TABLE 1: Records of Representative Wells: Selected from approximately 500 well logs in the quadrangle to demonstrate

0-31 sand & gravel

31-103 silty sand with

103-112 sand & gravel

with some boulders

the information used to infer subsurface geology.

## INTRODUCTION

NEW JERSEY GEOLOGICAL SURVEY

The Boonton quadrangle is located in northeastern Morris County, New Jersey, Surficial deposits in the quadrangle record at least two glaciations. Deposits on uplands consist of till and colluvium. They are generally less than 20 feet thick but may be as much as 60 feet thick. Valley-fill sediment consists of sand, gravel, silt, and clay deposited in glacial lakes and outwash sheets, and till deposited in the Terminal Moraine. The valley-fill deposits are as much as 400 feet thick. Post-glacial alluvium, swamp and marsh sediment, and talus overlie older deposits in place. They are generally thin and of small extent.

## GEOLOGIC SETTING

The Boonton quadrangle includes parts of the New Jersey Highlands, the Newark Basin and the Green Pond Outlier (fig. 1). The New Jersey Highlands lie north and west of a line extending from Montville through Boonton to Fox Hill. The Newark Basin lies south and east of this line. The Green Pond Outlier includes only the Copperas Mountain-Green Pond area in the far northwestern corner of the quadrangle. The New Jersey Highlands in the Boonton quadrangle are underlain primarily by Precambrian hornblende granite, alaskite, amphibolite, quartz diorite, and biotite-feldspar gneiss, with minor skarn, granite pegmatite, and Mesozoic diabase (Sims, 1958). The Precambrian units are interlayered, folded, and have a predominant northeast-southwest foliation and strike. In the central and eastern parts of the quadrangle the strike of the rock is expressed by northeast-southwest trending ridges and valleys. To the northwest variation in strike around fold noses creates irregular upland

The Highlands are bounded on the southeast by the Highland escarpment. This 200- to 400-foot high escarpment marks the Ramapo Fault, which separates resistant Precambrian rocks on the west from more easily eroded, downdropped Jurassic sedimentary rocks of the Newark Basin to the east. The Jurassic rocks include interbedded red siltstone, sandstone, and conglomerate (Olsen, 1980). Gently-sloping bedrock uplands are developed on the siltstone and sandstone; sharper bedrock hills and ridges form on the conglomerate. In the Boonton quadrangle, the Green Pond Outlier is downfaulted into Precambrian rock along a northeastsouthwest trending fault (Barnett, 1976). Bedrock in the outlier within the quadrangle is conglomerate and quartzite of the Silurian Shawangunk Formation. The strike of the formation is subparallel to the fault. Pre-glacial drainage followed the same routes as present drainage. The only major difference is that the pre-glacial Rockaway River occupied a valley trending across the Highland escarpment southeastward from Denville (as supposed, based on regional geomorphologic considerations, by Davis and Wood, 1889). This valley has become filled with as much as 400 feet of sediment and the Rockaway now flows northeastward from Denville, then eastward through a gap in the Highlands near Boonton.

## **GLACIAL HISTORY**

Deposits of at least two glaciations are preserved in the Boonton quadrangle. The younger deposits are of late Wisconsinan age. The southernmost extent of this glaciation is generally marked by the Terminal Moraine, which extends across the southwestern part of the quadrangle from Fox Hill to Rockaway Borough. The late Wisconsinan deposits were first described in some detail by Cook (1880) and were mapped and described in more detail by Salisbury (1902) and Darton and others

The older deposits are from a pre-late Wisconsinan glaciation and occur in the Highlands south of, and in places beneath, the Terminal Moraine. The pre-late Wisconsinan deposits were first described by Salisbury (1892), who considered them to be post-Kansan and, in places, Wisconsinan, in age, in contrast to the more deeply-weathered Kansan-age deposits further south in the state (Salisbury, 1902). Leverett (1934) and MacClintock (1940), based on the intensity of weathering, considered the deposits to be of Illinoian age. Ridge (1983) based on weathering characteristics and soil development, also postulated an Illinoian age for glacial deposits immediately south of the Terminal Moraine in the Delaware valley to the west of the Boonton quadrangle. Further west, Sevon and others (1975) describe both Illinoian and early Wisconsinan deposits south of the late Wisconsinan border in northeastern Pennsyl-

## Pre-Late Wisconsinan Deposits

In the Boonton quadrangle, no exposures of undisturbed pre-late Wisconsinan deposits were observed. At the surface south of the limit of late Wisconsinan glaciation, pre-late Wisconsinan till that formerly manled bedrock hills has moved downslope and mixed with the underlying weathered bedrock to accumulate in aprons of colluvium along slopes. Exposures show that the colluvium consists of an orange-brown silty sand to sandy silt containing many angular pebbles and cobbles derived from local weathered bedrock, and scattered erratic pebbles and cobbles. Crystalline erratics generally show some weathering of feldspar minerals; Paleozoic sandstone and quartzite erratics are unweathered. Erratics in late Wisconsinan till are unweathered and the matrix is more yellowish. The widespread colluviation and greater clast weathering of these deposits indicates that they predate the glaciation that formed the Terminal Moraine. However, in the absence of an undisturbed weathered profile, no definitive age correlation can be made.

In the subsurface, pre-late Wisconsinan sediment lies beneath late Wisconsinan sediment at and south of the Terminal Moraine. Records of wells south of Denville and in the filled pre-glacial Rockaway valley describe a probable till as much as 20 feet thick (Qplwt) beneath thick sections of late Wisconsinan till and stratified sediment (table 1 and sections AA' and CC'). Sand and gravel (Qplwg) occur above and below this lower till. These units are not exposed at the surface and their age and origin are uncertain. No pre-late Wisconsinan sediment has been observed either at the surface or in the subsurface north of the Terminal Moraine within the quadrangle.

**EXPLANATION** 

Spillway of glacial lake

Recessional ice margin

\_\_\_\_ Limit of late Wisconsinan ice

Terminal Moraine

> 60% Precambrian lithologies

> 40% Paleozoic lithologies

> 30% Mesozoic lithologies

0 1 2 3 km

Maximum extent of glacial

Striation

Pebble lithologies

## Late Wisconsinan Ice Flow

Ice-flow directions indicated by striations, streamlined landforms, scouring and plucking of bedrock outcrops and hills, and pebble lithologies suggest that during the late Wisconsinan advance the Boonton quadrangle was at the junction of a southward-flowing lobe advancing across the Highlands and a southwestwardflowing lobe moving down the lowlands of the Newark Basin (fig. 2). The northwestern third of the quadrangle was glaciated by southward-flowing ice; the southeastern corner by southwestward-flowing ice. Between these two areas of consistent flow there was an interlobate zone that may have been glaciated by ice moving at times to the south and at other times to the south-

Striations on ridgetops in the northwestern third of the quadrangle indicate generally southward flow of ice, oblique to the bedrock strike and topographic grain. Striations and streamlined hills in the southeastern half of the quadrangle indicate generally southwestward flow of ice, parallel to bedrock strike and topographic

Till in the northwestern half of the quadrangle is thicker and more continuous on the northwest-facing slopes. Where the bedrock surface is exposed on these slopes, it is generally smoothed. Southeast-facing slopes are steeper, till is thin and discontinuous, and bedrock crops out as small, joint-controlled cliffs. These observations suggest abrasion of bedrock and emplacement of till on northwest-facing slopes and plucking of bedrock on southeast-facing slopes, again indicating ice flow to the south or southeast. In the Highlands south and east of the Stony Brook Mountains there are no consistent patterns of continuous till or abraded and plucked bedrock surfaces, perhaps because this is the interlobate zone and till was deposited from ice moving at times to the south and at other times to the south-

Pebble lithologies of till or stratified sediment were determined at 47 sites throughout the quadrangle (table 2 and fig. 2). Except in till immediately southeast of Copperas Mountain and in stratified deposits in the area of Jurassic bedrock, Precambrian lithologies dominate. Percentages of pebbles of Precambrian rock range from 19 to 93, and average 69. Paleozoic lithologies, principally Shawangunk conglomerate and gray-brown Devonian sandstone, compose the remainder of the pebbles within the Highlands samples. Paleozoic lithologies drop from a high of 60 percent of the total near Copperas Mountain to a range of 20 to 30 percent in the southeastern two-thirds of the quadrangle. This pattern, like the pattern of striations and till distribution, indicates southerly or southeasterly ice flow across the Highlands. Jurassic and Triassic lithologies are confined to the area of Jurassic bedrock in the far southeastern corner of the quadrangle, where they compose between 8 and 80 percent and average 43 percent of the total. The restriction of these lithologies to east of the Highland escarpment further indicates southwestward flow of ice within the Newark Basin, generally parallel to regional strike. This data is in agreement with striations in the eastern part of the quadrangle. The absence of pebbles of Mesozoic rock within the Highlands indicates that ice did not flow westward or southwestward out of the Newark Basin into the Highlands.

## Maximum Ice Advance and the Terminal Moraine

The farthest advance of late Wisconsinan ice is marked by a sharp boundary between till to the north and older colluvium and fractured and rubbly bedrock outcrops to the south. Colluvium north of the late Wisconsinan limit is neither as widespread nor as thick as that south of the limit. Bedrock outcrops are less numerous south of the late Wisconsinan limit and, where present, display abundant residual rubble and extensive disintegration along joint and foliation planes. These features contrast with largely unweathered polished and plucked outcrops within the late Wisconsinan limit. Southwest of Denville the late Wisconsinan limit lies approximately one mile beyond the southern edge of ridge-and-kettle topography of the Terminal Moraine, indicating that the ice front retreated from its furthest position in places before stabilizing at the Terminal

As ice advanced to its furthest position, the southwesterly-flowing lobe occupying the Newark Basin extended approximately five miles beyond the edge of the south-flowing lobe in the Highlands, as indicated by the embayment of the Terminal Moraine along the Highland escarpment between Morristown and Denville. This advancing ice on the east blocked the pre-glacial Rockaway drainage at Boonton and Fox Hill, creating glacial Lake Denville (Harper, unpub.). Lake Denville spilled over a gap in a bedrock ridge at an elevation of approximately 525 feet, near Tabor in the Morristown quadrangle (fig. 2). Ice in the Highlands advancing through this lake caused deposition of three interbedded units: deltaic and sublacustrine sand and gravel (Qld1), lakebottom and deltaic silt and fine sand (Qldlb1), and till (Qlwt). This sequence attains thicknesses of 200 feet

beyond and beneath the Terminal Moraine. The Terminal Moraine is a belt of ridge-and-kettle topography mostly in till. In the Boonton quadrangle it is as much as 1.5 miles wide and has as much as 50 feet of relief. The topography consists of closed depressions separated by short, narrow-crested, steep-sided ridges or broader, more gently sloping ridges. The ridges within the moraine lack any preferred orientation, although west of Rainbow Lakes and at the hospital east of Denville tall, continuous ridges define the distal edge of the moraine. No such ridges occur on the northern edge of the moraine, where the ridge-and-kettle topography terminates gradually against bedrock ridges and smooth, till-mantled slopes. Several flat-topped, roughly circular, plateau-like mounds up to 800 feet across bounded steep scarps also occur within the moraine. Well records and exposures show that till of the

moraine ranges from approximately 20 to 150 feet thick. Good exposures in the moraine are sparse, but where observed the sediment is a massive, cobbly to bouldery, sand to silty sand, matrix-supported diamict, similar to till outside the moraine. Stratified sediment has been observed at the surface in the moraine in several places, but these deposits are of very small extent. In the vicinity of Denville and along the buried Rockaway valley, till of the moraine overlies the earlier late Wisconsinan and pre-late Wisconsinan units Qld1, Qldlb1, Qplwt, and Qplwg, described above (table 1 and sections AA', CC').

Apparent discontinuities of the moraine in this area,

noted by Salisbury (1902) and cited by Connally and

Sirkin (1973) as evidence for a younger moraine on the

MORRISTOWN OLIAD

River, including the modern alluvium, postdate the retreat of ice from the Rockaway basin. The oldest (Qgn) is a delta at an elevation of 320 feet on the northwest side of Boonton Reservoir. This delta was deposited in the Great Notch stage of Lake Passaic. At the Great

east overprinting an older moraine to the west, are the result of erosion of the moraine by later meltwater descending the Rockaway River and, in places, burial of the moraine by deposition of outwash (sections AA',

Deglaciation from the Terminal Moraine began before 18,000 years ago. This age is based on radiocarbon dates of basal post-glacial sediments at Francis Lake in Warren County (Cotter and others, 1983) and Budd Lake in Morris County (Harmon, 1968). Radiocarbon dates on concretions from glacial Lake Passaic sediment south of Morristown (Reimer, 1984) also suggest deglaciation at about this time. Although no continuous ice margin positions are

traceable across uplands north of the Terminal Moraine, stepwise retreat of a single ice front is indicated by the distribution of ice-marginal and proglacial meltwater channels, which generally slope to the south, and the location of small lacustrine sand and gravel deposits (Qml, Qbr, some of Qgu), which are generally confined to north-draining valleys. If ice had stagnated on a large scale, these features would occur in more scattered orientations controlled by the locations of stagnant ice masses rather than topography. However in several steep-walled, east-west trending valleys, notably at Deer Pond near Taylortown and in the valley of Hibernia Brook south of Marcella, the occurrence of meltwater channels and gravel terraces on both the north and south valley walls well above the level of any open drainage down the valleys suggests the presence of local stagnant ice blocks occupying the valley bottom. Stagnant ice in this topographic setting would be produced as downwasting of the glacier surface caused ice on the south sides of steep bedrock hills to become

detached from the active glacier. As the ice melted back from the Terminal Moraine, sublacustrine sand and gravel (Qld2), which may include sublacustrine fan deposits, collapsed deltaic deposits, and ice-contact diamict, were deposited at the ice front on the bottom of Lake Denville. In places, small deltas were built into the lake by meltwater flowing between the glacier and the side of the valley. These deltas extend along the valley walls and are contiguous in the subsurface with the sublacustrine gravel. They are included in Qld2. Lake-bottom and deltaic fine sand and silt (Qldlb2) were deposited on the lake bottom above the gravel when ice had receded further to the north

(sections AA', DD') Glacial Lake Denville extended up the valleys of Beaver Brook and Stony Brook, as indicated by the extent of gravel terraces (Qld2) graded to lake level. The lake drained when retreating ice in the Newark Basin on the east uncovered the gap in the Highland escarpment at Boonton. At this time the spillway at Tabor was abandoned and meltwater in the Rockaway basin was diverted eastward through the gap at Boonton. This meltwater deposited thin fluvial sand and gravel sheets (Qh, Qb, Qsb, and Qr) atop the Lake Denville sediments. These fluvial sheets form terraces that are graded to the Boonton gap and that are lower in elevation and texturally finer than the Qld2 terraces. Near the northern ends of the Beaver Brook and Stony Brook valleys, at Hibernia, Meriden, and Lake Juliet, the outwash units feather out where the valleys steepen onto bedrock uplands. Thus, meltwater carrying the outwash issued from ice margins on the bedrock uplands to the north of these locations

but within the Rockaway drainage basin. East of the Highland escarpment the retreating ice margin is marked by a succession of deltas (Qlp1, Qlp2 Qlp3, Qlp4) deposited in the Madison stage of glacial Lake Passaic (fig. 2) (Kummel, 1895). Glacial Lake Passaic was a large proglacial lake that filled the Passaic River basin when advancing ice blocked a preglacial gap through the Watchung Mountains at Summit, 12 miles southeast of Boonton. The outlet of Lake Passaic at this time was at an elevation of about 345 feet at Moggy Hollow near Liberty Corner in Somerset County, approximately 20 miles southwest of Boonton. In the Boonton quadrangle the elevation of the Madison stage shoreline is known, from the contact of deltaic topset and foreset beds exposed in the gravel pit in delta Qlp4, to be at an elevation of about 390 feet. The 45-foot increase in elevation between Moggy Hollow

and the Boonton quadrangle is due to isostatic rebound

of between 2 and 3 feet/mile to the north. The lobate shape of the ice margin marked by the configuration of the Terminal Moraine was maintained during deglaciation. As the ice margin descended along the Highland escarpment into the Newark Basin it traversed to the southwest. A minimum length for this traverse of approximately 4 miles is indicated by the position of outwash graded to the Boonton gap. These outwash units, as described above, were deposited from ice margins north of Lake Juliet, and could not have formed until the Boonton gap was uncovered. Therefore, at this time ice in Lake Passaic had just receded past the Boonton gap and could be no further south than delta Qlp2. Thus Qh, Qb, Qr, and Qsb in the Highlands are synchronous with or slightly younger than unit Qlp2 in Lake Passaic.

After the ice receded across the Rockaway-Pequannock divide, north-draining tributary valleys to the Pequannock were dammed to create small proglacial lakes draining to the south over bedrock ridges. In the Boonton quadrangles, Qbr and Qml are deltaic sand and gravel deposited in two such valleys; thin sand and gravel units south of Stickle Pond and along Stone House Brook may have been deposited in a similar set-

When the retreat of the ice front uncovered the outlet of the Pequannock River through the Highland escarpment at Riverdale, approximately 8 miles northeast of Boonton, meltwater in the Highlands was diverted eastward down the Pequannock and southward meltwater drainage through the Rockaway Basin ceased. At about the same time, the gap in the Watchung Mountains at Paterson was uncovered, Lake Passaic drained, and glacial deposition in the Boonton quadrangle ended.

# POST-GLACIAL HISTORY

Four units of alluvium deposited by the Rockaway

Passaic drained through a gap at an elevation of approximately 310 feet in First Watchung Mountain at Great Notch, approximately 10 miles east of Boonton. Downstream from the Boonton Reservoir gravel terraces at elevations of 220 to 260 feet (Qst1) occur 20 to 40 feet above the present floodplain. These terrace deposits are younger than Qgn and post-date complete draining of Lake Passaic through the gap at Paterson. The youngest stream-terrace deposits (Qst2) are notably finer-grained than Qgn and Qst1, and occur 5 to 10 feet above the modern floodplain (Qal). Alluvium deposited on the modern floodplain is also chiefly fine-grained. In addition to alluvium, post-glacial deposits include pond and swamp sediment and talus. Following deglaciation, silt and clay, then peat and muck (Qs), was, and continues to be, deposited in ponds, marshes, and

Notch stage (postulated by Kummel, 1895), Lake

swamps. On uplands these wetlands commonly occupy shallow basins eroded in bedrock; in the valleys of Beaver Brook, Stony Brook, and the Rockaway River, they occupy floodplains and, more rarely, kettle-hole On the southeast side of Copperas Mountain glacial plucking of the resistant, coarsely-jointed quartzite and conglomerate bedrock produced or enhanced cliffs. Coarse, angular talus (Qta) has accumulated at the base of these cliffs. Along most of the cliff the talus is unvegetated and probably still accumulating, but at places it has nearly reached the top of the cliff and the cliff is no longer shedding debris to the deposit.

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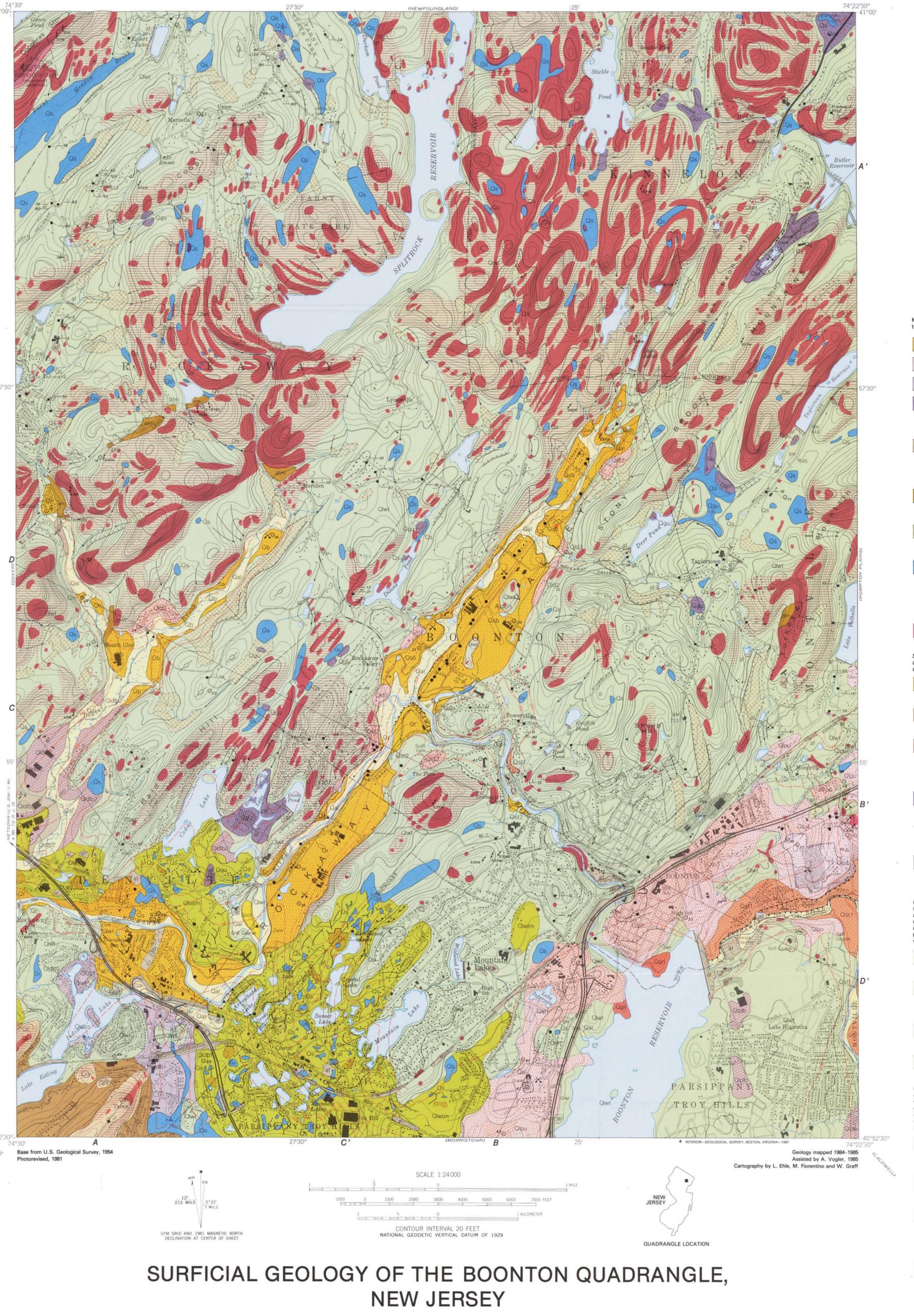
Bulletin 55, Part B, 278 p.

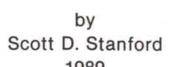
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Figure 1: Map showing location of Boonton quadrangle, drainage basins of the Rockaway

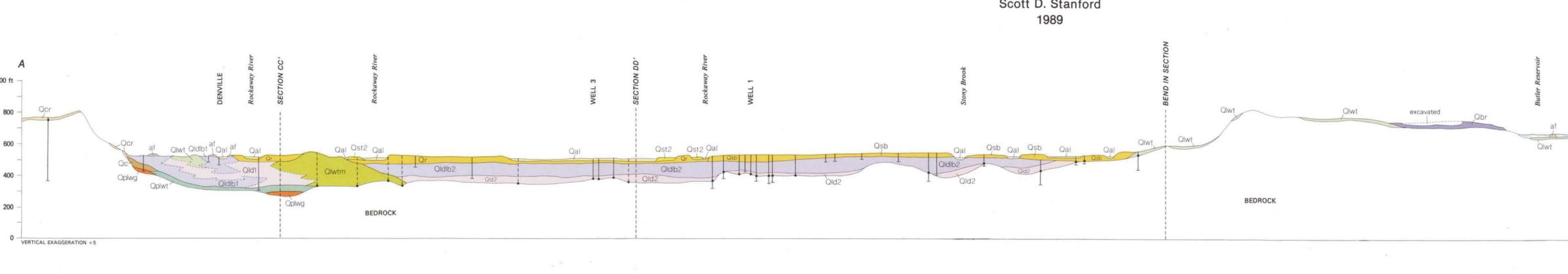
dashed blue lines are drainage basin boundaries.

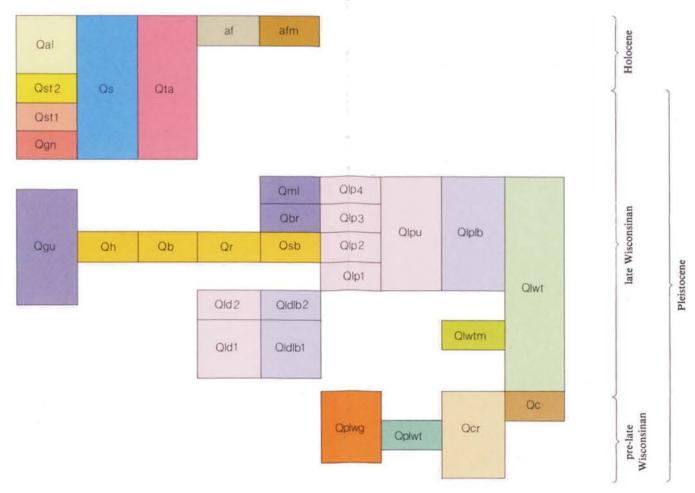
and Pequannock Rivers, geologic provinces, and features named in text. The





VERTICAL EXAGGERATION





CORRELATION OF MAP UNITS

# DESCRIPTION OF MAP UNITS Map units for stratified glacial deposits are colored according fluvial and fluvial-deltaic sand and gravel

upland lacustrine deposits (sand and gravel, minor silt, clay, and diamict) POST-GLACIAL DEPOSITS (HOLOCENE AND LATE WISCONSINAN) Artificial Fill: Excavated till, sand, gravel, and rock; construction debris (brick, concrete, asphalt); cinders and slag. In railroad and

deltaic and sublacustrine sand and gravel

deltaic and lake-bottom fine sand, silt, and clay

Generally less than 10 feet thick; as much as 20 feet thick. Many small areas of fill in urban areas Mine Tailings: Piles and embankments of waste rock excavated from iron mines and rock quarries. Includes angular boulders, cobbles, and pebbles of bedrock; minor sand, cinders, ash, and slag. As much as 20 feet thick.

highway embankments, dams, and filled land

Alluvium: Silt and fine sand; minor clay, pebble gravel, and cobble gravel. Contains variable amounts of organic matter. Includes some peat and muck along the lower reaches of Beaver Brook and Stony Brook. As much as 10 feet thick. Swamp and Marsh Deposits: Typically gray silt brown peat and dark brown to black muck and organic silt. Silt and clay may be interbedded with the peat. In swamps along larger streams peat Generally less than ten feet thick but may be as much as 25 feet thick (Waksman and others,

Talus: Angular boulders of bedrock with little or

no matrix material. Forms steep apron along base

of cliffs on southeast slope of Copperas Mountain. As much as 20 feet thick (estimated). Stream Terrace Deposits: Stratified sediment ranging from silt and fine sand to cobble gravel. Forms terraces 5 to 40 feet above the Rockaway River. Fine sand and silt with minor pebble gravel. Forms terraces 5 to 10 feet above present flood-

Cobble and pebble gravel. Forms terraces 10 to 40 feet above present floodplain. As much as 20 feet thick. Deposited after complete draining of glacial Great Notch Delta: Poorly-sorted, coarse cobble and pebble gravel as much as 10 feet thick. May

overlie as much as 50 feet (estimated) of foreset sand. Deposited into glacial Lake Passaic at the Great Notch stage. **GLACIAL DEPOSITS (LATE WISCONSINAN)** Maple Lake Deposits: Discontinuous pebble and cobble gravel as much as 10 feet thick overlain by ilt and fine sand as much as 100 feet thick. Deposited in a glacial lake within the valley along

over a spillway at an elevation of approximately 730 feet. Deposit thickens and coarsens toward an ice margin position north of Maple Lake in the Wanaque quadrangle. Butler Reservoir Deposits: Cobble and pebble gravel and sand partially filling valley south of Butler Reservoir, Deposited in a small glacial lake draining south over a spillway at an elevation of approximately 770 feet. Original thickness at least 30 feet; largely removed by excavation.

Kinnelon Road. This lake drained to the south

Rockaway Valley Outwash Deposits: Fluvial pebble gravel, sand, and minor cobble gravel deposited on top of lake-bottom and deltaic deposits (Qldlb1 and Qldlb2, described below) after draining of glacial Lake Denville. Includes contemporaneous deposits in the Hiberia Brook valley (Qh), Beaver Brook valley (Qb), along the Rockaway River (Qr), and in the Stony Brook

Stony Brook Outwash: Cobble gravel on north grading to sand and pebble gravel on south. eposited by meltwater from ice margins to the north of the deposit. As much as 30 feet thick. Rockaway River Outwash: Chiefly cobble and pebble gravel on west grading to chiefly sand on east. Deposited by meltwater from ice margins to the west and north in the Dover quadrangle. As much as 40 feet thick but generally less than 25 feet

Beaver Brook Outwash: Pebble gravel and sand, minor fine cobble gravel. Deposited by meltwater from ice margins north of Meriden. As much as 20 feet thick (estimated). Hibernia Brook Outwash: Pebble gravel and sand, minor fine cobble gravel. Deposited by meltwater from ice margins north of Hibernia. As much as 20 feet thick (estimated).

Glacial Lake Passaic Deposits: Deltaic deposits ranging in composition from fine sand and silt to cobble gravel (Qlp Qlp2, Qlp3, and Qlp4); sublacustrine fan deposits ranging in composition from medium sand to pebble gravel with minor cobble gravel (Qlpu); and lake-bottom deposits of fine sand, silt, and clay (QIpIb). Deposited in the Madison stage of glacial Sand and pebble gravel to south; sand and pebble

> north. Deposited from one or more ice margin positions south of the Rockaway River. As much as 100 feet thick. Overlies thick till. Pebble gravel and coarse cobble gravel as much as 20 feet thick overlying silt and sand. Deposited from an ice margin on northeast edge of deposit. As much as 60 feet thick (estimated).

gravel, locally coarse cobble and boulder gravel to

Sand with minor silt and pebble gravel overlain by

pebble and cobble gravel and some boulder

gravel. Deposited from an ice margin on northeast

edge of deposit and fed, in part, by meltwater

descending the Highland escarpment from the north. Thickens from a feather-edge on the northwest to an estimated 100 feet thick on the southeast. Overlies thick till on the northwest. Silt and fine sand as much as 50 feet thick overlain by sand and pebble gravel as much as 40 feet thick, in turn overlain by pebble to cobble gravel as much as 10 feet thick. Deposited from ice margin on northeast edge of deposit and fed. in part, by meltwater descending the Highland escarpment from the north. Entire deposit is approximately 50 feet thick on the northeast; 100

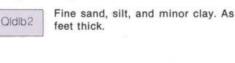
feet thick on the southeast. Medium sand to pebble gravel with minor cobble gravel. Deposited on the lake bottom at the ice front. Generally overlies till or bedrock. Occurs in low knolls or as sheets draped over bedrock. Con relation to major deltas uncertain. As much as 50 feet thick (estimated).

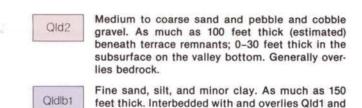
Thinly-layered to massive, fine sand, silt, and clay

deposited on the lake bottom at some distance

from the ice front. As much as 40 feet thick. Gradational to deltaic deposits in places. Glacial Lake Denville Deposits: Sediment deposited in glacial Lake Denville. South of the Terminal Moraine lake-bottom and deltaic fine sand, silt, and minor clay (Qldlb1) is interbedded with sublacustrine sand and gravel (Qld1) and till (Qlwt, described below). North of the Terminal Moraine there is a vertical sequence of sublacustrine sand and gravel (Qld2), overlain by lake-bottom and deltaic fine sand, silt, and minor

clay (Qldlb2). Qld2 includes small remnants of deltas deposited along the valley walls. Oldlb2 Fine sand, silt, and minor clay. As much as 100 feet thick.





Qldlb1 and, in places, Qlwt. As much as 100 feet thick. Occurs in subsurface only. Stratified Drift (uncorrelated): Chiefly lacustrine sand and pebble gravel, some cobble gravel; includes clayey silt in deposit along Stone House Brook in Kinnelon, Generally less than 20 feet thick. Forms small terraces and knolls; occurs as

glacial lakes uncertain.

Till: Unstratified and unsorted boulders, cobbles, and pebbles in a silty fine sand to fine to medium sand matrix. In the Highlands the matrix color is vellowish brown (10YR5/4-5/6) (oxidized) or gravish brown (10YR5/2) (unoxidized). Observed depths of oxidation range from about 5 to 20 feet. In the Newark Basin the matrix is commonly reddishbrown (5YR5/3-5/4). North of the Terminal Moraine the till is as much as 60 feet thick and averages about 20 feet thick in areas of continuous till. Til is generally thicker and more continuous on the northwest-facing slopes of principal ridges and hills. In places till is underlain by weathered bedrock. South of the Terminal Moraine, late Wisconsinan till extends as much as one mile beyond the limit of ridge-and-kettle topography. It is as much as 50 feet thick on the hill southeast of ndian Lake and occurs in patches as much as 50 feet thick interbedded with glacial Lake Denville

of steep slopes. Colluvium consists of erratic pebbles, cobbles, and boulders, and, in places, angular pebbles, cobbles, and boulders of local bedrock, in a matrix of orange-brown to yellowbrown silty fine sand to coarse sand. It may be as much as 10 feet thick. Till of the Terminal Moraine: Till as above forming ridge-and-kettle topography of the Terminal Moraine. Includes minor amounts of stratified sand and gravel. Average thickness about 50 feet; maximum thickness about 150 feet. The till is in-

glacial Lake Denville. **GLACIAL AND NON-GLACIAL DEPOSITS** plain. As much as 10 feet thick (estimated). Prob-(PRE-LATE WISCONSINAN) Colluvium: Unstratified and unsorted boulders cobbles, and pebbles of angular bedrock frag ments and some rounded erratics in an orangebrown silty sand matrix. Estimated to be as much

> Partly of late Wisconsinan age. Colluvium and Weathered Bedrock: Discontinuous colluvium, as above, generally less than 10 feet thick, overlying weathered bedrock. Weathered bedrock ranges from sandy (minor clayey sand) saprolite to a rubble of angular cobbles of frac tured rock with little or no matrix. It may be as much as 50 feet thick, although thickness is quite variable. In places the colluvium may be replaced by a diamict produced by in-place mixing of prelate Wisconsinan till and underlying weathered bedrock, with little or no downslope movement. Partly of late Wisconsinan age.

sinan deposits in and south of the Terminal Moraine. Inferred from records of wells and test borings. May be as much as 60 feet thick. Stratified Deposits: Sand and gravel with minor silt and clay, possibly deposited in a pre-late Wisconsinan glacial lake. May include pre-glacia or inter-glacial fluvial sand and gravel. Present in subsurface only. As much as 60 feet thick.

MAP SYMBOLS Bedrock Outcrop: Ruled pattern indicates scattered bedrock outcrop; surficial deposits generally

less than 10 feet thick. Solid pattern indicates extensive bedrock outcrop; surficial deposits generally absent. Dot indicates isolated bedrock outcrop in area where surficial deposits are generally greater than 10 feet thick. Surface accumulations of boulders, generally on terraces and valley bottoms. May be erosional lags produced by subglacial, proglacial, and icemarginal meltwater. Does not include talus (unit Meltwater channel: Narrow, linear, boulder-filled

Striation: observation at dot Axis of streamlined hill Contact: dashed where approximately located Scarp eroded by meltwater

Excavation scarp Post-glacial scarp Active gravel pit Inactive gravel pit Inactive quarry

feet, 100 feet where data is sparse. Shown only where depth to rock generally exceeds 20 feet. Contours based on approximately 500 well records and test borings selected from files of the N. J. Department of Environmental Protection, Division of Water Resources, and several dozen seismic traverses from Geonics (1979) and Stanford and Canace (unpub.).

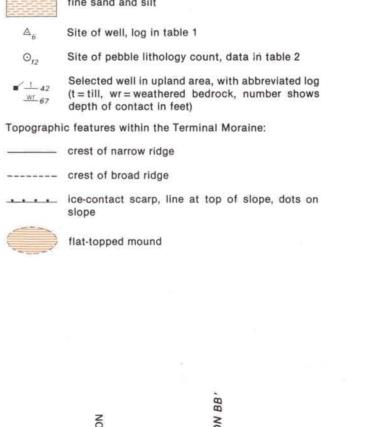
 Well or test boring used to construct section Seismic traverse used to construct section (Geonics, 1979; Stanford and Canace, unpub.) Well or test boring on section, dot indicates location of bedrock surface Seismic traverse on section, dot indicates loca-tion of bedrock surface

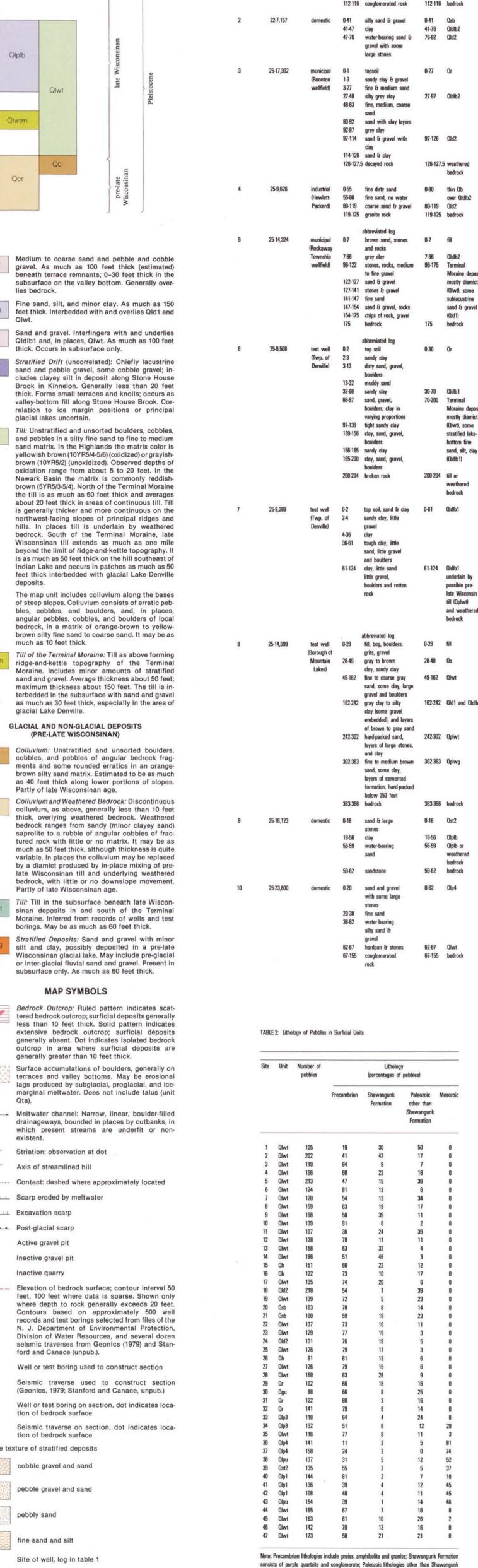
Surface texture of stratified deposits cobble gravel and sand pebble gravel and sand

fine sand and silt  $\triangle_6$  Site of well, log in table 1

depth of contact in feet) Topographic features within the Terminal Moraine:

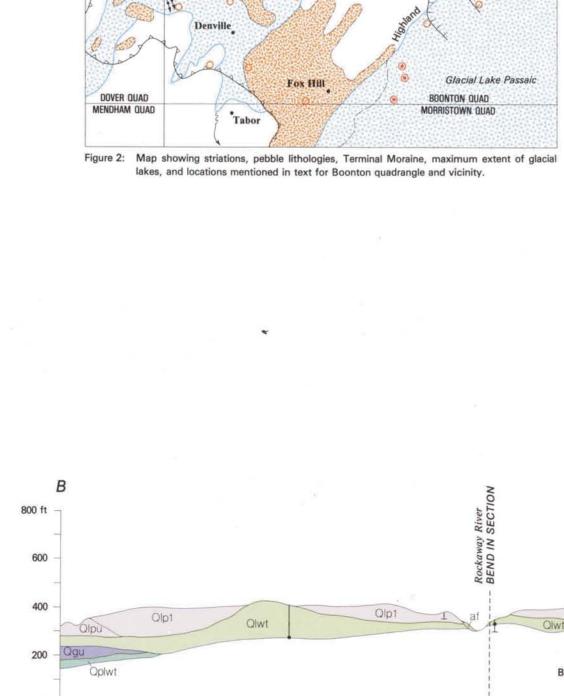
— crest of narrow ridge ----- crest of broad ridge





Formation are predominantly gray to brown sandstone and shale, with minor carbonate and

chert; and the Mesozoic lithologies are reddish-brown sandstone and shale.



VERTICAL EXAGGERATION ×