI), another channel has been incised deeply in rock. The deeply incised gorge west of the hamlet of East Street (C6, Pl. VI) is in till and rock. Warren (in press) believed these channels were cut during interglacial times due to stream diversion by thick till. The extent of incision in these channels appears to be comparable to the incision of channels at New Preston (NP1, Pl. VI), and near Northville Cemetery (K12, Pl. IV).

Channels can be traced to lower altitudes on the southeast slope wherever concentrated melt water occupied relatively low cross-divide routes. This indicates that melt waters flowed southeastward, partly on the lower altitude ice surfaces, and partly on the exposed terrain. These upland channels are interpreted as subaerial outflow channels if they lack glaciofluvial deposits near their entrances. Similar channels, with related glaciofluvial deposits, may have acted briefly as overflow channels.

Extensive glaciofluvial deposition, partly related to overflow channels, is found at lower altitudes along the northwest side of the upland ridge (Warren, in press; Holmes and others, 1971). This ridge (Fig. 9, Sub-area 4) has been incised, and now contains two wide, high-altitude valleys. These valleys are drained by the northward-flowing Hollenbeck River (SC3, Pl. VI) and the westerly-flowing Furnace Brook (C4, Pl. VI). Ice thinning and marginal retreat to the northwest lowered the melt-water drainage routes and terminated outflow and overflow across the high-altitude ridge cols. Melt water diverted from the cols found various escape routes to the southwest. Deposition by melt-water streams produced ice-contact features which are present north and south of East Street (C6, Pl. VI), including kames, kame terraces, knob-and-kettle topography, kame deltas, and ice-channel fillings. These materials, which range from sands through pebble sands to medium and coarse gravels, illustrate a transition in deposition associated with a rapidly disintegrating, stagnant ice tongue.

As the ice melted from the upper reaches of the Hollenbeck River, several proglacial lakes were impounded in that valley at altitudes controlled by a series of overflow channels which became successively ice free. The highest channel is at 980 feet and crosses the drainage divide between the Hollenbeck River and the tributaries to Furnace Brook. Kames, kame terraces, kame deltas, and a knob-and-kettle valley plug are deposited at altitudes which correlate with overflow channels at 980, 966, and 920 feet (Holmes and others, 1973). The knob-and-kettle complex north of Lower City (SC2, Pl. VI) is a valley plug which diverted the Hollenbeck River from its ancestral course to the valley which it now occupies.

High-altitude ice-contact deposits at Cornwall (C7, Pl. VI), including an ice-channel filling and lower altitude pitted outwash (Warren, in press), required continued melt-water flow to enter the valley from the north through The Ballyhack (C9, Pl. VI) as ice rapidly dissipated at Cornwall. The altitude of the active ice margin from which this melt water was derived was above 950 feet 2 miles north of Cornwall when the pitted outwash at Cornwall was emplaced at an altitude of 720 feet. This suggests a possible local ice-surface slope of 110 feet per mile.

The broad upland ridge southeast of the Housatonic River also extends to the southwest, but has lower average surface altitudes than the ridge extension to the northeast. During ice thinning, melt water sculptured several channels on the southern part of Long Mountain (K8, Pl. IV). Impermeable ice persisted in the southeast-trending reach of the nearby Housatonic Valley. The distinctive melt-water channels are not correlated with specific deposits, but apparently were occupied in sequence as thinning of the ice initiated drainage changes. Altitudes, gradients, orientations, and the lack of associated fluvial deposits suggest that melt-water streams flowing on or in the ice were superposed on upland till and rock surfaces by the thinning ice when the ice surface was above 800 feet in altitude. The long channel east of Long Mountain Road (K8, Pl. IV) trends northwest-to-southeast and is cut in till, although few cobbles and boulders are evident. Melt waters emerging from beneath the margin of ice under hydrostatic pressure may have excavated these till and bedrock channels and removed most of the debris to form hydrostatic pressure channels. Swamp accumulations on the channel floor may, however, obscure remaining debris. Abundant boulders extend in bands for short distances normal to this and other channels (Pl. II). Channels and drainage routes at lower altitudes became available until the 600-foot altitude channel along the eastern side of Long Mountain (K8, Pl. IV) was occupied and later abandoned by melt water. Cobbles and boulders on the hill slope west of this channel suggest that melt-water drainage continued as the ice thinned and gradually lowered the altitude of the melt-water stream. Evidence which might indicate whether this stream, lateral to the ice, was subaerial or submarginal is lacking.

South Kent Trough and Cobble Brook Valley

The Housatonic River valley has two main divisions (Fig. 9, Sub-area 5) in the Kent quadrangle area (Pl. II). The eastern part consists of a through-valley trough in which the small hamlet of South Kent is situated, and the western part consists of the valley through which the Housatonic River flows. The melt-water drainage and diversion from the South Kent trough was associated with melt water moving east and south of the hamlet of Flanders.

The locations of erosional and depositional features are indicated on Plate II, and their relationships are shown on Kent Section B-B' (Pl. I), and Kent Profile B-B' (Pl. IA). A few remnant features occur along the hill flanks as evidence of the major ice thinning prior to the deposition of the lower altitude features distinguishable today. In the Gaylordsville area, several valleys join, and surficial deposits in this area are a composite of the glacial and glaciofluvial activities which occurred in those valleys. Distinctive knob-and-kettle sediments (K20, Pl. IV; Qcd5) extending across the valley are breached by the Womenshenuk Brook. These deposits rest against Cedar Hill on the west to an altitude of 450 feet and flank a till-cored hill across the valley. Materials range in size from sand to cobble gravels, are poorly sorted, and generally have contorted strata. Perched, eroded till terraces associated with these materials indicate that ice in the intervening valley was requisite to their formation. A major melt-water col channel (K28, Pl. IV) on Spooner Hill west of South Kent School has a weakly incised downstream extension, now abandoned, which is directed southeastward and joins a lower till channel accordantly. This lower channel extends directly into the knob-and-kettle deposits (Qcd5).

On each side of Hatch Pond (K32, Pl. IV), eroded planar surfaces and small, abandoned channels in rock and till range in altitude from about 560 feet down to about 450 feet. Gravels in kames at the southeast end of Hatch Pond have been removed, but northward kame terrace gravels flank swampy kettle depressions. Narrow ice-channel ridges extend into and across the valley near Leonard Pond (K36, Pl. IV). The low-gradient of the southward-sloping kame terraces, descending from an altitude of around 450 feet, is evident in Kent Section B-B' (Pl. I), and Kent Profile B-B' (Pl. IA). The terraces demonstrate the paucity of materials deposited in this trough as thin ice disintegrated (Qcd7) (FNC; Koteff, 1974). Deposit morphology provides two lines of evidence that debris-laden melt-water flow terminated prior to final melting of the stagnating ice blocks. First, minor features such as cross-valley channel fillings near the northern part of the trough have not been buried beneath any subsequent prograding outwash materials. Second, melt-water streams have not eroded channels through the cross-valley channel fillings. Northward, this trough descends through a narrow col to lower altitude outwash materials (Qvt8) underlying the village of Kent (K42, Pl. IV).

The headwaters of the Womenshenuk Brook descend from the east to enter the South Kent trough near its northern end. This brook is separated from the northward-draining Cobble Brook by only a rock-floored divide with a 577-foot altitude threshold (K39, Pl. IV). High-altitude deposits along this part of the Womenshenuk Brook, and those along Cobble Brook Valley, are related to southward melt-water drainage initially controlled by thick ice which extended accordantly through these valleys (Qcd5; Qcd6) (FC, LC; Koteff, 1974).

Kent Profile C-C' (Pl. I) illustrates the surface altitudes of deposits and erosional features associated with the early melt-water drainage moving along this part of the Housatonic Valley. Plate II shows their areal relationships. The small, sandy, kame plain and ice-channel filling gravels grade to a 577-foot altitude base level north of the bedrock threshold (K39, Pl. IV). Materials in these deposits include boulder, cobble, and pebble gravels, and pebble sands. The variation in altitude of the channel-filling materials today suggests that some segments were initially deposited directly on the underlying terrain while others were deposited on ice and later lowered onto the underlying terrain when the ice melted. Short ice-channel fillings extending from deposits on both valley sides outline kettle depressions. A short channel in till crossing the ridge above the 577-foot threshold (K39, Pl. IV) has a reverse gradient, perhaps due to a subglacial or submarginal origin by melt waters under hydrostatic pressure.

West of Flanders (Pl. II; K48, Pl. IV), another small erosional channel is associated with low till mounds, and with a linear zone of large boulders which have long axes of 4 to 8 feet. The boulders, consisting primarily of local gneiss, granite, and quartzite (App. D, No. 9B1), extend intermittently east and southeast across the valley. The channel has a bifurcated entrance, a threshold altitude of about 465 feet, and an orientation towards the southwest which aligns with drainage in the western branch of the Housatonic River. Northeast of Flanders, sands and pebble sands of varying thickness (Qcd6) irregularly blanket the terrain to surface altitudes of about 600 feet, and can be traced northeastward into the Ellsworth quadrangle (Pl. III) to the vicinity of Kent Falls State Park (E3, Pl. V). Erosion has removed the thin sands in places, exposing the underlying till and rock terrain.

The presence of impermeable ice to an altitude somewhat higher than 580 feet in the Housatonic River valley west of Flanders was requisite for the development of stagnant features and of concomitant ponding behind the 577-foot threshold leading to Womenshenuk Brook and the South Kent trough. Melt waters escaping on or under ice west of Flanders (K48, Pl. IV) caused the ponded waters to drain and terminated deposition east of Flanders. A poorly defined, weakly active or stagnant, ice-marginal position may be traced across the Housatonic Valley at Flanders using the linear boulder concentration, eroded fluvial channels, and a small kame delta which consists of fine pebble gravels. These features all formed before the pond in Cobble Brook Valley drained in response to melt-water drainage diversion to the Housatonic River valley southwest of Flanders.

Housatonic River Valley

A variety of deglaciation features are present in the Housatonic River valley (Fig. 9, Sub-area 6). The Gaylordsville area (K10, Pl. IV), in the southwestern part of the Kent quadrangle (Pl. II), has a composite of glacial and glaciofluvial features derived from several valleys which converge there. Some deposition correlates closely with erosional and depositional features to the south in the northern part of the New Milford quadrangle. Melt water, supported partly by thick ice in the Housatonic River channel to the northeast, drained through a large, double-walled marginal channel with a threshold altitude of 410 feet (NM5, Pl. VI). A small gravel deposit at an altitude of 410 feet (Qcd5) grades to this channel.

Kame terraces (Qcd6) at lower altitudes slope about 40 feet per mile toward the southeast from a 370-foot altitude near Straits Rock to hummocky collapse sediments (NM6, Pl. VI), with surface altitudes of about 340 feet east and southeast of the Squash Hollow Brook channel. These materials revealed a wide range in texture and degree of sorting when freshly exposed in 1968. The underlying material was severely contorted layers of interstratified silts, sands, and gravels. Many large boulders and blocks, to lengths of 20 feet, were randomly scattered throughout the deposit. Contorted, varved silts and clays in the upper part of the section evidenced minor quiet ponding prior to final ice dissipation. Hummocky surface morphology dominates this terrain. Deposits at comparable altitudes across the river have ice-channel and irregular surface morphology consistent with ice-contact knob-and-kettle deposits. A lower altitude terrace along U.S. Route 7 has a surface gradient of about 20 feet per mile (Qcd7), and is underlain by 6 to 8 feet of well-sorted, horizontally stratified pebble gravel which, when observed in deep pit excavations, overlie and cap deeper, contorted ice-contact deposits.

These materials are interpreted as the lateral remnants of a valley plug which was cored by buried ice. The plug differentially influenced melt-water drainage and deposition on and behind the obstructing deposits, while stagnant dead ice south of Straits Rock (K7, Pl. IV) became insulated and armored with debris. Melting of ice behind the valley plug initiated ponding which facilitated dissipation of the ice and controlled deposition of kame terraces, flat-topped kames, channel fillings, and blanketing sands (Qcd7) (FC, LC; Koteff, 1974) in the Gaylordsville basin (Pl. IA, Kent Profiles A-A', B-B'; K10, Pl. IV). As the melt-water outlet across the valley plug became incised, minor erosion, reworking, and deposition of materials occurred at successively lower altitudes.

Erosion surfaces and small deposits at high altitudes around the Gaylordsville basin (K10, Pl. IV) record earlier melt-water activity on the hill slopes along both sides of the Housatonic River when thicker stagnant ice dominated the basin.

North of Gaylordsville, horizontal and cross-bedded pebble and cobble gravels (Qvt8) slope southward from altitudes of 300 feet, through the narrows at Straits Rock, and extend southeastward into the New Milford quadrangle. Unit Qvt8 materials also extend northwestward into the Dover Plains quadrangle to the confluence of the Housatonic and Tenmile Rivers (DP6, Pl. VI), and thence westward along the Tenmile River. They cannot, however, be traced continuously northward along the Housatonic River through the falls stream reach near Bulls Bridge (Pl. IA, Kent Profile A-A'; DP8, Pl. VI). Surface gradients along this deposit are between 10 and 15 feet per mile. The valley-train pebble and cobble deposits overlie gray, undistorted, lacustrine silts in the northern part of the Gaylordsville basin (K10, Pl. IV). The silts are local quiet water ponding during late deposition of the older Unit Qcd7.

Many borrow pits and large gravel mining operations have exploited much of the gravel material in this basin. Exposures in older pits are severely slumped, but variations in textures and sorting can be determined. Pebble counts (App. D) are significant, because carbonate percentages increase distinctly in Unit Qcd8 commensurate with the advent of outwash deposition from the carbonate section of the Dover Plains quadrangle. Melt waters entered the Gaylordsville basin area by several routes during different stages of deglaciation and left through the Straits Rock narrows (K4, Pl. IV). During early stages of deglaciation, melt water flowing southward in the South Kent trough was partly diverted through the Mud Pond basin (K29, Pl. IV). This melt water flowed in single-walled channels along the ice and eroded the till which was forming gently sloping surfaces. This is evidenced today by terraces and terrace fragments on the hill slopes east of Pine Hill (K22, Pl. IV).

Melt waters also crossed Spooner Hill from west to east through the now abandoned, deeply incised, curved channel (K28, Pl. IV) on this ridge to enter the South Kent trough and the Gaylordsville basin (Pl. II). Another deeply cut overflow channel west of Gaylordsville (K7, Pl. IV) carried melt water while impermeable ice at the New York-Connecticut border (DP2, Pl. VI) ponded and infilled the intervening valley (LFC; Koteff, 1974). Morrissey Brook (K1, Pl. IV) directed melt water into the basin from the south, while thick ice in the Pawling quadrangle directed melt water across the uplands (P3, Pl. VI) into the brook's headwater drainage.

On the southern rim of Cedar Hill (K23, Pl. IV), 3 straightwalled melt-water channels 10 to 15 feet deep have been carved in the rock with the lowest threshold altitude at about 715 feet (Pl. II). Melt waters occupying these channels left only the channels themselves as evidence of their southward flow across this ridge. Some time later, as ice thinning continued, melt waters were diverted eastward through the col on Spooner Hill (K18, Pl. IV) at altitudes initially around 700 feet. Today, a small rock threshold on the northwest rim of this channel is more than 50 feet above the 605-foot threshold of the main channel. Till, which has no evidence of colluvial slope movement, dominates the V-shaped gorge. This channel may have formed submarginally or subglacially, and was then partly filled with till from overlying ice. It may have been subsequently excavated by continued melt water activity. Its form and size suggest, however, that it formed earlier, was partly filled with till during the last glaciation, and was re-excavated by melt-water erosion during the last deglaciation. During at least the last deglaciation, it acted as a subaerial or subglacial outflow channel while initially active ice gradually stagnated. On the west slope of Spooner Hill, north of this channel, a descending series of boulder-strewn terraces are weakly incised in till. These terraces are believed to represent melt-water drainage which was either marginal or submarginal to the containing ice lying to the west. These flat-floored terraces are either single-walled marginal channels or submarginal channels. At lower altitudes, sands and fine pebble gravels (Qcd5; Qcd6) thinly blanket the underlying terrain. West of the outflow channel entrance, a deeply incised, flat-floored, single-walled, boulder-strewn terrace extends southward toward the steep west slope of Cedar Hill. Melt water, which flowed along the west flank of Cedar Hill, occupied the channels at the southern end of Cedar Hill, and the water was directed toward the east and south. Melt waters occupying these various channels and routes first deposited, and then eroded materials in Units Qcd5 and Qcd6 (FNC, LNC; Koteff, 1974).

A short reach of the Housatonic River near Bulls Bridge (DP8, Pl. VI) is in the Dover Plains quadrangle west of the primary study area. East of the river, a series of small, fluvially smoothed rock knobs at descending altitudes northeast of Bulls Bridge, have thin sandy gravel on their flanks. West of the river, sandy pebble-cobble gravels have a surface altitude to 390 feet. Several large subangular blocks with lengths ranging from 10 to 15 feet, and numerous boulders of 1 to 2 feet in diameter are partly buried in the surface of these latter deposits. South of the falls, near Bulls Bridge (DP8, Pl. VI), the Housatonic River is confined for almost 1 mile to a narrow, vertically walled canyon cut locally more than 70 feet deep in steeply dipping Stockbridge marble. In view of the limited erosional incision in Stockbridge marbles at Great Falls (SC4, Pl. VI), the size of this canyon suggests an initial origin prior to the last glaciation. Thick till southwest of Bulls Bridge probably blocked a preglacial river channel, causing the drainage derangement which forced the Housatonic to cross and erode the Stockbridge marbles. Neither the route of the preglacial channel nor the time of derangement have been established.

The Tenmile River joins the Housatonic just south of the canyon (DP6, Pl. VI). Several abandoned fragments of higher altitude stream channels incised in rock and till on both sides of the Housatonic River show earlier routes occupied by melt water or the early Holocene Housatonic River.

Tenmile River enters the Housatonic Valley after flowing through a mile-wide, low-altitude col in the Housatonic Highlands (Fig. 10). North and south of this col, Schaghticoke Mountain and Tenmile River rise to altitudes of 700 to 1,000 feet above the river level. Bedrock has not been observed in the walls or on the floor of Tenmile River from at least the New York-Connecticut border to the mouth of Tenmile River. Smooth, molded till mantles the irregular floor of the col from Dogtail Corners (DP7, Pl. VI) eastward at altitudes of 450 feet.

A channel incised in till is about 1,500 feet east of Dogtail Corners. This channel directed waters eastward and northeastward around the flanks of Schaghticoke Mountain. Field relationships indicate the melt water moved along the west side of Schaghticoke Mountain, through Dogtail Corners (DP7, Pl. VI), and thence east and northeast towards the

Housatonic River. This erosional channel is believed to have served as a subglacial outflow channel while an ice margin receded westward from Bulls Bridge (DP8, Pl. VI).

Terrace deposits, 1 mile south of Dogtail Corners (DP7, Pl. VI), at altitudes of around 320 feet along Tenmile River, slope upstream to altitudes of around 360 feet. The terrace deposits have pebble and cobble gravels, contain shallow pits, and slope downstream to the 300-foot altitude, valley-train deposits (Qvt8) north of Gaylordsville. Low relief, structurally controlled ridges and valleys west of Dogtail Corners reflect the severe folding of the Stockbridge marble. During deglaciation, however, melt water was directed southward through each of these valley channels toward Tenmile River. Debris deposited at that time by melt waters merges with the terrace at the 360-foot altitude. All of these materials are part of the depositional sequence during a phase of the deglaciation of the Pawling-Dover Plains-Amenia valley west of the Housatonic Highlands (p. 139).

Very few ice-contact deposits are present along the Housatonic River between Bulls Bridge and the northern border of the Kent quadrangle. In addition to pebble-cobble gravels, small deposits of fine sand and gravels occur in association with rock proturberances (Qcd7; Pl. IA, Kent Profile A-A'; Pl. II). The perched, abandoned drainage channels, and the linear form of these materials indicate that control was exerted by a dissipating stagnant ice tongue. Additional debris may have been flushed southward to become incorporated with materials from Tenmile River in the deposits southeast of Bulls Bridge (DP8, Pl. VI).

Pebble gravels associated with drainage from Thayer Brook, half a mile north of Birch Hill (K35, Pl. IV), have altitudes between 400 and 420 feet. This feature lacks internal exposures but exhibits a delta morphology, with distal portions partly truncated by erosion. Its entire form is devoid of ice-contact slopes. Upper surfaces are almost level or slope gently towards the valley from an altitude of about 415 to 520 feet. Above these altitudes, the surface materials are coarse, and include subangular cobble-size fragments. The relationship of material textures and surface topography suggests that the upper part is a subaerial fan deposit.

The lack of ice-contact faces indicates a rapid ice dissipation between emplacement of Units Qcd7 and Qvt8, due in part to continued melt-water drainage through Cobble Brook and the South Kent trough, as discussed above (p. 102). Debris delivered to the Housatonic River valley from Macedonia Brook (K44, Pl. IV) was probably restricted at this time. Since few melt-water streams delivered debris to the ice surface between Bulls Bridge (DP8, Pl. VI) and

Flanders (K48, Pl. IV), the surface of stagnant ice may have been clean or only thinly mantled with debris. This condition may have caused increased rapid melting and provided very little debris for deposition of higher altitude, ice-contact features from Flanders to Bulls Bridge while through melt-water drainage continued to move along the Cobble Brook-South Kent route.

One mile northeast of Birch Hill (K35, Pl. IV), near Pine Ledges, boulders and blocks are prevalent in a deposit which has an irregular surface terrain at an altitude of approximately 450 feet. This deposit, although poorly exposed, is believed to be primarily colluvial materials combined with slide-rock which slumped on and against ice in response to steep rock slopes, a severe late glacial climate, and a lack of vegetation. Perhaps lateral streams flowing between the ice and the hill slope from Macedonia Brook (K44, Pl. IV) also contributed some debris to these deposits. The collapsed appearance of the surface, surface altitudes, and ice-contact slopes facing the valley indicate emplacement of these materials against ice earlier than the formation of the fan-delta feature discussed above (p. 115).

Horizontally stratified pebble gravels (Qvt8) dominate the materials underlying the terrace surface extending beneath the village of Kent (K42, Pl. IV). The altitude relationship of materials along this reach of the river is illustrated on Kent Section A-A' (Pl. I) and Kent Profile A-A' (Pl. IA). The underlying bedrock configuration is inferred from well and test hole logs (App. B, No. K29U, K5th, K6th, K9th) which reveal thick sands, silts, and clays at depths beneath overlying surface materials. Thick, fine-grained sediments beneath coarse gravels suggest an ice-free ponding in this valley which extended from the vicinity of Bulls Bridge northeastward through Kent and Kent Furnace. Outwash (Qvt8) prograding into this pond from the northeast buried deeper, fine-grained, lacustrine sediments (FLC; Koteff, 1974). Kame terraces (Qcd8), deposited along Macedonia Brook northwest of Kent village, are graded to the same altitude as the valley materials in the Housatonic River valley. A base level control for this lake and the deposits entering it was near Bulls Bridge (DP8, Pl. VI) at an altitude of about 400 to 410 feet (Pl. IA, Kent Profile A-A'), between 60 and 80 feet higher than the modern Housatonic River level near Bulls Bridge prior to reservoir construction.

Northwest of the village of Kent, the kame terrace deposits (Qcd8), flanking the valley slope along Macedonia Brook (K44, Pl. IV), slope southeast from an altitude of 450 feet near the hamlet of Macedonia to join deposits in the Housatonic Valley accordantly. Pits in the terraces along the northeast valley wall have weakly stratified, pebble-cobble gravels. Logs for wells in the marginal stratified deposits record gravel depths to 40 and 53 feet (App. B., No. K78W, K49W; Pl. II). Melvin (1970) reported 90 feet of sediment in the central part of this valley with interlayered, thick sand and gravel layers dominant (App. B, No. K10th). Thirteen feet of overlying gravels, including five feet of sand, comprise the capping fan and alluvial deposits at the test well locations. Dead, stagnant ice, lying in the deeper central portion of the valley, controlled lateral drainage Sediments in these deposits were derived from Macedonia Brook runoff, and from Bog Hollow Brook melt water. and deposition of the kame terrace materials. A block of stagnant ice remained in Bog Hollow (A1, Pl. VI) during deposition of the kame terraces. This block persisted until melt-water drainage through Bog Hollow from wasting of ice in the northwest was terminated. These melt waters were derived from ice in the large valley west of the Housatonic Highlands. Melt water coursing through Bog Hollow may have deposited most of its coarse material enroute, but large amounts of fine material were transported into the pond which formed as the central ice block southeast of Macedonia (K44, Pl. IV) melted. These sand and fine-gravel sediments filled the pond and were, in turn, capped with the fan gravels. Gravel knobs near the north end of Bog Hollow (A1, Pl. VI) partly restricted this valley. These knobs served as a small valley plug, north of which additional gravelly sediments were trapped. The deglaciation events in the Bog Hollow gorge are similar to those which occurred along the South Kent trough previously discussed (p. 102). Here, the elongate ice block situated in Bog Hollow persisted after through melt-water drainage ceased, and after melting formed a large kettle depression now occupied by a swamp. In the Macedonia Valley downstream, melting and concomitant melt-water deposition infilled the ice depression (FC changing to FLC; Koteff, 1974).

Glacial ice and local topography control the location and altitude of many deposits in the Housatonic River valley northeast of Kent village. The areal and vertical relationships of these deposits are indicated on Plate III, and on Ellsworth Profile A-A' (Pl. IA) and Section B-B' (Pl. IA). High-altitude deposits (Qcd1) along Wilson Road (E1, Pl. V) were discussed above (p. 96). As the ice thinned in the Housatonic Valley, small deposits at successively lower levels were emplaced on the hill flank. Deposits at lower altitudes are presumably younger. Those along Gunn Brook and Kent Falls Brook are considered correlative, and are grouped into the same units (Qcd4 through Qcd6). Correlated deposits are believed to have been emplaced by the same melt-water stream at approximately the same time. This inference is based on a lack of evidence for an active ice margin between deposits, and on the application of reasonable slope gradients determined for younger, lower deposits nearby. Older deposits (Qcd1 through Qcd3) are too high to be conveniently included on Ellsworth Profile A-A' (Pl. IA).

Along U.S. Route 7 kames, ice-channel fillings, and sheet sands to altitudes of around 620 feet (Qcd6) extend northward to the vicinity of Kent Falls State Park (E3, Pl. V). These materials are related to deposition and drainage through the Cobble Brook and South Kent trough discussed above (p. 102). Terraces immediately south of both Gunn Brook and Kent Falls Brook, are weakly eroded in till, and descend the hill slopes in a distinctive step-like configuration. Most tributaries entering the Housatonic Valley have similar descending terraces which formed as each stream adjusted its lower channel gradient to the gradually descending base level presented by thinning ice. Some terrace fragments are erosional in till; others consist of gravel or thin gravels mantling till.

Planar fragments of outwash and extensive planar outwash surfaces at low altitudes along the Housatonic River extend from north of Bulls Bridge (DP8, Pl. VI) to Cornwall Bridge (C4, Pl. VI), and continue into the Housatonic Meadows State Park (E14, Pl. V). Surface gradients along these features range from over 50 feet per mile on eroded till surfaces and channels to 7 or 8 feet per mile along low-altitude stream terraces near the modern river (Pl. IA, Kent Profile A-A'; Ellsworth Profile A-A'). Altitude differences between adjacent surfaces are frequently small and gradients tend to decrease on subjacent levels. Planar surfaces observed along the Housatonic River have been formed by five mechanisms:

1. melt-water erosion of till and bedrock surfaces;
2. ice-marginal kame terrace and kame delta deposition;
3. outwash deposition in prograding valley trains;
4. melt-water and postglacial stream terrace erosion in older material; and
5. modern Housatonic River meander migration and alluviation.

In evaluating planar surfaces to determine their genesis and significance, careful consideration has been given to valley geometry. Outwash materials in valley trains confined to narrow valleys may extend farther downstream than comparable outwash deposits associated with broad valleys or in locally broad reaches of otherwise narrow valleys. Outwash wedges grading from ice may be short, and may slope rather steeply if derived from rapidly wasting or receding ice. Outwash extending from a persistent ice position upstream can, however, extend a wedge of material at low surface gradients through and beyond older, steep wedges. The upper surface of outwash, or its dissected remnants which extend beyond the margin of the valley ice tongue, may slope either from the ice or to some local base level threshold. The wedge-shaped deposits extending from ice gradually lengthen and raise their surface levels during intervals when ice thickness and melt-water flow remain constant. Kame terrace surfaces may grade into valley-train deposits downstream or to local base levels consisting of rock or till. Downwasting causes nested or en-echelon deposition of kame terraces as successively lower base levels become available.

Kame deltas deposited into impoundments against ice form small planar surfaces. Additional small planar surfaces are remnants of extensive erosion of large kame terraces. Marginal deposition beside large, lingering, ice blocks is followed by deposition at lower altitudes. Thick ice in wide, overdeepened, rock basins melts more slowly than adjacent ice occupying narrow, shallow, valley segments on riegels. As the ice melts, these basins become sediment-trapping ponds in which fine-grained, underlying, older deposits are buried by upward-coarsening, prograding gravels.

Streams incise into earlier, thick, valley-filling deposits to form channels and terrace fragments at lower altitudes. Such fragments may record only short episodes of melt-water stream erosion which occur in response to changing stream regimes.

Kames and kettles, and several small ice-channel fillings, persisted among outwash deposits at low altitudes along the Housatonic River (Qcd8, Qcd9, Qcd10) (FC, FLC; Koteff, 1974). The underlying ice was stagnant, thin and dead during the deposition of these features. Small altitude differences between remnants of kame terraces suggest that continuous thinning of stagnant ice initiated frequent drainage changes, and caused streams to occupy successively lower altitude routes.

Kent and Ellsworth Profiles A-A' (Pl. IA) illustrate the en-echelon relationship between kame terraces and outwash materials which extend through the Kent village area in the Kent quadrangle to the northern part of the Ellsworth quadrangle. Units Qcd8 and Qcd9 have a decreasing number of fragments upstream, and finally lack traceable remnants. The upstream limit of related kame terrace and ice-contact materials in each successive unit is defined by the disappearance of the remnants. Stream deposits were emplaced both on and along the ice, but only those deposits which were emplaced against the hill slope and not subsequently eroded remain as remnants of the once-continuous, integrated stream. Kame terrace materials grade downstream into related pitted outwash and valley-train material. The relationship between deposits in Units Qcd8 and Qcd9 vaguely defines the marginal zone of the stagnant ice tongue as it wasted, thinned, and dissipated into isolated blocks.

Collapse topography north of Calhoun Corners (E8, Pl. V), and kames (Qcd8) at Millard Brook (E6, Pl. V), are believed to approximate an identifiable terminal ice zone of a stagnant ice tongue beyond which dissipating fragments and blocks of ice extended farther downstream. Coarse cobble gravels are present in this unit (Qcd8) at Calhoun Corners (E8, Pl. V), and related deposits coarsen upstream. Irregular topography (Qcd8) along Hatch Brook (E13, Pl. V) is forested and lacks internal exposures. Its morphology and surface materials support an interpretation of collapsed, ice-contact, cobble-boulder gravels.

Thinning of ice caused the margin of thicker impermeable ice to migrate upstream which initiated deposition of Unit Qcd9 material. Textural relations, including the rapid surface boulder size increase from 4 to 12 feet, indicate a terminal zone for this unit north of Cornwall Bridge (C6, Pl. VI) with the valley to the north occupied by an impermeable tongue of ice which controlled lateral deposition of kame terraces. Downstream, through Cornwall Bridge, outwash was deposited on and around isolated, dissipating ice which remained in the deeper central parts of the valley to Deep Brook.

It is inferred from slope morphology that wet, unvegetated till, south of Deep Brook, became activated and moved onto ice still occupying the main Housatonic channel during late phases of Unit Qcd8 deposition, or during the early phase of Unit Qcd9 deposition. This material armored and insulated the surface of the ice, and formed an ice-cored valley plug creating a shallow, short-lived pond on the ice and on the adjacent exposed terrain. This pond served as a temporarily higher base level for upstream drainage at altitudes between 510 and 520 feet. An erosion terrace on this dam material slopes southwestward, beginning at a 520-foot altitude about 1,000 feet northeast of Deep Brook (E13, Pl. V) and extending to around 2,000 feet south of Deep Brook. Ice in the river channel south of this dam thinned quickly, but insulated ice coring the temporary dam melted more slowly. As this core gradually melted, drainage probably shifted across the surface toward the northwest to a position over the deeper part of the valley. Kames, terraces, and till surfaces previously formed northwest of

Deep Brook were mantled with thick silt to altitudes of about 510 feet. Deposits south of Deep Brook lack this thick silt mantle. Thin, eolian, silt deposits along this valley are typically 6 to 18 inches thick, but lacustrine silts often exceed 4 feet.

The upstream end of the pond received sands at least 73 feet thick (App. B, No. S3th), and kame deltas were deposited lateral to the ice along the basin north of Calhoun Corners (E8, Pl. V). Melting of the ice core lowered the base level, and outwash gravels of Unit Qcd9 buried deeper sands and silts, filled crevasses in ice north of Deep Brook (E4, Pl. V), and extended lower altitude valley-train materials southwest toward Flanders (K47, Pl. IV). Surfaces of channel fillings and kame terraces included in this unit lack the thick silt mantle, and overlie, or are mixed with silt and sand. The surface altitude of these gravel deposits slopes consistently southwestward (Pl. IA, Ellsworth Profile A-A'), revealing the continuity of the deposition of Unit Qcd9 material after the dam at Deep Brook ceased impounding waters. Dissipating ice blocks persisted in the central parts of the overdeepened basins (Pl. I, Ellsworth Section A-A'; Pl. III) northwest of both Millard Brook (E6, Pl. V) and Calhoun Corners (E8, Pl. V). As these ice blocks melted, thick, massive sands accumulated in ponds, and were subsequently covered by prograding outwash deposits.

Deposits are not continuous through a narrow valley gap west of Flanders. Units Qcd8 and Qvt8 in the Kent quadrangle, therefore, may not correlate precisely with Qcd8 units in the Ellsworth quadrangle. The valley-train materials through the Kent village basin may, in part, be composed of materials which correlate best with Units Qcd9 and Qvt9 in the Ellsworth quadrangle. This possible relationship of units is illustrated in the Kent and Ellsworth Profiles A-A' (Pl. IA).

Unit Qcd10 also repeats the pattern of deposition of related outwash features extending through a marginal stagnation zone, but a terminal zone of impermeable ice is not found within the primary study area. This unit is chiefly defined on the vertical relationship of deposits. An interpretation that it represents a distinct, late, thinning phase of Qcd9 is rejected, however, because deposition of nearly horizontal cobble-pebble gravel in Unit Qcd10 on dissipating ice blocks at Cornwall Bridge requires a somewhat later time of deposition than the higher altitude, adjacent deposits in Unit Qcd9. Several 4 to 6 foot, subrounded boulders are included in sands underlying imbricated gravels of Unit Qcd10 at Cornwall Bridge (C4, Pl. VI). Boulders observed were either dropped or slipped from floating ice, as shown by their inclusion within the upper part of the thick, massive sands.

A linear ridge trends normal to the valley at Cornwall Bridge (C4, Pl. VI), and consists primarily of boulders with longest axes ranging from 4 to 8 feet. Sand and gravel are found only interstitially. This coarse-textured ridge is interpreted as an ice-channel filling (Warren, 1970 personal communication), and correlates with the Qcd9 materials in the Ellsworth quadrangle.

A channel near the mouth of Guinea Brook (E10, Pl. V) has a flat, boulder-strewn floor, suggesting a possible semi-marginal melt-water channel origin for this feature. It descends steeply, however, at a gradient of 250 feet per mile. Deposits at its base consist of sandy, pebble-cobble gravels (Qcd9) with a low surface gradient. The contact of these materials with the channel occurs at a distinct break-in-slope, indicating that the planar surface terrace is unrelated to this channel. The channel is, therefore, interpreted to be a subglacial chute which directed melt waters to lower, englacial, and subglacial routes prior to the the Qcd9 phase.

Northward, from 1 mile northwest of Cornwall Bridge, the Housatonic River is confined to a narrow valley in the granitic gneiss of the Housatonic Highlands. Fragments of kame terraces, kames, and stream terraces (Qcd9, Qcd10) are at successively lower levels along this valley. Good examples may be found in Housatonic Meadows State Park (E14, Pl. V). Similar fragments have been identified farther north (Warren, in press; Holmes and others, 1971). Eroded channels, in and against bedrock spurs near the north end of the park, have related gravel deposits. These features collectively reflect the combined control of marginal drainage by a narrow tongue of ice, partially filling the valley, and by the adjacent rock and till proturberances.

In the adjacent, secondary study area, a knob-and-kettle valley plug extends northward for approximately 2 miles in the narrow Housatonic River valley north of the Tarradiddle (SC1, Pl. VI). These valley-plug deposits begin approximately 2 miles northeast of the northern boundary of the Housatonic Meadows State Park (E14, Pl. V). Materials consist of contorted, stratified, pebble-boulder gravels, and till. The hummocky surface morphology and exposed materials observed in pits during reconnaissance suggest that these deposits were formed by the retreat of an active ice margin from this northern part of the narrow Housatonic Valley. Detailed investigation (Newman, 1970 personal communication) supports this conclusion. Drainage channels and planar surfaces in the collapsed terrain are fragmentary, and gradients, where defined, are often steep. Shear planes in the margin of the active ice delivered till to the ice surface where it was partly mixed with fluvial materials by melt water and deposited on thin, stagnant ice distal to the active ice. Based on the internal, contorted configurations observed, this till may have been emplaced as flowtill (Hartshorn, 1958), or may have become contorted along with stratified units as underlying ice melted. Outwash materials were deposited downstream as kame terraces against thinning, stagnant ice south of the gradually receding active ice margin.

Recession of the active ice northward caused ponding to an altitude of 600 feet in the fosse behind the valley plug. This pond trapped sediments, including those in a delta on which the Lime Rock Race Track (S4, Pl. VI) is now built. The valley-plug material was eventually truncated, and outwash materials incised by melt-water and postglacial streams formed low-altitude stream terraces. Gradients along the stream terraces approximate the gradient of the modern Housatonic River, but occur from 5 to 10 feet above modern, alluviated, flood-plain surfaces.

Housatonic Highlands

The broad Housatonic Highlands ridge (Fig. 9, Sub-area 7), west of the Housatonic River, rises steeply from the river level to altitudes which provide more than 1,000 feet of local relief. With few exceptions, highest surface altitudes along this ridge tend to rise northward. Broad and narrow cols through this ridge provide access between adjoining valleys. Figure 10 shows a generalized view of the surface configuration along this ridge from west of Gaylordsville (K10, Pl. IV) northward to the Taconic Range north of Lakeville (S5, Pl. VI), and delineates potential cols through which ice and melt water had access to the Housatonic Valley from the west.

Many erosional and depositional features along the ridge are separated areally and vertically to an extent which prohibits correlation. Several significant aspects of deglaciation, however, are evident and will be briefly considered.

High-altitude drainage channels cross the ridge near Leather Hill (DP3, Pl. VI), 1.25 miles southeast of Webatuck (DP5, Pl. VI), and ice-contact deposits flank the hill slopes beyond. Ice, with surface altitudes between 800 and 875 feet, pressed against the north and west slopes of Leather Hill, and melt water cut subaerial outflow channels on the upland rock and till as it crossed the ridge to enter steeply descending subaerial or subglacial chutes. These chutes terminated at or in lower altitude ice southwest of the ridge.

The melt water, which deposited the kame terraces on the hill slope southwest of Leather Hill at altitudes of 650 feet, was unable to escape southward. The lowest channel threshold for melt-water escape to the south is 195 feet higher, at an 845-foot altitude (P2, Pl. VI), and could not have served as the base level for the lower altitude deposits. Significantly, and outflow channel on the ridge east of Deuel Hollow Brook (DP1, Pl. VI) valley served as the controlling base level until subsequent ice thinning established drainage farther north. At lower altitudes, coarse, sandy, bouldery, ice-contact deposits drape underlying rock knobs west of the New York-Connecticut border along U.S. Route 55 (DP2, Pl. VI).

An ice-contact slope has more than 70 feet of relief east of the state border (DP2, Pl. VI), along State Route 55. The surface slopes gently eastward to an incised notch (K7, Pl. IV) west of Gaylordsville now occupied by the Wimisink Brook. This outwash clearly indicates an ice-marginal face from which sediments graded and completely infilled the intervening proglacial pond to the level of the overflow channel (LFC; Koteff, 1974). No evidence for an outwash fan is found extending into the Gaylordsville basin from this overflow channel. Melt-water flow across the ice and outwash, from the ice west of the state line (DP2, Pl.

VI), suddenly terminated when drainage returned to the Tenmile River route 1-1/2 miles farther north.

Deglaciation features on the Housatonic Highlands ridge are dominated by erosional forms. Plates II and III indicate many drainage channels which were once part of an integrated fluvial drainage system which flowed on impermeable ice and exposed parts of the upland. Many upland channels southwest of Kent village (K42, Pl. IV) have linear orientation due to the underlying structual controls. In the Ellsworth quadrangle (Pl. III), channels incised in till as well as in bedrock tend to cross structural elements.

Guinea Brook (E10, Pl. V) and its tributaries directed melt waters from the uplands towards the Housatonic Valley prior to the exposure of the upper reaches of Macedonia Brook (E2, Pl. V). Macedonia Brook later provided an available escape route for melt waters from thick ice northwest of the highlands after Guinea Brook and other routes across the highlands were abandoned.

Coarse, hummocky deposits to altitudes of 700 feet west of Macedonia Brook (E2, Pl. V) near its confluence with Pond Mountain Brook (Pl. III), consist of poorly sorted, ice-contact, pebble-cobble gravels. These materials were delivered to the surface of thinning ice occupying the lower reaches of Macedonia Brook by melt water and runoff from higher altitudes on the Housatonic Highland. This event predates deposition of Qcd8 terraces southeast of the hamlet of Macedonia. Ice-contact deposits thinly mantle underlying rock and till surfaces south of West Woods (E9, Pl. V). Deposition on and against stagnating, isolated ice blocks occurred here as melt water flowed southward against flanks of the highlands southwest of Ford Pond and Bog Meadow Pond (E15, Pl. V). Maintenance of this drainage required the presence of impermeable ice northwest of the highlands.

Numerous bogs and fens are scattered on the upland surface throughout this region. Some occupy abandoned melt-water channels; others have developed in basins in rock and till. Some contain only a thin deposit of postglacial organic material; others have deposits several feet thick.

Gross' bog (E7, Pl. V), at an altitude of 1,080 feet on the northwest flank of the Housatonic Highlands, has deposits exceeding 24 feet in thickness. organic material, 18 feet thick overlies, 6 feet of gray silt and clay with interbedded layers of black, organic-rich bands. Preliminary results of pollen analysis shows a high concentration of spruce pollen (*Picea*) in lower peat samples 6 inches above the interface with underlying silts and clays. A sample collected at the interface has a radiocarbon age of 12,750 ± 230 B.P. (RL-245). Comparison of this date with other bogs in Connecticut and New York

(Davis, 1958; 1969; Connally and Sirkin, 1970) indicates the material at the interface may be in the upper part of the herb zone (Pollen Zone T). If this is correct, the boundary between the Pollen Zones T and A4 is presumably in the 6 inch interval between the level of spruce pollen concentration and the dated material. The duration of deposition of silts and organic material prior to the level dated has not been ascertained. Only a minimum age can be inferred from this material for the time of deglaciation of this upland ridge.

A high-altitude ice-contact deposit west of South Ellsworth (Pl. III; E11, Pl. V) consists of poorly sorted, sandy, pebble-cobble gravel. A large angular rock protrudes from bouldery, fluvial gravel in the depression along State Route 4, 1.25 miles east of South Ellsworth (Pl. III). Several abandoned melt-water channels and three active tributaries merge at this site. Torrential runoff or melt waters crossing the divide delivered coarse boulder materials to this basin after stagnating ice emplaced the large angular fragment. The tributary to Guinea Brook, extending northward parallel to East Street Road (E12, Pl. V), is underfit for the channel incised in till and stratified material (Qcd). Boulders and cobbles from the original materials form a lag deposit armoring most of the channel floor.

Small deposits along Carse Brook (PL. III; E16, PL. V) record the movement of melt water through this trough from the northwest. Materials decrease in size toward the southeast from coarse, cobble-boulder gravels to pebble-cobble gravels. Gently sloping kame terraces indicate the presence of thin ice during deposition. At Tan Fat Hill (S1, Pl. VI), southwest of Carse Brook, tills and stratified drift at altitudes of 1,150 feet are intermixed in a narrow zone about a half mile wide. These morainal deposits formed at the margin of active ice which was pressing against the Housatonic Highlands from the northwest. The valley east of Red Mountain (S2, Pl. VI) has prominant, cross-valley till ridges at descending altitudes along the valley toward the northeast. These ridges consist of thickened till, probably formed at active, ice-marginal, stillstand positions during ice retreat.

The Sharon Area

South of the village of Sharon (Fig. 9, Sub-area 8), a well log in the northwest part of the primary study area (Pl. III) indicates that thick till underlies an undulatory, terrace-like shelf adjacent to the Housatonic Highlands (App. B, No. S11W). Abandoned tributary channels cross this shelf and join a large channel which directed melt water southwest along the flank of the Housatonic Highlands. Hatch Pond (E17, Pl. V) is artificially impounded in this channel and Mill Brook, flowing to the southwest, is an underfit stream (Pl. IA, Ellsworth Profile C-C'). Bedrock is exposed only on the southeast side of the channel, but till is dominant elsewhere. Minor accumulations of sand and gravel occur infrequently along its abandoned stream banks. This is the main channel of a branching system which collected melt waters from several miles of an ice front. The glacial ice lay to the north and northwest. The main channel, incised in till, begins abruptly at a 900-foot altitude above Beeslich Pond (S3, Pl. VI) near the central part of the Sharon quadrangle area. The channel extends southwestward through Beardsley Pond to the village of Sharon along Beardsley Pond Brook, thence south and southwestward through Hatch Pond and Mill Brook to the hamlet of Amenia Union. The intermittent nature of this channel indicates the presence of ice in depressions across which melt-waters flowed. Taylor (1903) believed this channel defined the interlobate margin which developed between ice flowing southward along adjacent sides of the Mount Washington Range of the Taconic Mountains located to the north.

Several "hanging" tributary channels, now abandoned, directed melt water from ice to the main channel (Pl. IA, Ellsworth Profile C-C'). One tributary has a reversed gradient caused by escaping melt water flowing partly in submarginal channels under hydrostatic pressure. These are subglacial outflow channels. Water flow terminated in the hanging tributaries before flow terminated in the main channel, permitting the main channel to erode 20 to 30 feet below the mouth of each tributary. Taylor (1903) concluded that thick till associated with these melt-water channels was deposited at an active ice margin as part of either a lateral or terminal moraine. This is accepted in this study.

Channels and erosionally washed till surfaces at higher altitudes on the Housatonic Highlands east and southeast of the main Sharon drainage channel are evidence of older melt-water activity. Each feature records relatively brief intervals of melt-water flow as the active ice margin gradually descended the hill slopes in response to factors of ablation. Deglaciation of the Sharon area (Pl. III) is only one part of a complex sequence of deglaciation events which evolved through several miles in the large valley west of the Housatonic Highlands. This relationship is indicated on page 146.

Valley West of the Housatonic Highlands

Features significant for the interpretation of regional deglaciation have been reconnoitered from southwest of the primary study area northward for approximately 40 miles in the valley west of the Housatonic Highlands (Fig. 9, Sub-area 9). The location, altitude, and areal extent of gravel plains, gravel fans, and collapse sediments indicate that a definable sequence of events evolved in this valley during late phases of deglaciation.

First, waning, weakly active ice delivered entrained debris to its active ice margin and to the surface of thin, distal, stagnant ice. Second, active ice-marginal positions successively formed from 3 to 5 miles behind previously active positions. Ice remnants, drainage thresholds, and ponded waters, distal to each active position, controlled outwash deposition. Third, ice-margin recession and dissipation of isolated remnant ice opened new drainage channels, established lower base levels for ponds, and caused concomitant changes to lower altitude deposition of outwash fans and plains. Fourth, isostatic rebound elevated northerly deposits and channels relative to southern deposits and drainage thresholds.

Southwest of the primary study area, south of Pawling, New York (P1, Pl. VI), irregular knob-and-kettle topography

3 miles wide has intermixed till and contorted stratified gravel deposited in an active ice-marginal zone. Large swamps and outwash gravels north and south of the knob-and-kettle accumulation provide evidence of thin, dissipating ice during late phases of through melt-water drainage.

Most of the valley is underlain by folded and differentially eroded carbonate rocks of the Stockbridge formation, but zones of irregular topography east of Dover Furnace and 1 mile southeast of Dover Plains consist at least partly of collapse sediments. Flat-floored, lateral, melt-water channels flank these deposits and can be readily discerned on aerial photographs and 7-1/2 minute topographic maps. Areal relationships indicate that some were subaerial outflow channels and others were semi-marginal channels. The collapse sediments are interpreted as having formed in the zone between the stillstand margins of weakly active ice and the adjacent stagnant ice.

Outwash deposits form flat to gently undulating plains and gently sloping fans. Ice-contact slopes are evident along the margins of many plains, indicating their deposition around large, stagnant, dissipating ice blocks. Flat or undulatory surfaces usually slope to specific rock or drainage-channel thresholds. The large gravel plains in this valley were formed by extensive infilling of shallow ponds around ice while temporary base levels were maintained at overflow channels. Ice thinning opened new drainage routes and melt-water erosion lowered base levels, permitting outwash plain deposition to terminate on one level and continue at a lower level.

Swamps and planar outwash surfaces dominate the deposits in the valley north of Wingdale (DP4, Pl. VI), and modern drainage through this region is sluggish. Outwash plains west of Wingdale contain horizontally stratified and cross-bedded material ranging from sand to pebble-cobble gravel with surface altitudes of approximately 500 feet. Two planar surfaces are evident near Dover Furnace to the north, one between 480 and 490 feet, and the second between 450 and 460 feet. Farther north, near Dover Plains, surfaces at 400-foot altitudes prevail. These variations in surface altitude are attributed to uncovering of lower thresholds as ice thinned. Deposition of materials higher than 450 feet between Dover Plains and Pawling was controlled by base level changes within the knob-and-kettle materials at Pawling (P1, Pl. VI).

Outwash fans demonstrate the occasional upstream control of sediment deposition by melt water in this valley in contrast to the downstream base level control exhibited by horizontal and cross-bedded gravel plains. Two variations are present here. The first fan type, deposited by melt water directly from ice, is exemplified near Oniontown

(DP10, Pl. VI) where a fan slopes southward which formed directly from ice at Dover Plains (DP11, Pl. VI) (FC; Koteff, 1974). The second fan type, outwash grading to a base level beyond which materials extend as a fan, is apparent near Leedsville (A2, Pl. VI), where melt-water deposits slope to a threshold (FC or LFC; Koteff, 1974) in an overflow channel beyond which sediments accumulated as an expanding fan (FNC; Koteff, 1974). Infilling of any intervening pond is required before initiation of fan deposition.

A low-gradient, modern, alluvial fan 2 miles south of Pawling (P1, Pl. VI) extends into The Great Swamp, and consists chiefly of Late Wisconsin or Holocene-age materials deposited by runoff from Brady Brook. Several gravel knobs in the fan reflect earlier outwash deposition on ice when the lower part of Brady Brook served as a semi-marginal, melt-water channel lateral to the knob-and-kettle deposits. Similar alluvial fans enter the valley from other tributaries.

Streams entering this main valley display a series of step-like erosional and depositional terraces similar to the step terraces on tributaries along the Housatonic River (p. 120). Each stream adjusted its gradient to an adjacent descending base level. The elusive base level in this valley was the thinning ice, a marginal melt-water stream, or the ponds in which gravel plains developed.

Today, a narrow, melt-water overflow channel at Pawling contains a swamp and has a threshold altitude of 435 feet. This channel crosses the modern drainage divide between the north-flowing Swamp River, tributary to the Housatonic River drainage system, and the south-flowing East Branch Croton River, tributary to the Hudson River drainage system (Fig. 2). Melt-water flow through the divide channel may have been initiated by melting of an ice core in the knob-and-kettle, valley-plug deposit, or it may have been initiated as headward sapping by percolating pond waters.

Melt water from receding and wasting ice generally drained along each side of the valley in lateral channels. Drainage along the east side of the valley followed the flanks of the Housatonic Highlands toward the col at Dogtail Corners (DP7, Pl. VI), and was later directed toward Bog Hollow (A1, Pl. VI).

Melt-water drainage along the west side of the ice-blocked valley south of Dover Plains (DP11, Pl. VI) continued to move southward through Pawling (P1, Pl. VI) until lower drainage routes north of Pawling opened toward Gaylordsville (K10, Pl. IV) and Bulls Bridge (DP8, Pl. VI). Potential drainage routes to the east are found at positions which are 7, 9-1/2, and 11 miles north of Pawling. At

Webatuck (DP5, Pl. VI), the threshold altitude is 465 feet. The next threshold, near Dover Furnace (DP9, Pl. VI), is at 415 feet, and the third threshold is the free, modern drainage route 1-1/2 miles farther north near the confluence of the Swamp and Tenmile Rivers.

A flat-floored feature, oriented toward the south, has a threshold altitude of about 465 feet in the village of Webatuck (DP5, Pl. VI). This feature is about 7 miles north of the Pawling divide, and is the first low-altitude route for possible eastward melt-water drainage into the Housatonic River valley. Its threshold altitude is too high to redirect melt-water drainage from its southward route through Pawling. In addition, a broad, flat-topped kame or kame delta is situated in the southern part of the channel. This feature has surface altitudes of 490 feet, which correspond to kame terrace fragments on the hill slope 1,000 feet farther south. Comparable surface altitudes occur on outwash plains west of Wingdale (DP4, Pl. VI), and on other kame terrace deposits that extend southward towards Pawling.

Internally, the kame near Webatuck has contorted strata of sands and fine pebble gravels, but erosional evidence is absent along the flanks of this kame. It is speculated that the flat-floored Webatuck feature was not a major melt-water drainage route, although it may have served briefly as a submarginal channel directing melt water to the south, after which stagnant ice controlled emplacement of the kame materials.

On the low ridge between Dover Furnace (DP9, Pl. VI) and the Tenmile River, cross-ridge channels which trend west-to-east served briefly as overflow drainage, while ice to the north blocked the modern, free drainage routes. One channel has a threshold of 415 feet, and is the lowest level, abandoned, melt-water drainage route north of the 465-foot threshold of the flat-floored feature near Webatuck. Materials situated 1/2 to 1-1/2 miles north of Dover Furnace appear to correlate with the 415-foot channel.

The valley from Wassic and South Amenia northward to Millerton bifurcates into two smaller valleys with a series of ridges between them. Till-mantled Stockbridge marble east of State Route 41, between South Amenia and Amenia Union, forms parallel strips which partly reflect underlying structural control and partly reflect melt-water erosion. Till, deposited on differentially weathered marble ridges, which trend northeast-to-southwest retained the underlying, gently furrowed configuration of the ridges. Melt water used the minor surface alignments successively for drainage, and brief erosional episodes accentuated each furrow as channels were successively occupied and abandoned by melt waters.

Ice thinning terminated active, marginal, melt-water flow along the base of the Housatonic Highland ridge through the Sharon, Connecticut region (p. 136), and new active marginal positions up-ice became loci of till thickening and distal ice stagnation. Taylor (1903) indicated that successive stillstands of active marginal positions farther north were located:

1. near Indian Lake (M2, Pl. VI);
2. about 2 miles north of Millerton (M3, Pl. VI);
3. at Boston Corners (Co2, Pl. VII);
4. at Copake Furnace, probably the site of the village of Copake Falls (Co3, Pl. VII) today; and
5. at Hillsdale (H1, Pl. VII).

Recent reconnaissance indicates that:

1. the positions indicated by Taylor (1903) are valid;
2. materials in these features change from dominantly till near Sharon to to increased amounts of stratified drift at successive locations northward; and

3. features in small valleys to the west, not included by Taylor, may correlate with his marginal features in this valley and perhaps east and northeast in Massachusetts.

Webatuck Creek is a tributary to Tenmile River. Its drainage was blocked or deranged by till and other deposits near Coleman Station (M1, Pl. VI), and south of Millerton (M3, Pl. VI). This stream is underfit for the till gorges to which it is confined today. The north-flowing Naster Kill is also underfit for its channel at Boston Corners (Co2, Pl. VII). Drainage from Whitehouse Crossing (Co1, Pl. VII), northward by the Naster Kill, ultimately moves westward to the Hudson River (Fig. 2). This route was blocked by ice as the ice margin retreated from Sharon northward, and the blockage forced melt water to flow southward through Boston Corners, Millerton, and the till ridge east of Coleman Station. This southward-flowing melt water excavated the channels in the ridges as the ice margin retreated approximately 15 miles northward. Delta foreset beds dip steeply southward near Whitehouse Crossing and Boston Corners. These beds are evidence of kame delta deposition in local ponds between the active ice and the valley-plugging till and the drift ridges.

Narrow outflow and overflow channels and related fluvial deposits define drainage across Silver Mountain, the north-to-south upland ridge west of Sharon, Millerton, and Boston Corners. Drainage toward the southeast persisted until drainage routes to the southwest and west became ice free. An overflow channel west of Millerton has ice-contact deposits grading to a threshold of 1,000 feet. Fan deposits, 2 miles southeast of the threshold, extend from the mouth of this channel at a 650-foot altitude. Vertical differences of 175 feet per mile between ice-surface altitudes on adjacent sides of this ridge support an active ice-marginal recession rather than regional stagnation in this area.

Discussion and Interpretation

The preponderance of evidence presented in this chapter has been related to stagnant ice features. This tends to support concepts of either regional or marginal zone stagnation as the operative mode of deglaciation in this region. Specific features in the primary study area, however, require active or weakly active ice. Notable features include those found southeast of the East Aspetuck River valley, at Spooner Hill (K28, Pl. IV) east of Bulls

Bridge, on the uplands near East Kent (K46, Pl. IV), and flanking the Housatonic Highlands near Sharon. Additional active ice-marginal features are located in the secondary study area at Pawling (P1, Pl. VI), Dover Furnace (DP9, Pl. VI), Dover Plains (DP11, Pl. VI), Tan Fat Hill (S1, Pl. VI) east of Sharon, in the Housatonic River gorge north of the Tarradiddle (SC1, Pl. VI), on Silver Mountain west of Millerton (M3, Pl. VI), and north of Sharon at the sites previously defined by Taylor (1903).

Deposition of active or stagnant ice features is contingent upon the regime of local ice. Maintenance of active ice near the margin causes steepening of the surface gradient in response to unbalanced, directed forces. Movement occurs when the directed forces are sufficient to overcome the elements of flow resistance. Increased resistance to flow develops in narrow valleys due to the interaction of ice with the valley walls and the valley floor. This resistance further steepens the ice surface gradient at the ice terminus.

Ice becomes stagnant as the general ice flow slows and stops, after which wasting and thinning of the ice and internal adjustments in response to gravity cause the ice surface to become nearly horizontal, or to assume a low-angle gradient. This low-gradient surface is retained until hills and ridges emerge through the ice surface as nunataks.

hall local changes in gradient are then caused by variations in the effects of absorbed and reflected insolation, and local insulation of underlying ice by accumulated rock debris derived from exposed upland surfaces. Stagnant ice on opposite sides of each ridge wastes and thins at approximately equal rates, and maintains comparable but disconnected ice-surface altitudes.

Active and stagnant ice features within the same region are compatible. Active ice retreat from valleys which are oriented parallel to the direction of glacial ice flow can strand remnants of thin ice which become buried beneath outwash near active ice-marginal stillstand positions (Flint, 1942; Demorest, 1942; Rich, 1943; White, 1947; Cadwell, 1972). Active ice, moving perpendicular or transverse to ridges, may be cut off when ablation reduces ice thickness below a critical value, thus stranding distal ice and initiating stagnation. Surface gradients are steep near the margin of active ice, but rapidly become lower on the stagnant ice nearby (Nye, 1952). The effective "working surface" for active ice recession across successive upland ridges is the plane which approximates the average altitude of the upland. Stagnant ice in valleys beyond the active ice margin becomes isolated. It then wastes and thins, while ice conveyed to the ridge crest maintains its surface altitude. Differences which develop between the ice surface altitudes are today revealed by erosional and depositional features. The difference altitude of ice surfaces across ridges can be used as a specific criterion to delineate active ice flow during deglaciation. Applied to the study area, altitude differences have been determined at Wilson Road (K49, Pl. IV; E1, Pl. V) near East Kent, on Spooner Hill (K28, Pl. IV), in Mohawk State Forest (C3, Pl. VII), and at Tan Fat Hill (S1, Pl. VI) east of Sharon. Drainage patterns on the ridge southeast of the East Aspetuck River and on Silver Mountain west of Millerton also suggest significant ice-surface altitude differences.

Depositional features related to halts of the active ice margin occur in this upland region. In suitable locations, ice flow was maintained when the active ice margin gradually receded down the northwest-facing hill slopes. Erosional and depositional features were formed in this manner along the northwest side of the Housatonic Highlands. The east wall of the Housatonic River valley, however, in the lee shadow zone of the Housatonic Highlands, has evidence of a low-gradient, stagnant, ice margin. This is shown by the slope of planar erosional and depositional segments along the hill flank. The higher Housatonic Highlands terminated active ice flow into the Housatonic River valley, and isolated a thick ice tongue that extended throughout most of this valley in the study area. Ice flow through the low-altitude Dogtail Corners (DP7, Pl. VI) col west of Bulls Bridge was not restricted immediately, and active ice moved into the Housatonic Valley and areas beyond toward the east and southeast. The weakly active ice margin receded rapidly westward towards the col as the ice thinned during late stages of deglaciation. Melt-water erosional features at Spooner Hill (K28, Pl. IV) indicate a difference between ice surfaces of 100 to 150 feet. This disparity is best explained by the maintenance of active ice on the west slope of Spooner Hill, while stagnant ice wasted on the east side of the hill.

Evidence in this study area supports the concept of specific mechanisms as causes for stranding and ice stagnation. Fundamentally, each mechanism requires the thinning of ice below a critical thickness requisite for ice flow. The transition from active ice to stagnant ice on uplands transverse to flow was initiated by the underlying topography. Resistance to ice flow afforded by the restricting sides of cols and narrow troughs became increasingly significant, and finally critical, as the active ice continued to thin. Simple, rapid downwasting at rates exceeding backwasting reduced ice thickness in broad valleys below a critical thickness required for ice flow, forming stagnant ice sheets too weak to be pushed by the still-active ice upstream.

Thinning and melt water activity reworked, sorted, and concentrated rock debris as ice became stagnant, remnant ice ultimately controlled the position and deposition of the ice-contact deposits evident today. Most fine material trapped in an ice block is flushed away by melt water released from that ice and deposited elsewhere. Deposits of medium and fine sediment indicate that through-flowing melt water was maintained during their deposition. Slope and stream runoff from unvegetated hillsides also contributed significant amounts of sediments to small restricted basins.

Estimating the width of a stagnation zone requires data concerning initial ice thickness as stagnation begins, and the difference in altitude which develops between the stagnant and active ice surfaces. Local relief approximates the thickness of the stagnant ice. Altitude differences between active and stagnant ice have been estimated across some ridges in the study area. These estimates range from 90 feet per mile across the low-altitude ridges at Spooner Hill (K28, Pl. IV), to approximately 210 feet per mile across the high-altitude ridges near Wilson Road (K49, Pl. IV; E1, Pl. V). Since the maximum relief in the primary study area is 1,300 feet, a stagnation zone between 6-1/2 and 14-1/2 miles in width may have existed in this region. This is consistent with deposits in the Unit Qcd1 near Wilson Road (K35, K36, Pl. IV), at the north and south ends of Kent Hollow (K17, K22, Pl. IV), and along the East Aspetuck River (K13, Pl. IV), all of which are believed to have been deposited by a melt-water stream controlled by low-gradient, stagnant ice.

In the absence of superposed "upper" and "lower" till, interpreting multiple glaciations requires consideration of several lines of evidence In a subsequent investigation of an anomalous, modern stream channel configuration observed by the writer along the Housatonic south of West Cornwall (C10, Pl. VI), Mr. Charles Warren concluded that the Housatonic River drainage had been deranged by thick, compact till filling a preglacial channel (Warren, 1971).

Today the river flows through a short, rock-walled gorge eroded 110 feet into the resistant, granitic rocks of the Housatonic Highlands. Most stream water flowing through this gorge also flows over Great Falls (SC4, Pl. VI). The falls are formed on weak, easily eroded Stockbridge marble, and erosion has cut only 15 to 20 feet into the marble. Although an active ice margin developed between these two sites (p. 129), the difference in the total discharge through each of these stream reaches during Late Wisconsin and Holocene times is insufficient to account for this large discrepancy in erosional incision. Development of the gorge required greater erosional activity than the erosion required for the minor incision at Great Falls (SC4, Pl.

VI). Warren (1971) also found one tributary at the gorge with an oversteepened gradient and an anomalous confluence angle with the Housatonic River. From the areal relationships of these data, Warren concluded that at least two glacial and three interglacial intervals were required to produce the modern-day diversions at this place on the Housatonic River. This time duration would also be consistent with the erosion of the mile-long canyon at Bulls Bridge (DP8, Pl. VI).

Several, now abandoned, upland melt-water channels in the primary study area appear to be anomalous. Some are exceptionally deep, and others have peculiar entrances. Field relationships suggest multiple melt-water occupancy. Channels situated in low cols makes them prime areas for modification during glaciations, and for re-occupancy by melt waters during subsequent deglaciations. Associated with the East Kent channel, and paralleling its direction, are a series of rock-floored shelves, which are erosional features not specifically controlled by underlying rock structure. Fine glacial striations are retained on these shelves, which indicate that streams did not erode them after the ice melted. South of State Route 341, these shelves are directed toward a deeply incised fluvial channel. Melt water crossing the East Kent channel threshold was diverted westward, and entered this deeper fluvial channel anomalously. A possible preglacial origin for the fluvial channel is inferred from these relationships, which further supports the concept of multiple glaciation in this region.

Comparable drainage anomalies have been observed by Warren (1970 personal communication) in the upper reaches of the melt-water drainage channels in the Mohawk State Forest (C3, Pl. VI), and in The Ballyhack (C9, Pl. VI), north of the village of Cornall. Multiple drainage cycles also help explain the observed channel configurations at these locations. The initial channel formation, and subsequent re-occupancy by melt water in some channels, requires at least two ice recessions during which comparable ice-marginal orientations prevailed.

Till in the channel at New Preston (NP1, Pl. VI) may have been emplaced after the channel was initially formed. Subglacial and hydrostatic pressure channels eroded beneath active ice may have subsequently received till deposition during melt water quiescence or changing glacial ice regimes. Prolonged erosion was required to produce the vertical walls, and the extent of rock excavation, in the New Preston channel. This channel is the lowest route available for drainage from Lake Waramaug and drainage, once established, has probably been maintained without interruption. The presence of till in this channel, therefore, supports the concept of multiple glaciations and a re-excavation of preglacial channels by melt water.

CHAPTER V

HISTORY AND CHRONOLOGY OF DEGLACIATION

Introduction

A combination of backwasting and downwasting of ice toward the northwest in the study area initiated deglaciation. The receding margin of weakly active ice came to a stillstand on the low ridge southeast of the East Aspetuck River valley. Ice farther southeast stagnated and thinned while till continued to thicken on the ridge. Melt water issuing from the ice incised drainage channels on the southeast slope. Continued ablation resulted in ice which was too thin to maintain ice flow across the upland ridge southeast of the Housatonic River valley. Stagnant ice southeast of that ridge downwasted about 400 feet before the active ice margin shifted to the crest of the Housatonic Highlands, initiating stagnation in the Housatonic River valley (Fig. 5). At that time, the stagnation zone presumably consisted of thick ice in the Housatonic River valley, thinner ice in the semi-isolated basin area, and disintegrating remnants in the East Aspetuck River valley. Active ice flow probably continued briefly through cols, chiefly at Bulls Bridge and near Lakeville (Fig. 10), after ice flow across the Housatonic Highlands terminated. Minor flow was presumably maintained through the narrow Bog Hollow-Macedonia Brook pass. Ice flow through cols was responsible for local thickening of ice and diversion of melt water into the South Kent trough-Cobble Brook Valley area near the village of Kent. Thick, weakly active ice flow was maintained briefly southeast of Bulls Bridge to the Bear Hill-Mount Tom area. The margin of this active ice rapidly shifted northwest and west as ice thinned and backwasted toward Bulls Bridge. Brief episodes of ice-marginal activity during this retreat are recorded by the linear boulder concentrations and associated melt-water drainage features present between the Bear Hill-Mount Tom area and the Bulls Bridge area (Pl. II).

Although the Housatonic Highlands restricted ice flow into the Housatonic River valley, a stillstand of the active ice margin at high altitudes on the ridge cannot be defined. Impermeable ice against the west slope of the highlands forced drainage across the uplands into Guinea Brook and Macedonia Brook. At lower altitudes, a stillstand is recorded by deposits at Tan Fat Hill. Southeast of Sharon, thick till and related marginal drainage define the last active ice position northwest of the highlands in the primary study area.

Ice flow directional indicators on the upland show that Late Wisconsin active ice flow was transverse to the axes of the ridges that extend from Bulls Bridge northeastward beyond the study area. The axial trends of the ridges are about N.35-40°E. The angular relationship of 30°±10° between the ridges and a northeast-trending ice margin was responsible for short active ice tongues protruding southward into intervening valleys.

A gradual rise in the altitudes along the upland ridge crest toward the northeast was exceeded by the rise in the altitudes on the ice surface to the northeast. The ice-surface slope toward the northeast, however, was less steep than the ice surface slope directly up-ice to the northwest. The relationship between ice and topography permitted some high-altitude rock prominences to become hinge points around which active ice flow diverged. Restriction of ice flow across ridges was not synchronous during deglaciation; specifically, the termination of glacier flow progressed from southwest to northeast along each ridge. Active ice in the northern part of the Ellsworth quadrangle continued briefly to overtop the Housatonic Highlands after flow terminated across the highlands farther southwest. This ice flow maintained thick ice in the Housatonic River valley. Minor, continuous or sporadic downwasting or other recessional activity by the glacier northwest of the ghlands produced major changes in the regime of the ice tongues projecting down valleys oriented transverse to the ice margin but nearly normal to the ice flow.

The recession of ice down the west slope of the Housatonic Highlands was accompanied by retreat of ice from Pawling, New York (P1, Pl. VI). Initiation of stagnation and dissipation of the southward-sloping ice between Pawling and Sharon was due, in part, to ice flow restriction by ridges farther west beyond the study area. Outwash heads, stagnation deposits, and till ridges record retreatal positions during a series of deglaciation events that evolved in the valley west of the Housatonic Highlands.

In the Housatonic Valley, valley-plug materials south of Gaylordsville and Straits Rock (K4, Pl. IV), and knob-and-kettle topography north of the Tarradiddle (SC1, Pl. VI), define active ice-marginal positions which correlate with nearby deposits in other valleys. Only vague stagnant ice-marginal positions have been defined between these locations in the primary study area. Changes in ice-surface altitudes and drainage routes were caused by the interaction of thinning ice and topographic elements, and led to the concurrent development of physically separated features. The numerous features discussed in Chapter IV can be fitted into sequences of events related to the active and stagnant ice-marginal positions.

The events associated with active and stagnant ice-marginal positions overlap in time. Their history and chronology, however, can be defined. Active positions include:

1. The ridge southeast of the East Aspetuck River valley (Fig. 9, Sub-area 1);
2. the ridge southeast of the Housatonic River valley (Fig. 9, Sub-area 4); and
3. the west slopes of the Housatonic Highlands (Fig. 9, Sub-area 7).

Stagnant positions include;

1. the Housatonic River valley (Fig. 9, Sub-area 6); and
2. the valley west of the Housatonic Highlands (Fig. 9, Sub-area 9).

The East Aspetuck Ridge

Only a few deposits related to the ridge southeast of the East Aspetuck River valley position (Fig. 9, Sub-area 1) have been examined in detail in this study. Deposits previously studied (Gates and Bradley, 1952; Malde, 1967; Colton, 1969) consist of till and lower altitude ice-contact deposits. Stagnant ice thinned to the southeast, while active ice deposited till on the ridge, resulting in an undetermined surface altitude difference between the active and stagnant ice masses. Melt water flowing southeast from the ice margin eroded outflow channels on the exposed southeast slope. Differential melting and variations in topography during this interval also produced drainage changes east of New Milford. Active ice on the ridge became stagnant when ice flow across the uplands southeast of the Housatonic River valley was restricted.

Ridge Southeast of the Housatonic River Valley

The margin of the active ice on the ridge southeast of the Housatonic River valley (Fig. 9, Sub-area 4) was weakly tive, and receded rapidly across the upland. Ice-contact slopes, till, and stratified drift exposed in pits near Wilson Road (K49, Pl. IV; E1, Pl. V) record the presence of thick, impermeable ice late in the uncovering of the upland. Stranded stagnant ice southeast of the ridge acquired a low-gradient surface sloping to the southeast, indicated by both the gradients of eroded single-walled marginal drainage channels and by the fine-grained texture of collapse sediments which accumulated in the ponds at the south end of Kent Hollow.

Outflow and overflow melt-water drainage, from the thick ice that pressed against the upland, passed through the East Kent channel (K46, Pl. IV). This melt-water followed several routes to the southeast, as thinning of the stagnant ice caused drainage changes. Ice sloping to the southeast directed melt waters to the 750-foot channel between Sawyer Hill and Bear Hill (K19, Pl. IV). The melt water mixed and washed till materials, forming the nearby modified till deposit (Qtm). The melt waters continued southwestward along the hill flank and occupied channels near Camp Ella Fohs (K9, Pl. IV). Thick, impermeable ice blocked drainage to the west at Camp Ella Fohs, and in the West Aspetuck drainage north of the Sawyer Hill-Bear Hill channel (K19, Pl. IV). When ice thinned, the lower 710-foot Sawyer Hill-Bear Hill channel was occupied, and ice-contact deposits

Qcd1) accumulated on both sides of the channel. The ice-contact materials in the East Aspetuck Valley were deposited on thick ice, and awaited further thinning of the ice for final emplacement on the underlying terrain. Ice-contact materials to the north grade to the Sawyer Hill-Bear Hill channel (K19, Pl. IV). Their surface altitudes indicate the level of a small pond in which these materials accumulated.

During this time, melt water deposited sand and gravel (Qcd1) around stagnant ice blocks near Wilson Road (K49, Pl. IV; E1, Pl. V). This melt water descended to the thinning ice in the northern part of Kent Hollow The absence of deposits on till in the central part of the depression indicates that melt-water flow terminated before the ice blocks in Kent Hollow (K38, Pl. IV) completely melted.

Drainage changes evolved in response to thinning of ice in Kent Hollow. Melt water was diverted into the northwestern part of Lake Waramaug, moved south along the hill flank, and returned to Kent Hollow through the channel near Ash Swamp. Some water, perhaps from the melting ice and slope runoff in the Waramaug basin, exited at New Preston and briefly crossed ice, rock, and till to enter Bee Brook, and thence into the Shepaug River. Continued ice thinning diverted water from Lake Waramaug through the rock channel at New Preston, and thence southwestward along the East Aspetuck River.

Thinning ice in the Waramaug basin terminated the return flow of water to Kent Hollow from the western part of Lake Waramaug, and created a brief interval of drainage through the Waramaug basin. Melt-water drainage into Lake Waramaug later terminated, but drainage through the overflow channel at Sawyer Hill-Bear Hill (K19, Pl. IV) continued until ice in the West Aspetuck River thinned which permitted flow along the ice edge through the West Aspetuck drainage system. Thinning ice emplaced the Qcd2 deposits in both the southern part of Kent Hollow and in the East Aspetuck Valley. The deposits in Kent Hollow, however, may have accumulated on thin ice somewhat earlier than the ice-marginal deposit in the East Aspetuck Valley. The Qcd2 deposits are of approximately the same age, but they were not formed by the same melt-water stream.

Erosional till surfaces, channels, a coarse gravel deposit at the north end of Kent Hollow, and the lack of major fans confirm that thinning ice persisted while melt water from the East Kent channel descended into the basin. Lacustrine deposits, derived chiefly from slope runoff, subsequently accumulated in the Kent Hollow. A small valley plug at the south end of Kent Hollow was breached by water overflow, but little erosion and a paucity of deposits downstream indicate that this incision occurred after melt-water flow through the East Kent channel terminated.

While the melt-water activity evolved in Kent Hollow, comparable melt-water activity associated with outflow channels occurred to the northeast in the Cornwall quadrangle (Warren, in press). Outflow channels in rock and till, till ridges truncated by drainage channels, and a variety of ice-contact deposits in the Cornwall quadrangle (Warren, in press), and in the South Canaan quadrangle (Holmes and others, 1971), indicate rapid recession of active ice. This was then followed by stagnation and isolation of ice in the northern part of the Cornwall quadrangle, and in the southern part of the South Canaan quadrangle. Melt water from all of these features flowed toward the Housatonic River valley through the Furnace Brook drainage system until routes farther north opened in response to subsequent ice thinning and recession north and northwest of the Housatonic Highlands.

Average altitudes decrease southwestward along this ridge and along the Housatonic Highlands ridge. The altitude decrease permitted active ice flow into and across the semi-isolated basin area towards the southeast to a marginal position on the western slopes of Bear Hill, Iron Hill and Mount Tom as ice stagnation began north and east of these hills. Evidence for this weakly active ice includes the blocked drainage near Camp Ella Fohs (K9, Pl. IV), the minor ice-contact valley plug in the West Aspetuck River, the recessional deposits of boulders south of Upper Merryall, and the boulders in the vicinity of West Meetinghouse Hill Road (Pl. II; K13, Pl. IV).

Housatonic Highlands

Thinning ice over the Housatonic Highlands (Fig. 9, Sub-area 7) restricted flow to the southeast, and ice in the Housatonic River valley became stagnant. Ice moving through the Dogtail Corners (DP7, Pl. VI) col towards the southeast weakened until the active ice margin receded to the col area. Active ice in the semi-isolated basin area then became stagnant, but thick, impermeable ice over that area controlled ice-marginal drainage. Waters diverted from the uplands channel at South Kent were directed southwestward along the flank of the hills. The waters were subsequently directed southeastward, around Bull Mountain and away from the Housatonic River valley, returning to the valley farther south.

Melt waters from active ice were directed across the Housatonic Highlands in the primary study area, toward the Housatonic River valley through Guinea Brook (E10, Pl. V) and its tributaries, and were subsequently directed through Macedonia Brook (K44, Pl. IV; E2, Pl. V), while the active e margin gradually but consistently receded northwestward. Only a few deposits formed on these uplands, because materials were derived from relatively clean ice in the higher parts of the glacier. Melt waters, from both the uplands and the wasting tongue in the Housatonic River valley, flowed into the semi-isolated basin area and thence southeast towards New Milford on ice and on exposed parts of the adjacent terrain.

Impermeable ice directed waters into the upper reaches of Macedonia Brook (Pl. III) when downwasting thinned the ice from 1,200 to 975-foot altitudes northwest of the Housatonic Highlands. Ice-contact deposits (Qcd) downstream at 700-foot altitudes provide a minimum differential of about 300 feet between active and stagnant ice across the broad Housatonic Highlands. Deglaciation of the highlands allowed initial sedimentation sometime prior to 12,750 ± 230 years B.P. in Gross' bog. Backwasting and downwasting of the ice northwest of the Housatonic Highlands caused the ice margin to slowly descend the hill slope. Rapid downwasting of stagnant ice in the Housatonic River valley and the semi-isolated basins returned through drainage of melt water to parts of the Housatonic River valley.

Housatonic River Valley

The transverse orientation of active ice-marginal recession to the upland ridges, and the continued ice recession northwest of the Housatonic Highlands, eventually stranded a long tongue of stagnant ice in the Housatonic River valley (Fig. 9, Sub-area 6). This tongue had an initial slope greater than the gradient of the modern river. Local replenishing and thickening of ice continued, at least briefly, through the low-altitude cols near Bulls Bridge, Macedonia Brook, and Lakeville. Downwasting of the wedge-shaped ice tongue initiated rapid upstream recession of its terminal margin.

Thick ice in the Housatonic River valley and in the semi-isolated basin area downwasted, but only a few small deposits record marginal drainage. These deposits (Qcd3; Qcd4) occur along Merryall Brook (K5, Pl. IV). Deposits in the Ellsworth quadrangle (Pl. III; Qcd3; Qcd4) were formed by marginal melt-water streams lateral to ice near Gunn Brook. Materials at Kent Falls (E3, Pl. V) may be contemporaneous with those along Merryall Brook.

Melt-water streams, superposed and frequently diverted by the melting ice, cut channels on Aspetuck Hill (NM2, Pl. VI) and Long Mountain (K26, Pl. IV) which provide a fragmented erosional record of the once-integrated drainage system developed on the ice and on these terrain features.

Squash Hollow channel (NM7, Pl. VI) conducted melt water from the Gaylordsville basin while ice and debris to at least 429 feet in altitude blocked drainage in the main Housatonic Valley east of this channel. Materials in the zone of the ice-cored valley plug indicate a changing depositional environment including active-ice till deposition, coarse fluvial gravels, and pockets of laminated, laoustrine silts and clays. The knob-and-kettle, ice-contact morphology of these materials is consistent with an ice-marginal ablation moraine (Kaye, 1960). The Squash Hollow channel was operative late in the development of the valley plug. The narrowness of the valley at Straits Rock presumably restricted flow of the weakly active ice extending into the Gaylordsville basin from the col west of Bulls Bridge. Active ice and melt water northwest of the narrows at Straits Rock delivered debris to the ice surface beyond. This active ice maintained a marginal position against Long Mountain at the modified till (Qtm) knobs northeast of Merwinsville and at the Straits Rock narrows. It also controlled melt-water excavation of the higher altitude parts of the Spooner Hill (K28, Pl. IV) and Wimisink (K7, Pl. IV) channels.

Melt-water flow through the deep channels crossing Spooner Hill (K28, Pl. IV) and the ridge west of Gaylordsville (K7, Pl. IV) was maintained by weakly active ice pressing against hill slopes from the northwest. Materials in Unit Qcd5 were deposited in the Gaylordsville basin by melt waters:

1. crossing Spooner Hill (K28, Pl. IV);
2. moving south along the South Kent trough and through the Mud Pond area; and
3. entering through Wimisink channel (K7, Pl. IV) west of Gaylordsville.

The rate of ice stagnation and thinning in the Gaylordsville basin exceeded the melting rate of buried ice in the valley plug south of Straits Rock. This resulted in ponding in the Gaylordsville basin, and affected ice dissipation and related deposition (Qcd6; Qcd7). Active ice west of Spooner Hill stagnated and formed small ponds of short duration. These ponds trapped sand and pebbles which were later let down onto the hill slope (Qcd5; Qcd6). Melt waters were diverted between the ice and the steep west rock face of Cedar Hill (K23, Pl. IV). As the ice margin receded northwestward from a position at the state line (DP2, Pl. VI), melt-water flow through the Wimisink channel (K7, Pl. IV) terminated.

When the Dogtail Corners col ice stagnated, it was presumably thicker than ice lying immediately north or south in the Housatonic River valley. Melting and downwasting caused lateral infilling (Qcd7) along the ice northeast of Bulls Bridge. This deposition was followed by ice dissipation and the expansion of a long, narrow lake at a 420-foot altitude extending northward through Kent village (K42, Pl. IV). Some melt water from ice in the valley west of the Housatonic River flowed from Dogtail Corners northeastward into this lake, while other melt waters flowed southeastward towards Gaylordsville. Ice in the South Kent trough downwasted, but received little sediment from the melt water moving through the sediment-trapping Cobble Brook Valley.

The retreat of ice northward in the Housatonic Valley caused ponding on and around ice in the northward-sloping Cobble Brook Valley. Deposits (Qcd6) formed at this time extend northward and include a small kame delta, kames, ice-channel fillings, and sheet sands. Deposition of all these materials was controlled by the 575-foot outflow channel at the south end of this valley. Thick ice in the main channel, through the village of Kent, blocked drainage until ice thinned and allowed subglacial drainage at around a 465-foot altitude near Flanders (K48, Pl. IV). As the Cobble Brook Valley pond drained, thick ice near the village of

Kent (K42, Pl. IV) briefly directed water flow into the South Kent trough onto dissipating, separated, ice blocks that controlled deposition of Qcd7 materials. Related meltwater drainage in the main Housatonic Valley emplaced only small, ice-contact features near Birch Hill (K35, Pl. IV). Units Qcd6 and Qcd7 extend northeastward as far as Calhoun Corners and are believed to relate to comparable Units Qcd6 and Qcd7 which extend southward beyond Bulls Bridge (DP8, Pl. VI) into the Gaylordsville basin.

Continued melting:

1. caused northward migration of the stagnant ice margin;
2. initiated deposition of younger, low-altitude, ice-contact deposits; and
3. effected expansion through Kent of the long, narrow lake north of Bulls Bridge.

The ice-contact deposits (Qcd8; Qcd9; Qcd10) and their related outwash materials (Qvt8; Qvt9; Qvt10) identify receding, wasting, and dissipating ice northeast in the Housatonic River valley, including the brief, interrupting pond interval caused by slope movement near Deep Brook (E4, Pl. V). A lake extending through Kent received prograding sediments from both Qcd8 and Qcd9 units. These prograding units overran the finer, underlying, lacustrine sediments but did not completely infill the lake before sediments from stream became trapped in ephemeral ponds farther north. This trapping of sediments initiated deposition of Qcd10 material from ice beyond the primary study area.

Tributaries near Cornwall Bridge continued to deliver materials to ice in the Housatonic Valley. These materials can be correlated with Units Qcd6, Qcd7, Qcd8, and Qcd9. Some of these materials were delivered by melt water from stagnant ice isolated in the uplands, while others were delivered by waters derived from slope runoff.

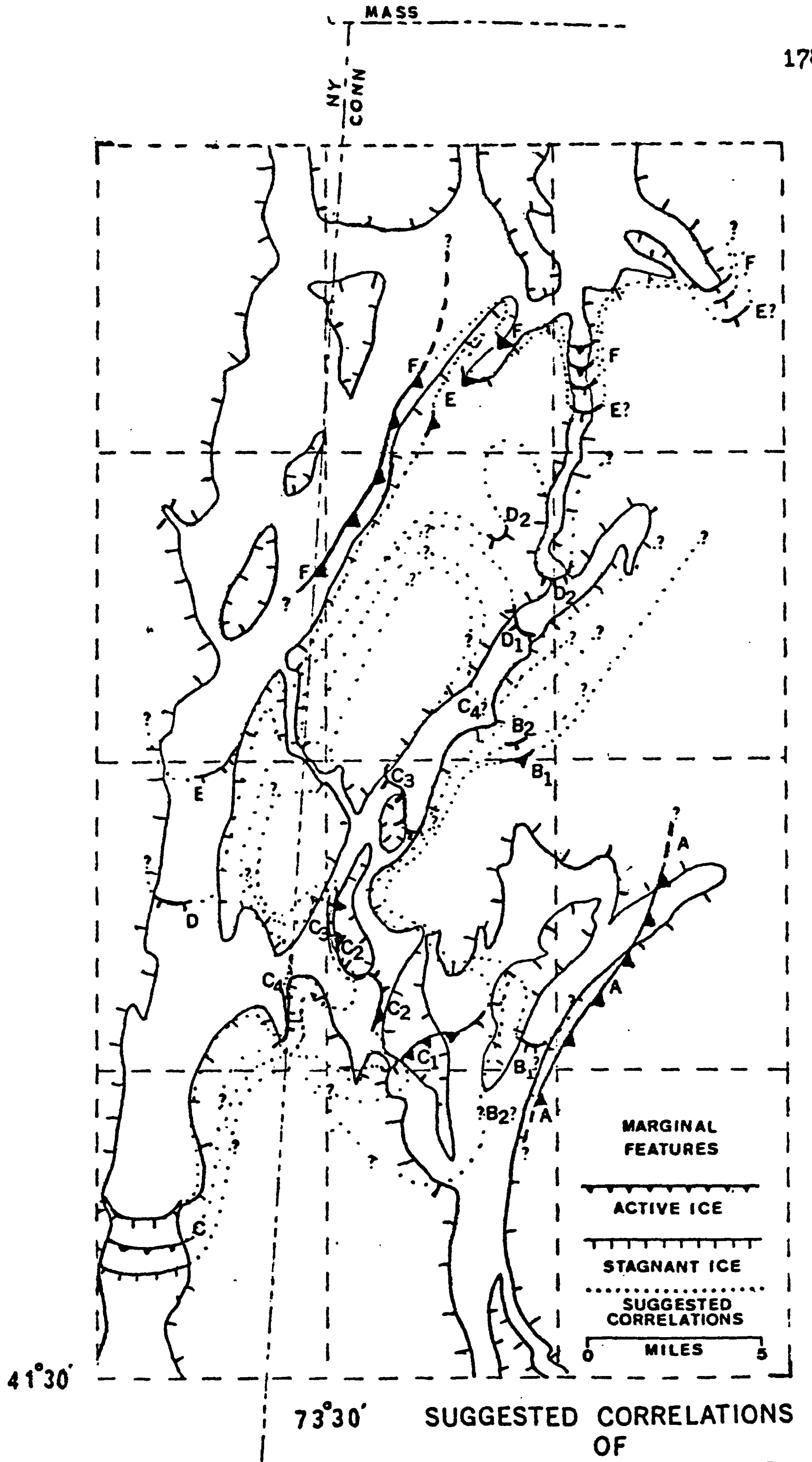
The knob-and-kettle ablation terrain in the Housatonic gorge north of the Tarradiddle (SC1, Pl. VI) defines an active ice-marginal position. The active ice delivered materials to the surface of the distal, stagnant ice. Stagnant ice downstream in the Housatonic Valley thinned and dissipated. Comparable morainal deposits are located 4 miles to the east near Lower City (SC 2, Pl. VI).

Valley West of the Housatonic Highlands

Weak ice activity near Pawling may correlate with the active ice in the Gaylordsville basin. Termination of ice flow in both cases may have been influenced by ice thinning on the next upland ridge west of the Housatonic Highlands. Backwasting and downwasting caused the active margins to shift back through the col west of Bulls Bridge, and stagnant ice blocks became stranded south of Dover Furnace and Dover Plains, in the valley west of the Housatonic Highlands (Fig. 9, Sub-area 9). Drainage along the east side of the valley north of Webatuck (DP5, Pl. VI) contributed outwash materials to the valley-train deposits (Qvt8) which extend through Gaylordsville. Drainage west of Webatuck developed large kame plains between the stagnant ice and the hill slopes.

Ice wasted and thinned in the Housatonic River valley during deposition of the materials in Units Qcd8, Qcd9, and Qcd10, and the margin receded northward to the morainal deposits north of the Tarradiddle (SC1, Pl. VI). Concurrently, northward melting and recession from Dover Plains toward Sharon evolved in the valley west of the Housatonic Highlands. A lake which was ponded near Great Falls (SC4, Pl. VI), in the fosse behind the moraine, enlarged as the ice margin retreated northwestward from Sharon towards Indian Mountain. Taylor (1903) considered the ice-marginal position near Lime Rock and Great Falls to be related to ice flowing on the east side of the Taconic Range, and ice positions near Sharon to be related to comparable and synchronous ice flow west of the Taconic Range. His concept is consistent, therefore, with the active and stagnant ice positions identified in this current study extending farther south. The inferred relationship of active or stagnant ice margins in the study area are summarized in Figure 12. Letters on this figure indicate successively younger marginal deposits which are inferred to be related. Distinction between related marginal positions is indicated numerically where rapid changes in marginal positions are evident in one area but are not evident elsewhere. Symbols on the figure distinguish between inferred active and stagnant marginal positions. Depositional sequences in the Kent and Ellsworth quadrangles are associated with each ice-marginal position on Figure 12 as follows:

Ice-marginal position	Depositional sequence
A	none
B1, B2	Qcd1, Qtm, west side of East Aspetuck Valley
C1	Qcd2
C2	Qcd3, Qcd4 (? ?)
C3	Qcd5
C4	Qcd6
D1	Qcd7
D2	Qcd8
E-F	Qcd9-Qcd10



SUGGESTED CORRELATIONS OF ICE-MARGINAL FEATURES

FIGURE 12

CHAPTER VI

CONCLUSIONS

Multiple glaciations in the Housatonic River region of northwestern Connecticut are evidenced by:

1. till diversion of the Housatonic River drainage near West Cornwall;
2. anomalous configurations of melt-water channels on the uplands at East Kent and near Mohawk State Forest;
3. the disparity of erosional incisions in the Stockbridge marble at Great Falls and Bulls Bridge; and
4. till retention in the New Preston melt-water channel.

Erosional competence of the last glacial ice may have been weak in the study area, as indicated by:

1. several wells which contain weathered rock beneath till;
2. several small, pre-Late Wisconsin, upland melt-water channels which evidence only minor glacial modification; and
3. the lack of excavation of stream-diverting till near West Cornwall.

The latest active ice flow across this region was part of the east lateral margin of the Hudson-Champlain Valley ice lobe, as indicated by:

1. the consistent regional trend from northwest to southeast of ice-flow indicators including striations, drumlin axes, and stoss-and-lee topography; and
2. the regional trend of upland melt-water flow towards the southeast from thicker ice to the northwest.

High topographic relief controlled waning glacial ice flow which caused leeward effects responsible for Late Wisconsin ice-flow diversions in regions north and east of the primary study area. This is supported by the lack in the primary study area of north-to-south and northeast-to-southwest striations and secondary drumlin tails, but these ice-flow directional indicators are found in the nearby regions.

Deglaciation in this region was initiated by recession of an active ice margin from southeast to northwest, as evidenced by:

1. active ice-marginal till thickening and associated outflow melt-water drainage on the ridge southeast of the East Aspetuck River valley; and

2. the persistence of thick ice and associated deposits northwest of ridges versus associated but stagnant ice with related features southwest of each ridge.

Striations and the orientation of erosional remnants of melt-water drainage indicate the receding active ice margin was transverse to the trend of the major ridge elements in the primary study area.

Scattered, small, ice-marginal deposits and fragmentary drainage channels preclude correlation of definable, upland, active ice-marginal stillstands, and thus support the concept of a generally rapid, active ice-marginal recession across the uplands.

Ice thinning resulting from backwasting and downwasting eventually caused topographic relief to become the dominant factor controlling the local mode of deglaciation. This is evidenced by the successive transition from weakly active ice-marginal features to stagnation morphologies when ice flow to the southwest was restricted by the upland ridges.

Active ice continued to flow through broad, low-altitude cols during late phases of deglaciation after flow across the uplands terminated, as evidence by:

1. the development of valley plugs south of Gaylordsville near the Dogtail Corners col, and north of the Tarradiddle near the Lakeville col; and
2. drainage diversions, linear boulder concentrations, and associated melt-water drainage features east of Gaylordsville.

Low-gradient, ice-contact outwash deposits indicate that downwasting of stagnant ice tongues and blocks dominated deglaciation in the narrow valleys and semi-isloated basins following the restriction of active ice flow by topographic uplands.

Small, fragmentary outwash heads and small, vertical intervals between kame terraces record the gradual change of terminal and marginal position of stagnant ice tongues. These changes were in response to the interaction of the slope of the ice surface as the ice downwasted and the configuration of the underlying terrain.

The limited areal extent and thickness of ice-contact sediments associated with disintegrating ice blocks in the semi-isolated basins and valleys which were restricted from through melt-water flow, and the general regional thinnness of till, suggest that entrained rock debris was sparse in the ice masses overlying this region.

Incised melt-water channels and chutes, and the ɔsition, textural composition, and internal and external haracteristics of glaciofluvial deposits indicate that melt ater moved on, along, in and beneath active and stagnant ce as melt-water flow toward the southwest frequently hanged its drainage routes.

Lacustrine silts and varved clays define small, ephemeral ponds which developed in the narrow Housatonic River valley and in semi-isolated basins during late phases of deglaciation. Larger valleys to the west and areas with northward drainage developed larger, persistent ponds into which prograding outwash extended and buried or partly buried underlying lacustrine materials.

An isotopic radiocarbon date and preliminary pollen analysis made on samples of buried peat indicate that the Housatonic Highlands were free of ice and that forest vegetation was becoming re-established in this region by 12,750 ± 230 years B.P.

A P P E N D I C E S

APPENDIX A

INDEX TO SITE LOCATIONS DISCUSSED IN TEXT

To aid in locating sites discussed in the text, each site has been designated by letter and numeral. Letters abbreviate the names of U. S. Geological Survey 7-1/2 minute quadrangle maps in the study area. Numerals are sequential at increased latitudes in each quadrangle. Latitude and longitude coordinates for each site consist of a 13-digit number followed by the letter N to indicate north latitude. The last 7 digits are degrees, minutes and seconds of longitude.

Kent Quadrangle (Plate IV)

Number	Map Region	Feature	Coordinates
K 1	Morrissey Brook		413735N0732900
K 2	Northville	Thick till (Well NM30U)	413750N0732330
K 3	Northville	Collapsed topography	413755N0732315
K 4	Straits Rock	Restrictive narrows	413755N0732825
K 5	Merryall Brook	Varved deposits	413755N0732550
K 6	Northeast of Northville	Boulder field	413810N0732305
K 7	Wimisink Brook		413820N0732945
K 8	Drainage channels on Long Mountain	Melt-water channels in rock and till	413825N0732740
K 9	Camp Ella Fohs	Drainage routes	413830N0732400
K10	Gaylordsville area	Glacial and glaciofluvial deposits	413840N0732900

APPENDIX A (Continued)

Kent Quadrangle (Plate IV) (continued)

Number	Map Region	Feature	Coordinates
K11	Strastrom Pond	Melt-water route	413840N0732445
K12	Valley plug, East Aspetuck River	Knob-and-kettle topography	413840N0732305
K13	Channels near West Meetinghouse Road	Melt-water channel	413850N0732605
K14	Lower Merryall	Melt-water diversion	413855N0732455
K15	Aspetuck River		413905N0732255
K16	Northville Cemetery area	Modified till	413910N0732315
K17	West of West Meetinghouse Rd.	Kame terraces	413915N0732635
K18	West of West Meetinghouse Rd.	Boulder concentration	413920N0732655
K19	Sawyer Hill-Bear Hill channel	Melt-water overflow channel	413930N0732305
K20	South Kent trough	Valley plug	413935N0732840
K21	West of West Meetinghouse Rd.	Kames and sheet sands	413940N0732635
K22	Pine Hill	Erosional incision in till	413955N0732800
K23	Cedar Hill	Melt-water channel incised in rock	414000N0732930
K24	West Aspetuck River		414010N0732410
K25	Upper Merryall Cemetery	Cols	414012N0732445
K26	Long Mountain	Truncated spurs	414015N0732650
K27	Lower Kent Hollow	Washed till and sheet sand	414025N0732340
K28	Spooner Hill	Col channel and ice-walled channels	414030N0732910
K29	Mud Pond Region	Melt-water route	414035N0732715
K30	Long Mountain-Ore Hill Gap	Melt-water route	414040N0732645
K31	South Kent	Thick till (Well K30U)	414045N0732810

APPENDIX A (Continued)

Kent Quadrangle (Plate IV) (continued)

Number	Map Region	Feature	Coordinates
K32	Hatch Pond	Melt-water route (erosion)	414055N0732830
K33	Ash Swamp	Melt-water route	414115N0732300
K34	Bull Mountain	Roche Moutonnee	414125N0732750
K35	Birch Hill		414200N0732930
K36	Leonard Pond	Isolated ice features	414210N0732830
K37	Northwest of Lake Waramaug	Melt-water channel	414245N0732320
K38	North end of Kent Hollow	Alluvial fan	414255N0732340
K39	Head of Cobble Brook Valley	Base level threshold	414305N0732725
K40	Drainage route from East Kent channel	Stream incision	414315N0732350
K41	Bald Hill	Upland melt-water channels	414320N0732600
K42	Kent village	Valley train outwash	414335N0732820
K43	Beaman Pond, East Kent	Lunate fractures, quarry	414355N0732420
K44	Macedonia Brook	Rock basins; Kame terraces	414405N0732930
K45	Bromica Mountain	Upland melt-water channels	414410N0732515
K46	East Kent channel	Upland overflow channel	414410N0732345
K47	Flanders	Linear boulder concentration	414420N0732720
K48	West of Flanders	Melt-water channels in till	414430N0732735
K49	East of Wilson Road	Ponded sediments	414450N0732320
K50	West of Wilson Road	Kame terrace	414455N0732410
K51	Good Hill Cemetery	Thick till (Well K34U)	414455N0732655

APPENDIX A (Continued)

Ellsworth Quadrangle (Plate V) (continued)

Number	Map Region	Feature	Coordinates
E 1	Wilson Road	Ponded sediments	414505N0732325
E 2	Macedonia Brook	Melt-water route	414520N0732930
E 3	Kent Falls State Park	Initiation of Qcd6 deposits	414635N0732450
E 4	Deep Brook	Erosion terrace; till slump	414705N0732435
E 5	Whitcomb Hill Road	Striations and grooves	414715N0732250
E 6	Millard Brook	Collapse topography; Kames	414735N0732400
E 7	Gross Bog	Radiocarbon dated	414800N0732935
E 8	Calhoun Corners	Till diversion; collapse topography	414815N0732250
E 9	West Woods	Melt-water drainage	414830N0732835
E10	Guinea Brook	Channel	414855N0732245
E11	South Ellsworth	Ice-contact deposits	414910N0732545
E12	East Street	Underfit stream	415000N0732420
E13	Hatch Brook	Collapsed topography	415005N0732310
E14	Housatonic Meadows State Park	Planar outwash surface	415015N0732250
E15	Ford and Bog Meadows Pond		415100N0732655
E16	Carse Brook	Outwash	415125N0732220
E17	Hatch Pond	Large melt-water channel	415145N0732810
E18	West of Hatch Pond	200 ft till thickness (Well S11W)	415155N0732820

APPENDIX A (Continued)

Amenia Quadrangle (Plate VI)

Number	Map Region	Feature	Coordinates
A1	Bog Hollow	Gravel knobs; stagnant ice block	414540N0733110
A2	Leedsville	Fan outwash beyond rock threshold	415115N0733045

Cornwall Quadrangle (Plate VI)

Number	Map Region	Feature	Coordinates
C 1	Milton	Melt-water channel	414615N0731630
C 2	The Hogback	Cross-divide melt-water channel	414755N0731715
C 3	Mohawk State Forest	Ice-contact deposit	414910N0731715
C 4	Cornwall Bridge	Thick till	414920N0732205
C 5	West Goshen	Melt-water channel	414940N0731515
C 6	East Street	Melt-water channel	415005N0731910
C 7	Cornwall village		415040N0731940
C 8	Red Mountain area	Cross-divide melt-water channel	415045N0731725
C 9	The Ballyhack	Drainage	415110N0731945
C10	West Cornwall	Diversion by till	415225N0732135

APPENDIX A (Continued)

<u>Dover Plains Quadrangle</u> (Plate VI)

Number	Map Region	Feature	Coordinates
DP 1	Ridge east of Deuel Hollow Brook		413805N0733055
DP 2	Connecticut-New York border	Head of outwash	413840N0733115
DP 3	Leather Hill	Drainage channels	413845N0733140
DP 4	Wingdale	Planar outwash features	413855N0733430
DP 5	Webatuck	Drainage features	413910N0733320
DP 6	Confluence of Tenmile and Housatonic Rivers		413955N0733020
DP 7	Dogtail Corners	Till; drainage channel	414015N0733145
DP 8	Bulls Bridge area	Drainage; rock incision	414030N0733025
DP 9	Dover Furnace	Drainage threshold; ice-margin	414105N0733505
DP10	Oniontown	Outwash fan head	414320N0733455
DP11	Dover Plains	Gravel; Kame plains	414420N0733420

<u>Millerton Quadrangle</u> (Plate VI)

Number	Map Region	Feature	Coordinates
M1	Coleman Station	Drainage derangement	415405N0733120
M2	Indian Lake	Ice-marginal position	415525N0733020
M3	Millerton	Ice-marginal position	415720N0733120

APPENDIX A (Continued)

New Milford Quadrangle (Plate VI)

Number	Map Region	Feature	Coordinates
NM1	New Milford Reservoir 3 & 4	Melt-water drainage channel	413515N0732250
NM2	Aspetuck Hill	Melt-water channel	413520N0732440
NM3	Hill east of Rt. 25, near Park Lane	Melt-water channel	413620N0732345
NM4	Northeast of Park Lane	Great Brook melt-water channel	413630N0732405
NM5	Deposits east of Squash Hollow	Ice-marginal positions	413645N0732755
NM6	Hickory Haven	Gravel deposits	413720N0732800
NM7	Squash Hollow Brook	Marginal melt-water channel	413725N0732350

New Preston Quadrangle (Plate VI)

Number	Map Region	Feature	Coordinates
NP1	New Preston village	Drainage channel	414035N0732115
NP2	East of New Preston village	Stream diversion	414045N0732035

APPENDIX A (Continued)

Pawling Quadrangle (Plate VI)

Number	Map Region	Feature	Coordinates
P1	Pawling	Ice-marginal position	413335N0733635
P2	Eroded channel	High-level melt water	413530N0733340
P3	Uplands divide west of Morrissey Brook		413636N0733235

Sharon Quadrangle (Plate VI)

Number	Map Region	Feature	Coordinates
S1	Tan Fat Hill	Ice-marginal position	415310N0732625
S2	Red Mountain area		415420N0732550
S3	Beeslich Pond	Initial large drainage channel	415515N0732616
S4	Lime Rock Race Track	Outwash delta	415540N0732310
S5	Lakeville area		415800N0732635

<u>South Canaan Quadrangle</u> (Plate VI)

Number	Map Region	Feature	Coordinates
SC1	Tarradiddle	Ice-marginal collapsed topography	415300N0732130
SC2	Lower City	Ice-marginal collapsed topography	415530N0731650
SC3	Hollenbeck River	Diversion of the river	415535N0731635
SC4	Great Falls	Relatively minor stream incision	415745N0732210

<u>Copake Quadrangle</u> (Plate VII)

Number	Map Region	Feature	Coordinates
CO1	Whitehouse Crossing	Ice-directed drainage	420125N0733105
CO2	Boston Corners	Ice-marginal position	420310N0733105
CO3	Copake Falls village	Ice-marginal position	420700N0733140

<u>Hillsdale Quadrangle</u> (Plate VII)

Number	Map Region	Feature	Coordinates
H1	Hillsdale	Ice-directed drainage	421050N0733140

APPENDIX B

MECHANICAL ANALYSES FOR SELECTED SAMPLES

Numbering and Location Systems (from Melvin, 1970)

"In Connecticut each well, ... and test hole inventoried by the U. S. Geological Survey is assigned a sequential number based on the town in which it is located. A separate sequence of serial numbers is used for each town. Prefix letters are used to designate the town name and the suffix letters ... 'th' are used for ... test holes ....

To aid in locating wells, ... and test holes on the map, a location system based on latitude and longitude is used. Following the 'town' number in each table is a 14-digit number. The first 6 digits are the degrees, minutes and seconds of latitude at the site of the well, ... or test hole followed by the letter N to indicate north latitude; the next 7 digits are degrees, minutes and seconds of longitude. The last number following the decimal place indicates whether the well, ... or test hole referred to is the 1st, 2nd, 3rd, etc. inventoried within the area defined by the latitude and longitude coordinates. These numbers define a tract of land having dimensions of one second of latitude and longitude, measuring about 100 x 75 ft.

...

APPENDIX B (continued)

Logs of Selected Test Holes

Under each entry are listed test-hole number, location, owner, year drilled, altitude and source of log.

Test-hole number and location: See [Page 194] for explanation of test-hole numbering and location systems.

Altitude: Land surface at test-hole site expressed in feet above mean sea level, estimated from topographic map with 10 ft contour interval. Some altitudes of test holes by the Connecticut State Highway Department and U. S. Department of Agriculture, Soil Conservation Service determined by instrument leveling.

...

Materials descriptions: U. S. Geological Survey logs: All these are from auger borings and were prepared by geologists after field examination of cuttings and split-spoon samples and mechanical analysis of selected samples. The grain-size classification system is the Wentworth grade scale.

...

Connecticut State Highway Department logs: Borings put down by the State Highway Department or by commercial test-drilling firms under contract. Logs were prepared mainly by drillers and are based on split-spoon samples, cuttings, and behavior of boring rig during operation. Drillers' logs are commonly revised by the State Highway Department on the basis of mechanical analyses of selected samples and some have been further simplified by this report. Underscored terms are interpretations ...

Other logs: Include those from several different drilling firms and a few prepared by consulting geologists and engineers.

..."

Following are those well reports from Melvin (1970) which are applicable to this dissertation.

APPENDIX B (continued)

Logs of Selected Test Holes

TOWN OF KENT

	Thickness (feet)	Depth to bottom (feet)
K 1 th. 414253N0732819.1. Kent Water Co. Drilled 1965. Altitude 395 ft. Log by S. G. Church Co.		
Swamp muck	10	10
Clay and peat	5	15
Clay and silt, gray	21	36
Gravel and clay (till?)	5	41
K 2 th. 414500N0732737.1. Conn. Hwy. Dept. Drilled 1936. Altitude 365 ft. Driller's log.		
Sand, fine; some medium sand	24	24
Gravel, hard	8	32
Boulder	1.5	33.5
Gravel, hard	1.5	35
K 5 th. 414337N0732855.1. Conn. Hwy. Dept. Drilled 1965. Altitude 360 ft. Driller's log.		
Topsoil	2	2
Sand, very fine to fine, and silt	2	4
Sand, fine to coarse, and gravel; some cobbles; some silt	5	9
Sand, coarse; little fine sand to gravel; some cobbles; little silt	4	13
Sand, very fine; little fine sand and silt	5	18
Sand, very fine, and silt	6	24
Sand, fine; some silt	27.5	51.5
K 6 th. 414335N0732853.1. Conn. Hwy. Dept. Drilled 1965. Altitude 359.3 ft. Driller's log.		
Topsoil	2	2
Sand, fine to coarse, and gravel; few cobbles; little silt	2	4
Sand, coarse; little fine sand to gravel; some silt	11	15
Sand, fine to medium; some coarse sand; little gravel; some silt	4	19
Sand, very fine to fine; some silt	28	47
Sand, fine to coarse; little silt	4.5	51.5

APPENDIX B (continued)

Logs of Selected Test Holes

	Thickness (feet)	Depth to bottom (feet)
TOWN OF KENT (continued)		
K 7 th. 414312N0732913.1. Kent School for Boys. Drilled 1968. Altitude 375 ft. Log by Conn. Test Borings Inc., driller.		
Topsoil, dark brown; little coarse to fine gravel.	7	7
Sand, coarse to fine, and coarse to fine gravel; trace of silt . . .	9	16
Sand, coarse to fine, and medium to fine gravel; trace of silt . . .	5	21
Silt, gray.	20.5	41.5
K 8 th. 414550N0732627.1. Stanley Works Inc. Drilled 1968. Altitude 385 ft. (approx. altitude of bottom of sand and gravel pit) Log by Conn. Test Borings Inc., driller.		
Gravel.	3	3
Sand, medium to very coarse; little fine gravel; trace of fine sand . .	10	13
Sand, very fine to very coarse; little silt; little clay; trace of fine gravel.	11	24
Clay; trace of silt	14	38
Sand, medium to very coarse, silt, clay and pebble gravel.	1.5	39.5
Sand, fine to very coarse	1.5	41
Sand, fine to very coarse, and fine gravel	7	48
Gravel, fine, poorly sorted	1.5	49.5
Sand and fine gravel.	8.5	58
Gravel.	5	63
Sand, fine to very coarse, and gravel.	11	74
Refusal		at 74

APPENDIX B (continued)

Logs of Selected Test Holes

TOWN OF KENT (continued)

K 9 th. 414402N0732827.1. Mr. Jack Casey.
Drilled 1968. Altitude 365 ft.
Log by U. S. Geol. Survey.

	Thickness (feet)	Depth to bottom (feet)
Sand, fine to very fine, and silt (alluvium)	9	9
Gravel and medium to fine sand	3	12
Sand, medium	1	13
Sand and fine gravel	5	18
Sand, medium; little fine sand; trace of coarse to very coarse sand	5	23
Sand, medium; some fine sand; trace of very fine sand, well sorted	1.5	24.5
Sand, medium; some fine sand	8.5	33
Sand, medium; little fine sand	16	49
Sand, medium; some fine sand	10	59
Sand, very fine to medium and silt	8	67
Silt and clay; trace of sand	8	75
Silt; little fine to very fine sand; trace of medium sand	2	77
Clay and silt; little medium sand	4	81
Clay, sand and silt; occasional small granules (till?)	12	93
Till	6	99
Refusal		at 99

APPENDIX B (continued)

Logs of Selected Test Holes

TOWN OF KENT (continued)

K 10 th. 414417N0732935.1. Kent School for Boys. Drilled 1968. Altitude 377 ft. Log by U. S. Geol. Survey.

	Thickness (feet)	Depth to bottom (feet)
Topsoil and fine silty sand	5	5
Gravel.	3	8
Gravel, pebbly, and sand.	5	13
Sand, fine to medium; some coarse to very coarse sand	3.5	16.5
Gravel.	1.5	18
Sand, coarse to very coarse; little medium to very fine sand; occasional pebbles.	15	33
Sand, fine to very coarse; some fine gravel; trace of very fine sand . .	1.5	34.5
Sand, fine to medium; little coarse to very coarse sand; little fine gravel.	8.5	43
Sand, coarse; little medium to fine sand; grading into very coarse sand and fine gravel.	1.5	44.5
Sand and fine gravel.	8.5	53
Sand, fine, and dirty pebble gravel .	1.5	54.5
Gravel; little fine to very coarse sand	18.5	73
Gravel; some coarse to very coarse sand.	10	83
Sand, coarse.	3	86
Gravel, coarse.	4	90
Refusal		at 90

APPENDIX B (continued)

Logs of Selected Test Holes

TOWN OF NEW MILFORD

NM 34 th. 413850N0732302.1. Town of New Milford.
Drilled 1968. Altitude 448 ft.
Log by U. S. Geol. Survey.

	Thickness (feet)	Depth to bottom (feet)
Gravel (artificial fill).	5	5
Sand.	4	9
Gravel, coarse.	3	12
Sand.	1	13
Gravel, fine to medium, and medium to very çoarse sand	5	18
Gravel; little sand	5	23
Sand; little fine to medium gravel.	6.5	29.5
Sand, medium to very coarse, and gravel.	10	39.5
Sand, fine to very coarse, and gravel.	3.5	43
Sand, fine to medium; little coarse to very coarse sand; little pebble gravel.	5	48
Sand, medium to very fine; little gravel; trace of silt and coarse to very coarse sand.	1.5	49.5
Sand, medium to fine, and gravel; little coarse to very coarse sand .	8.5	58
Till.	4	62
Refusal		at 62

APPENDIX B (continued)

Logs of Selected Test Holes

TOWN OF NEW MILFORD (continued)

	Thickness (feet)	Depth to bottom (feet)
NM 35 th. 413848N0732848.1. Peter Prange. Drilled 1968. Altitude 245 ft. Log by U. S. Geol. Survey.		
Topsoil and sand.	2	2
Gravel, coarse.	4.5	6.5
Sand, medium to fine; trace of coarse to very coarse sand.	11.5	18
Sand, medium; some fine sand; trace of fine gravel.	5	23
Sand, medium to fine; little coarse sand; trace of gravel; trace of very fine sand; trace of silt and clay.	1.5	24.5
Sand, medium; little coarse to fine sand; trace of gravel.	1.5	26
Gravel.	2	28
Sand, medium; little coarse sand; little fine sand to silt.	7	35
Sand, fine to medium.	1	36
Gravel or till.	3	39
Refusal		at 39
NM 36 th. 413756N0732557.1. Frank Gawel. Drilled 1968. Altitude 385 ft. Log by U. S. Geol. Survey.		
Clay and silt (alluvium).	3	3
Silt and very fine sand, gray	15	18
Silt and clay, gray	15	33
Silt and clay, varved, greenish-gray.	20	53
Clay, gray.	1	54
Sand, fine to very fine; little silt, tan.	2.5	56.5
Sand, very fine; silt and clay with occasional stones (till?). . .	1.5	58
Refusal		at 58

APPENDIX B (continued)

Logs of Selected Test Holes

OWN OF NEW MILFORD (continued)

	Thickness (feet)	Depth to bottom (feet)
M 37 th. 413949N0732827.1. Town of New Milford Drilled 1968. Altitude 340 ft. Log by U. S. Geol. Survey.		
Topsoil, sand and clay.	6	6
Gravel.	2	8
Gravel; little sand	5	14
Refusal, large boulder or bedrock . .		at 14
NM 38 th. 413833N0732856.1. Conn. Light and Power Co. Drilled 1968. Altitude 243 ft. Log by U. S. Geol. Survey.		
Topsoil	2	2
Sand, fine to very fine; trace of medium sand; trace of silt.	6	8
Gravel; some sand from 11 to 13 ft. .	5	13
Sand; little gravel	5	18
Sand, fine to very fine, and silt . .	10	28
Sand, very fine; some fine sand; some silt and clay; trace of medium sand; occasional pebbles . .	1.5	29.5
Sand, fine to very fine; little clay and silt.	15.5	45
Sand, fine to very fine; trace of silt	15	60
Gravel or till.	3	63
Till.	1.5	64.5
Till, some weathered marble	1.5	66
Refusal		at 66

APPENDIX B (continued)

Logs of Selected Test Holes

TOWN OF SHARON

S 1 th. 414748N0732413.1. Stanley Works Inc.
Drilled 1968. Altitude 415 ft.
Log by U. S. Geol. Survey.

	Thickness (feet)	Depth to bottom (feet)
Sand, very fine, and silt; trace of clay	11	11
Sand, medium to fine, and fine gravel	2	13
Sand, fine; little medium to very coarse sand; trace of very fine sand and silt	5	18
Sand, fine to very coarse; trace of fine gravel	6.5	24.5
Sand, medium to very coarse, and fine gravel, very clean	10	34.5
Sand, medium to very coarse, and pebble gravel	8.5	43
Gravel and medium to very coarse sand; trace of fine sand	15	58
Sand, medium to very coarse; some gravel	5	63
Sand, coarse to very coarse, clean; occasional small pebbles	3	66
Sand, medium to very fine	2	68
Refusal (bedrock?)		at 68

APPENDIX B (continued)

Logs of Selected Test Holes

TOWN OF SHARON (continued)

S2 th. 414835N0732311.1. G. Gay
Drilled 1968. Altitude 431 ft.
Log by U. S. Geol. Survey.

	Thickness (feet)	Depth to bottom (feet)
Gravel, coarse	10	10
Sand and gravel	3	13
Sand, medium to fine; trace of coarse to very coarse sand	5	18
Sand, medium to very fine; some silt; trace of coarse to very coarse sand	6	24
Gravel and silty sand	12	36
Sand, coarse to very coarse, and pebble gravel; trace of medium to very fine sand	3	39
Sand and gravel	4	43
Gravel, coarse	5	48
Sand, mainly coarse to very coarse, and fine gravel, very clean	13	61
Sand, mainly coarse to very coarse, clean; some gravel	11	72
Gravel	2	74
Sand, coarse to very coarse, clean, and pebble gravel	6	80
Gravel	3	83
Sand and gravel	19	102
Refusal (bedrock)		at 102

APPENDIX B (continued)

Logs of Selected Test Holes

TOWN OF SHARON (continued)

S 3 th. 414926N0732235.1. Conn. State Park and Forest Comm. Drilled 1968. Altitude 452 ft. Log by U. S. Geol. Survey.

	Thickness (feet)	Depth to bottom (feet)
Gravel, coarse, and boulder	3	3
Sand, very fine; little fine sand	10	13
Sand, very fine; little silt; little fine sand	20	33
Sand, medium, and silt; trace of fine to very fine sand	1.5	34.5
Sand, fine to very fine	8.5	43
Silt; some very fine sand	11.5	54.5
Sand, fine to very fine; little silt	1.5	56
Sand, fine to very fine	15	71
Gravel	1	72
Sand, fine	2	74
Pebble gravel	2	76
Till or gravel	3	79

S 4 th. 415027N0732241.1. Conn. State Park and Forest Comm. Drilled 1968. Altitude 468 ft. Log by U. S. Geol. Survey.

	Thickness (feet)	Depth to bottom (feet)
Sand, fine; little medium sand	6	6
Gravel, coarse	7	13
Sand	2	15
Gravel and sand, fairly clean	13	28
Refusal		at 28

APPENDIX B (continued)

Logs of Selected Wells

Under each entry are listed well number and location. See [page 194] for explanation of well numbering and location systems.

	Thickness (feet)	Depth to bottom (feet)
TOWN OF CORNWALL		
C 12 U. 414820N0732258.1.		
Gravel, coarse and very hard boulder.	52	52
Limestone, white, hard	20	72
Rock, brown, hard; changing to limestone	30	102
C 25 W. 414833N0732242.1.		
Coarse gravel and cobble	12	12
Hard sand.	13	25
Boulders (till?)	20	45
Rock (limestone)		?
C 50 W. 414803N0732321.1.		
Hardpan.	54	54
Limestone.	66	120+
C 63 W. 414822N0732253.1.		
Sand, gravel and boulders.	70	70
Rock..		70+
TOWN OF KENT		
K 2 W. 414604N0732542.1.		
Hardpan and boulders	120	120
Clay (weathered rock?)	35	155
Limestone.	66	216

APPENDIX B (continued)

Logs of Selected Wells

	Thickness (feet)	Depth to bottom (feet)
TOWN OF KENT (continued)		
K 8 U. 414606N0732539.1.		
Hardpan and boulders	115	115
Bedrock	55	170
K 17 U. 414316N0732730.1.		
Cobbles	10	10
Sand, fine	40	50
Hardpan (till)	7	57
Ledge		at 57
K 29 U. 414155N0732946.1.		
Sand and gravel	45	45
Clay, gray	25	70
Clay, brown	16	86
Sand and gravel (till?)	6	110
Gravel, coarse, and sand (weathered rock?)	4	114
K 30 U. 414043N0732815.1.		
Hardpan and boulders with some sand and gravel (till?)	60	60
Clay, dark gray	40	100
Sand and gravel	20	120
Clay	20	140
Gravel, very coarse (till?)	8	148
K 34 U. 414453N0732653.1.		
Hardpan and boulders (till)	70	70
Limestone	165	235

APPENDIX B (continued)

Logs of Selected Wells

TOWN OF KENT (continued)

K 36 U. 414442N0732634.1.

	Thickness (feet)	Depth to bottom (feet)
Sand and some gravel	60	60
Clay (till?)	28	88
Rock, hard and soft, dark brown to light gray	112	200

K 49 W. 414427N0732947.1.

	Thickness (feet)	Depth to bottom (feet)
Coarse gravel with cobble-to-boulders (dark gray rock)	53	53
Rock		53+

K50 W. 414608N0732512.1.

	Thickness (feet)	Depth to bottom (feet)
Gravel and clay	95	95
Rock	55	150

K 61 W. 414157N0732926.1.

	Thickness (feet)	Depth to bottom (feet)
Sand (till)	22	22
Rock, hard and soft	428	450

K 67 W. 414547N0732417.1.

	Thickness (feet)	Depth to bottom (feet)
Hard gravel (till?)	19	19
Rock	126	145

K 77 W. 414619N0732500.1.

	Thickness (feet)	Depth to bottom (feet)
Gravel, little hardpan and boulders	80	80
Limestone	82	162

K 78 W. 414436N0732936.1.

	Thickness (feet)	Depth to bottom (feet)
Coarse gravel	40	40
Rock, hard and soft	120	160

K 82 W. 414422N0732802.1.

	Thickness (feet)	Depth to bottom (feet)
Sand and boulders	65	65
Limestone, white and gray	385	450

APPENDIX B (continued)

Logs of Selected Wells

	Thickness (feet)	Depth to bottom (feet)
TOWN OF KENT (continued)		
K 88 W. 414408N0732936.1.		
Sand, gravel, with some boulders . .	59	59
Rock		59+
K 89 W. 414616N0732506.1.		
Sand, boulders, hardpan.	113	113
Rock (limestone)	72	185
K 113 W. 414428N0732645.1.		
Sand, gravel, and some boulders. . .	61	61
Rock, gray to brown.	64	125
TOWN OF NEW MILFORD		
NM 30 U. 413821N0732313.3.		
Fine sand.	70	70
Soft limestone] [	85	155
Sand, fine] (weathered limestone) [	15	170
Gravel] [	10	180
TOWN OF SHARON		
S 7 W. 415218N0732301.2.		
Gravel	45	45
Granite (Gneiss)	25	70
S 9 U. 414847N0732400.1.		
Soil (till).	8	8
Very hard rock	392	400
S 11 W. 415154N0732805.1.		
Hardpan with boulders.	100	100
Hardpan with gravel (till or weathered rock??)	100	200
Clay and sand on gravel (very good gravel!) (weathered rock?? or gravel) . . .	25	225

APPENDIX B (continued)

Logs of Selected Wells

	Thickness (feet)	Depth to bottom (feet)
:OWN OF SHARON (continued)		
; 19 W. 414856N0732237.1.		
Sand, gravel, boulders	88	88
Rock, hard, gray	58	146
S 67 W. 415017N0732220.1.		
Gravel and boulders.	20	20
Granite (gneiss?).	170	190
TOWN OF SHERMAN		
Sh 4 U. 413845N0732933.1.		
Sand and boulders.	20	20
Sand, fine, brown.	90	110
Gravel (0.5-in. diam.)	14	124

APPENDIX C

SUMMARY OF SEDIMENTARY STATISTICS FOR SELECTED SAMPLES (Folk and Ward parameters)

Kent and Ellsworth Quadrangles

Definitions:

Median . . . . = Md
Graphic mean . . . . = M_z
Inclusive graphic standard deviation = σ_I
Inclusive graphic skewness . . . . . . = Sk_I
Kurtosis . . . . = K_G

Kent Sample Number	Md		M_z		σ_I	Sk_I	K_G
	ϕ	mm	ϕ	mm	ϕ		
9K62	+2.62	0.163	+2.49	0.178	1.80	−0.226	1.40
9K63	+1.15	0.451	+0.63	0.645	2.26	−0.274	0.99
9K72	+4.10	0.058	+4.04	0.061	0.77	−0.085	0.95
9K77	−0.15	1.110	−0.43	1.350	2.41	−0.153	0.71
9K78	−0.30	1.231	−0.40	1.320	2.42	−0.092	1.04
9K79	+1.80	0.287	+1.90	0.269	0.93	+0.130	1.08
9K82	−0.80	1.741	−0.70	1.625	2.20	+0.111	0.86
9K83	+0.35	0.785	+0.25	0.841	1.62	−0.028	0.84
71K12	+0.70	0.616	+0.45	0.732	2.25	−0.065	0.90
71K14	+2.05	0.241	+2.08	0.236	1.05	−0.108	1.66
71K15	+1.45	0.366	+1.35	0.392	2.05	−0.081	1.11
Ellsworth Sample Number							
9K51	+1.62	0.325	+1.86	0.275	1.00	+0.439	1.35
9K52	+1.25	0.420	+0.93	0.524	2.25	−0.141	0.95
9K55	+1.43	0.372	+1.56	0.339	1.12	+0.141	1.56
9K56	−0.50	1.414	−0.33	1.260	2.27	+0.167	0.75
9K57	+1.75	0.297	+0.25	0.841	3.25	−0.536	0.80
9K59	+3.70	0.077	+3.73	0.075	1.45	+0.126	1.08

APPENDIX D

PEBBLE COUNT PERCENTAGES FOR SELECTED SAMPLE SITES

Kent Quadrangle

Sample Site Number	Gneiss	Granite	Schist	Phyllite	Quartzite	Quartz	Fine-grained Mafics	Carbonates	Rotten Rock	Miscellaneous
9K11	27	40	7	2	7	15		1		1
9K42	35	32	3	3	27					
9K44	50	24	8	8	8	2				
9K62	34	20	14		16	6	2	6		2
9K68	...48..		...32..		...12..		8			
9K69	...40..		...30..		...22..					8
9K70	42	16	4	2	...16..			16		4
9K72	...52..			8	12	26			2	
9K75	...20..			6	....6..			68		
9K77	38	28	2		26			6		
9K78	...56..			2	32	6	2			2
9K79	30	24	2			24	10	8		2
9K81	16	2		6	14	26		32	4	
9K82	36	20		6	18		2	8	6	4
9K83	46	22		8	2	8		10	4	
9K86	46	20	...12..		6	4	8		4	
71K12	50	8	8		22	6			4	2
71K14	52	16	2		...26..				2	2
71K15	62	20	6		4	6				2
9B1	76	15			9					

APPENDIX D

PEBBLE COUNT PERCENTAGES FOR SELECTED SAMPLE SITES

Ellsworth Quadrangle

Sample Site Number	Gneiss	Granite	Schist	Phyllite	Quartzite	Quartz	Fine-grained Mafics	Carbonates	Rotten Rock	Miscellaneous
9K50	...61..		....3..		14	16		5	1	
9K51	...67..		10	2	...21..					
9K52	...58..		14	26					2	
9K53	70	8	2	4		10	2		2	2
9K54	56	20			12	8	2			2
9K55	...70..		...10..		16	2			2	
9K56	40		8		30	18	2		2	
9K57	...44..		...38..		...18..					
9K59	...56..			6	...34..				4	
9K60	36	42	....2..		...14..			4		2
9K61	80	6	4			2	4		4	
9K64	...48..			16	16	16				4
9K65	...61..		...13..		8		3	14	1	
9K66	...54..		6	6	6	16	8			4
9K67	...42..		...42..		...16..					

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