PREPARED IN COOPERATION WITH THE
U. S. GEOLOGICAL SURVEY
NATIONAL GEOLOGIC MAPPING PROGRAM

DESCRIPTION OF UNITS

Map units denote unconsolidated materials more than 5 feet thick. Color designations, based on Munsell Color Company (1975), were determined from naturally moist samples. Numbers after a map symbol (for example Qbr1) identify a morphosequence, which is a meltwater deposit or suite of meltwater deposits laid down at and beyond the glacier margin, and associated with a unique ice-recessional position. Higher numbers represent younger morphosequences, and the letter "u" indicates an uncorrelated deposit. Numbering for the Paulins Kill deposits follow sequentially from Witte (1988).

Postglacial deposits

af Artificial fill -- Rock waste, gravel, sand, silt, and manufactured materials. As much as 25 feet thick. Not shown beneath roads, and railroads where it is less than 10 feet thick.

Qal Alluvium (Holocene) -- Stratified, well-to moderately-sorted sand, gravel, silt, and minor clay and organic material. Locally bouldery. As much as 25 feet thick. Includes planar- to cross-bedded gravel and sand in channel deposits, and cross-bedded and rippled sand, massive and parallel-laminated fine sand, and silt in flood-plain deposits. In places, overlain by and interlayered with thin organic material and colluvium.

Qcal Colluvium and alluvium undifferentiated (Holocene and late Wisconsinan) -- Sand, silt, and gravel in thin sheets occupying small valleys and basins in upland areas. Thinly bedded and poorly to moderately sorted. Locally underlain by and interlayered with silty to silty-sandy diamicton; as much as 15 feet thick. Includes lag boulders and cobbles in small upland valleys.

Qaf Alluvial-fan deposits (Holocene and late Wisconsinan) -- Stratified, moderately to poorly sorted sand, gravel, and silt in fan-shaped deposit. As much as 35 feet thick. Includes massively to planar-bedded sand and gravel and minor cross-bedded channel-fill sand. Beds dip as much as 30° toward the trunk valley. Stratified sediment is locally interlayered with poorly sorted, sandy-silty to sandy gravel.

Qst Stream-terrace deposits (Holocene and late Wisconsinan) -- Stratified, well- to moderately-sorted sand, and pebble gravel, and silt in terraces flanking present or former stream courses. As much as 25 feet thick. Includes planar to cross-bedded sand and gravel in stream-channel deposits, and massive to laminated fine sand and silt of overbank deposits.

Qs Swamp deposits (Holocene and late Wisconsinan) -- Peat of reed, sedge, and woody origin, and muck underlain by laminated organic-rich silt and clay. As much as 25 feet thick. Locally interbedded with alluvium and thin colluvium. In areas underlain by carbonate rock, marl as much as 20 feet thick, typically underlies peat and muck.

Qta Talus (Holocene and late Wisconsinan) -- Angular boulders, as much as 15 feet long, cobbles, and smaller rock fragments that lie at the base of bedrock cliffs and steep slopes. As much as 20 feet thick. In places may include colluviated till at its downslope termination.

Glacial Deposits

Till (late Wisconsinan)

Qkv Till -- Compact, unstratified, poorly sorted yellowish-brown (10YR 5/4), light yellowish-brown (2.5Y 6/4), light olive-brown (2.5Y 5/4) to grayish-brown (2.5Y 5/2), gray (5Y 5/1) to olive-gray (5Y 5/2) noncalcareous to calcareous silt and sandy silt that typically contains 5 to 15 percent gravel. As much as 100 feet thick. Locally overlain by thin, discontinuous, noncompact to slightly compact, poorly sorted, indistinctly layered, yellow-brown (10YR 5/6-8) to light yellowish-brown (10YR 6/4) sandy silt that contains as much as 30 percent gravel, and minor thin beds of well- to moderately sorted sand, gravel, and silt. Clasts chiefly consist of unweathered slate, siltstone and sandstone, dolomite, limestone, chert, minor quartzite, and quartz-pebble conglomerate. The matrix is a varied mixture of unweathered quartz, rock fragments, and silt; minor constituents include feldspar and clay. Derived chiefly from slate, graywacke, dolomite, and minor limestone in Kittatinny Valley, and limestone, argillaceous limestone, shale, and sandstone in Minisink Valley. Near New Jersey Highlands, additional minor constituents include mica, heavy minerals, and fragments of gneiss. Subscript "r" denotes areas of till less than 10 feet thick, and few bedrock outcrops.

Qkmq Till -- Slightly compact to compact, unstratified, poorly sorted yellowish-brown (10YR 5/4), brown (10YR 5/3, 7.5 YR 5/4) to light olive-brown (2.5Y 5/4) silty sand and sand containing 10 to 20 percent gravel. As much as 50 feet thick. Locally overlain by thin, discontinuous, noncompact, poorly sorted and layered, sand and minor silty sand, similar in color to lower till, that contains as much as 35 percent gravel, and minor thin beds of well- to moderately-sorted sand and pebbly sand. Clasts chiefly consist of unweathered quartz-pebble conglomerate, quartzite, red sandstone, and red shale. The matrix is a varied mixture of quartz, rock fragments, and silt, minor feldspar, and clay. Derived chiefly from quartzite, and quartz-pebble conglomerate of the Shawangunk Formation. Subscript "r" denotes areas of till less than 10 feet thick, and few bedrock outcrops.

Qkms Till -- Slightly compact to compact, unstratified, poorly sorted reddish-brown (5YR 5-4/3) noncalcareous sandy silt to silty sand containing 10 to 20 percent gravel. As much as 25 feet thick. Clasts chiefly consist of unweathered red sandstone, and red shale, some quartzite, quartz-pebble conglomerate, and minor carbonate rock, calcareous siltstone, and sandstone. The matrix is a varied mix of nonweathered quartz, rock fragments, silt, and minor clay. Restricted to the subsurface, beneath unit Qkmq (profile C-C').

Recessional Moraine (late Wisconsinan)

Unstratified to poorly stratified sand, gravel, and silt deposited at the margin of a glacier. As much as 80 feet (24 m) thick. Consist of poorly compact, stony till, silty-sandy compact till, and minor lenses and layers of water-laid sand, gravel, and silt, in discontinuous, bouldery, chiefly cross-valley segmented ridges marking the former lobate glacier margin.

Qom Ogdensburg-Culvers Gap Moraine -- Two morainal segments on Kittatinny Mountain southwest of Sunrise Mountain; as much as 60 feet thick (estimated). Correlative with Dingmans Ferry Moraine in Minisink Valley (Witte, 1991a).

Qam Augusta Moraine -- Eleven morainal segments in Kittatinny Valley and on Kittatinny Mountain; as much as 23 feet thick near Augusta (profile A-A'), and on Kittatinny Mountain estimated to be as much as 65 feet thick (profile C-C'). Correlative with Montague Moraine in Minisink Valley (Witte, 1991a).

Qlm Libertyville Moraine -- Small morainal ridge 0.5 mile north of Libertyville; as much as 45 feet thick (estimated).

Qm -- Small areas of hummocky topography underlain by till; origin uncertain.

Deposits of meltwater streams (Ice-marginal and non-ice-marginal fluvial morphosequences), **late Wisconsinan**

Qpdu Upper Papakating Creek, and Dry Brook deposits -- Cobble-pebble gravel and sand, and pebble gravel and sand as much as 40 feet thick (estimated) in uncorrelated and undifferentiated meltwater deposits laid down along the upper reaches of Papakating Creek, and Dry Brook. Deposits are graded to the surface of sequences Qpk14 and Qwk1a.

Qmt Meltwater terrace deposits -- Pebble gravel and sand, and pebbly sand as much as 10 feet thick in uncorrelated and undifferentiated outwash laid down as terrace deposits, and lag deposits of boulder-cobble gravel lying on erosional surfaces. Most are distal parts of morphosequences or strath terraces cut in meltwater deposits and till. Deposition followed lowering of local base-level control downvalley because of erosion or decline in lake level.

Deposits of glacial lakes Ice-marginal and non-ice-marginal lacustrine, fluvial-lacustrine, and lacustrine-fluvial morphosequences, **(late Wisconsinan)**

Lake Beaver Run deposits

Ice-marginal deltas, lacustrine-fan and lake-bottom deposits laid down in Lake Beaver Run. Deltas consist of cobble gravel, cobble-pebble gravel, and sand topset beds near collapsed heads of outwash to cobble-pebble, pebble gravel, and sand topset beds downstream. Topset beds overlie pebble gravel and sand, pebbly sand, and silt foreset beds that overlie and grade laterally in subsurface, and interfinger with lake-bottom deposits in southwestern part of lake basin. Lacustrine fan deposits lack topset beds.

Qbr1 (Harmonyvale Delta) -- Large ice-marginal delta as much as 90 feet thick (profile B-B') that partially fills the Beaver Run valley south of Harmonyvale; elevation of the delta-plain surface is estimated to be 585 feet. A till-floored spillway at the south end of the Crooked Swamp basin in the Newton East quadrangle controlled the level of Lake Beaver Run. The spillway has since been lowered by erosion.

Qbr2 -- Ice-marginal deltaic deposits (table 2, sec. no. 9) as much as 80 feet thick (estimated) near Harmonyvale laid down in a small lake ponded between the margin of the ice lobe and the Harmonyvale Delta. Altitudes of delta-plain surfaces are estimated to be 590 feet. This shows that the elevation of the small lake was controlled by a spillway cut through sequence Qbr1, elevation 575 feet, and that a lower outlet, 0.5 miles north of Harmonyvale, was covered by ice.

Qrblf -- Uncorrelated lacustrine fan deposits and collapsed deltaic sediment as much as 65 feet thick (estimated) laid down in Lake Beaver Run.

Qbru -- Small uncorrelated ice-marginal deltas, collapsed ice-channel deposits, and lacustrine-fan deposits as much as 35 feet thick (estimated) laid down in Lake Beaver Run.

Qbrlb -- Lake-bottom deposits laid down in Lake Beaver Run; as much as 50 feet thick (estimated). Chiefly in the subsurface, and overlain by swamp deposits or deltaic sediment.

Lake Wallkill deposits

Ice-marginal deltas, fluviodeltas, lacustrine fans, and lake-bottom deposits laid down in Lake Wallkill. Sequences Qwk1, Qwk1a, and Qwk2 were deposited during the Frankford Plains phase of Lake Wallkill, based on the estimated elevation of topset-foreset contacts. The lake's spillway during the Frankford Plains phase was over the Augusta Moraine and morphosequence Qpk14. It was situated as much as 25 feet higher than the stable Augusta spillway. Deltas consist chiefly of cobble gravel, pebble-cobble gravel, and sand topset beds near heads-of-outwash to pebble gravel and sand topset beds downstream. These overlie pebble gravel and sand, pebbly sand, and sand-silt foreset beds that overlie and grade laterally in subsurface and interfinger with, lake-bottom deposits. Lacustrine fan deposits have similar textures but lack topset beds.

Qwk1 -- Ice-marginal delta (table 2, sec. nos. 1 and 2), as much as 95 feet thick (profile A-A', well 8) north of the Augusta Moraine; elevation of delta plain is estimated at 525 feet. The delta is extensively collapsed and appears to have been deposited in an ice-walled channel. The main part of the delta is generally flat-topped. However, it was in part laid down on and against stagnant ice that occupied the lake basin south and west of the deposit. The Armstrong Delta is correlated with smaller ice-marginal deltas and lacustrine-fan deposits that are as much as 45 feet thick (estimated), and located on the west side of Papakating Creek, valley west of Pellettown and Armstrong.

Qwk1a (Frankford Plains Delta) -- Fluviodelta (table 2, sec. nos. 2 and 3), as much as 100 feet thick. Derived from outwash transported down a small tributary valley northwest of the deposit; elevation of delta plain is estimated at 530 feet and a topset-foreset contact exposed in a soil-test pit (sec. no. 2) near Frankford Plains Church revealed 12 feet of fine gravel-and-sand topset beds overlying sand-and-fine-gravel foreset beds. The delta has a digitate front and is partially built over the collapsed head-of-outwash of sequence Qwk1. This is shown by exposures in a small sand and gravel pit (sec. no. 3) found approximately 3000 feet southwest of Frankford Plains Church where sand and fine-gravel foreset beds of the delta overlie collapsed sand-and-coarse-gravel foreset beds of sequence Qwk1. Sequence Qwk1a consists of glaciofluvial sediment along the upper reaches of Papakating Creek

Qwk2 (Armstrong Delta) -- Large ice-marginal delta (table 2, sec. nos. 4, 12, and 13), as much as 80 feet thick (profile A-A') near Armstrong; elevation of topset-foreset contact is estimated at 525 feet, based on exposures in a sand and gravel pit (sec. no. 12). The northern part of the delta is extensively collapsed and appears to have been deposited in an ice-walled channel. The main part of the delta is generally flat-topped. However, it was in part laid down on and against stagnant ice that occupied the lake basin south and west of the deposit. The Armstrong Delta is correlated with smaller ice-marginal deltas and lacustrine-fan deposits that are as much as 45 feet thick (estimated), and located on the west side of Papakating Creek valley, west of Pellettown and Armstrong.

Qwk3 -- Small ice-marginal delta as much as 45 feet thick on the west slope of Papakating Creek valley, southwest of McCoys Corner; elevation of delta-plain surface is estimated at 520 feet. This suggests that the level of Lake Wallkill at this time was probably controlled by the Augusta spillway, which is approximately 5 miles to the southwest.

Qwk4 (McCoys Corner Delta) -- Fluviodelta (table 2, sec. no. 10), as much as 100 feet thick (profile C-C'). Delta consists of outwash from the West Branch Papakating Creek valley; elevation of delta-plain surface is estimated at 525 feet. The distal margin of the delta lacks lobate geometry, therefore, it presumably was deposited against ice, or it may have been eroded by postglacial streams.

Qwklf -- Uncorrelated lacustrine-fan deposits, and extensively collapsed small ice-marginal deltas and ice-channel fillings (table 2, sec. nos. 5 and 6) as much as 80 feet thick (estimated) laid down in Lake Wallkill. These deposits form small knolls and hillocks that protrude up through lake-bottom deposits.

Qwku -- Small, uncorrelated, meltwater deposits, presumably of glaciodeltaic origin, laid down in the Lake Wallkill drainage basin; as much as 45 feet thick (estimated).

Qwklb -- Lake-bottom deposits as much as 65 feet thick (profile A-A') laid down in Lake Wallkill. Chiefly fill lake basin northeast of the Armstrong delta.

West Branch Papakating Creek deposits

Ice-marginal deltas, fluviodeltas, ice-channel fillings, and lake-bottom deposits laid down in small, successively lowering, unnamed glacial lakes in the West Branch drainage basin. Deltaic deposits chiefly consist of cobble gravel, cobble-pebble gravel, and sand topset beds at collapsed heads-of-outwash to pebble gravel and sand downstream. Topset beds overlie foreset beds of pebble gravel and sand, pebbly sand, and sand with minor silt and clay. Foreset beds overlie and grade laterally, and interfinger with, lake-bottom deposits in the subsurface.

Qwb1 -- Small collapsed ice-channel filling, as much as 35 feet thick (estimated), northeast of Beemerville laid down between the margin of the ice lobe and the valley wall.

Qwb2 -- Ice-marginal delta (table 2, sec. nos. 15 and 16) as much as 80 feet thick (estimated) north of Beemerville that filled a small lake basin; elevation of delta-plain surface is estimated at 765 feet. The delta is graded to a spillway approximately 1000 feet west of the village of Beemerville, elevation 755 feet.

Qwb3 -- Small ice-marginal deltas, and lacustrine-fan deposits as much as 65 feet thick (estimated) northwest of Plumbsock; elevation of delta-plain surfaces is estimated at 730 feet. A spillway over a local drainage divide approximately 1 mile to the south at an elevation 705 feet, seems too low to have controlled the level of this lake. Presumably it was blocked by ice or drift.

Qwb4 -- Extensively collapsed ice-marginal delta and fluviodelta (table 2, sec. nos. 18, 19, 20, and 21), each as much as 150 feet thick (profile C-C') east of Plumbsock; elevation of delta-plain surfaces range between 675 and 625 feet. The altitude of glacial lake was initially controlled by a spillway approximately 5000 feet northwest of Woodbourne at an elevation 665 feet. The fluviodeltaic part of the sequence was laid down by outwash transported downstream along the deglaciated reach of West Branch valley. These deposits have been extensively eroded by later meltwater and postglacial streams.

Qwb5 -- Fluviodelta (table 2, sec. no. 17) as much as 80 feet thick (profile C-C') north of Woodbourne; elevation of delta-plain surfaces varies between 575 and 565 feet (estimated), suggesting that the lake's outlet was over drift or ice. The delta appears to consist of outwash transported downstream along the deglaciated reach of West Branch and an unnamed south-draining tributary valley. Erosional channels and surfaces, downcut into the delta plain to elevations between 635 and 625 feet, are probably graded to the surface of the McCoys Corner Delta, and suggest that during the later stages of deposition the lake drained.

Qwbu -- Small uncorrelated ice-marginal deltas, lacustrine fans, and ice-channel fillings (table 2, sec. no. 4) as much as 45 feet thick (estimated) in the West Branch drainage basin.

Qwblb -- Lake-bottom deposits as much as 50 feet thick (profile C-C') laid down in small proglacial lakes in the West Branch drainage basin. Lies chiefly in subsurface beneath Qwb2, Qwb3, and Qwb4 deltaic deposits.

Qwtu **Wykertown deposits** -- Chiefly cobble-pebble gravel, pebble gravel and sand; and pebbly sand, sand, and minor silt and clay in ice-marginal deltas, fluviodeltas, and possibly ice-channel fillings; as much as 45 feet thick (estimated). Deposits laid down in small, unnamed stream valleys in the Wykertown area; elevations range between 705 and 675 feet. One exposure (table 2, sec. no. 11), and similarity between elevations of deposits and low points on nearby drainage divides, suggest that these are deltaic deposits laid down in small proglacial lakes. This shows that drainage to Papakating Creek valley was blocked by ice and/or drift.

Qwtlb -- Lake-bottom deposits as much as 40 feet thick laid down in small glacial lakes near Wykertown. Chiefly in subsurface beneath Qwtu deposits.

Qcb1 **Clove Brook deposit** -- Ice-marginal delta as much as 80 feet thick (estimated) approximately 5000 feet east of Libertyville. Laid down in small proglacial lake that occupied a north-draining valley in the Clove Brook drainage basin; elevation of delta-plain surface is estimated at 665 feet. The delta is extensively collapsed and graded to a spillway at its south end; elevation 655 feet.

Upper Paulins Kill valley deposits

Ice-marginal deltas, fluviodeltas, and lake-bottom deposits laid down in small drift-dammed lakes in the upper Paulins Kill valley.

Qpk13 -- Ice-marginal delta as much as 50 feet thick (estimated) laid down in a small proglacial lake dammed by older recessional deposits downvalley in the Newton West quadrangle. The altitude of the delta-plain surface is estimated at 530 feet.

Qpk14 -- Ice-marginal delta and fluviodelta as much as 90 feet thick (profile A-A') laid down in a proglacial lake dammed by sequence Qpk13 and by older recessional deposits downvalley in the Newton West quadrangle. Altitudes of delta-plain in the Augusta area ranges from 530 to 510 feet. The Qpk14 deposits in the small valley east of Branchville have been extensively aggraded to an elevation above that of deltaic deposits in the valley.

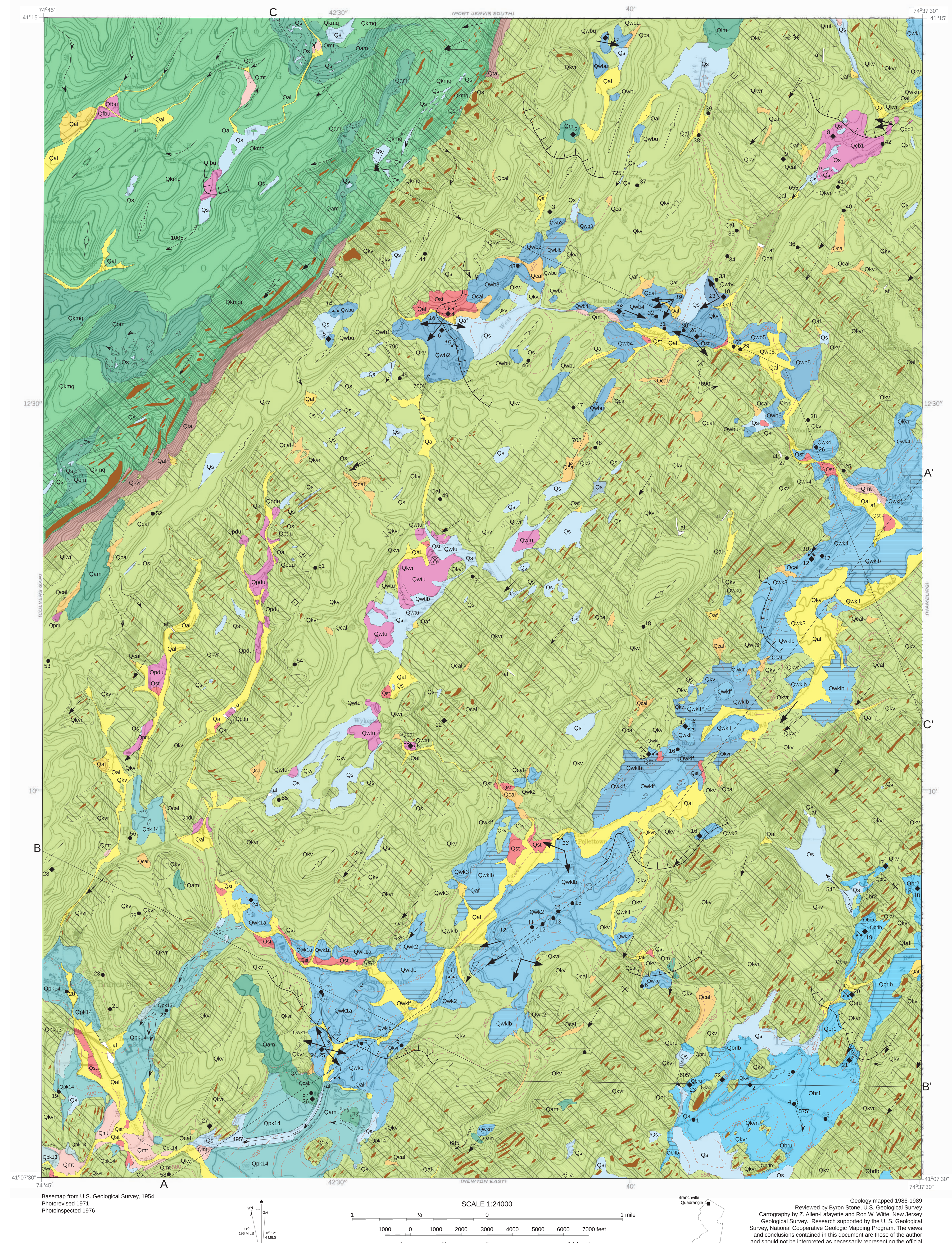
Qfbu **Big Flat Brook deposits** -- Uncorrelated and undifferentiated outwash as much as 40 feet thick (estimated) deposited in the Big Flat Brook drainage basin.

Pre-Wisconsinan deposits (Illinoian)

Qig -- In subsurface only (profile C-C'). Undifferentiated till and possibly meltwater sediment beneath late Wisconsinan glacial drift on Kittatinny Mountain. May form the core of some thick drumlins in Kittatinny Valley.

Bedrock

Bedrock--Extensive outcrops, minor regolith, and scattered erratics.



SURFICIAL GEOLOGIC MAP OF THE BRANCHVILLE QUADRANGLE, SUSSEX COUNTY, NEW JERSEY

by

Ron W. Witte

2008

EXPLANATION OF MAP SYMBOLS

Contacts, dashed where inferred.

Elevation of the bedrock surface, shown in valleys where depth to rock exceeds 50 feet.

Morainal ridge.

Meltwater-cut scarp.

Man-made scarp in a sand & gravel pit.

Position of ice margin. Tics point toward former ice sheet.

Fluvial scarp, tics point upslope.

Large kettle in glacial outwash or moraine.

Drumlin, denotes long axis.

Striation, measurement at tip of arrow.

Small meltwater channel.

Large meltwater channel.

Glacial-lake spillway with estimated elevation of its floor.

Direction foreset beds are dipping.

Active sand and gravel pit.

Inactive sand and gravel pit.

Active quarry.

Inactive quarry.

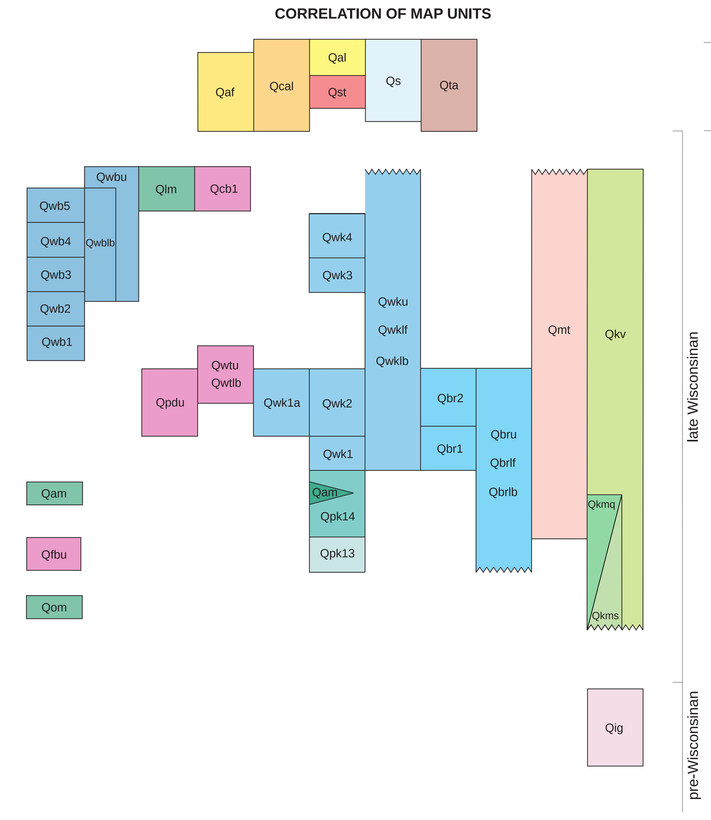
Well or boring. Geologic log in Table 1.

Gneiss erratic.

Description of materials observed in sand and gravel pits, excavations, and soil test pits in Table 2, Plate 2.

Location of pebble sample, composition shown in Table 3, Plate 2.

CORRELATION OF MAP UNITS



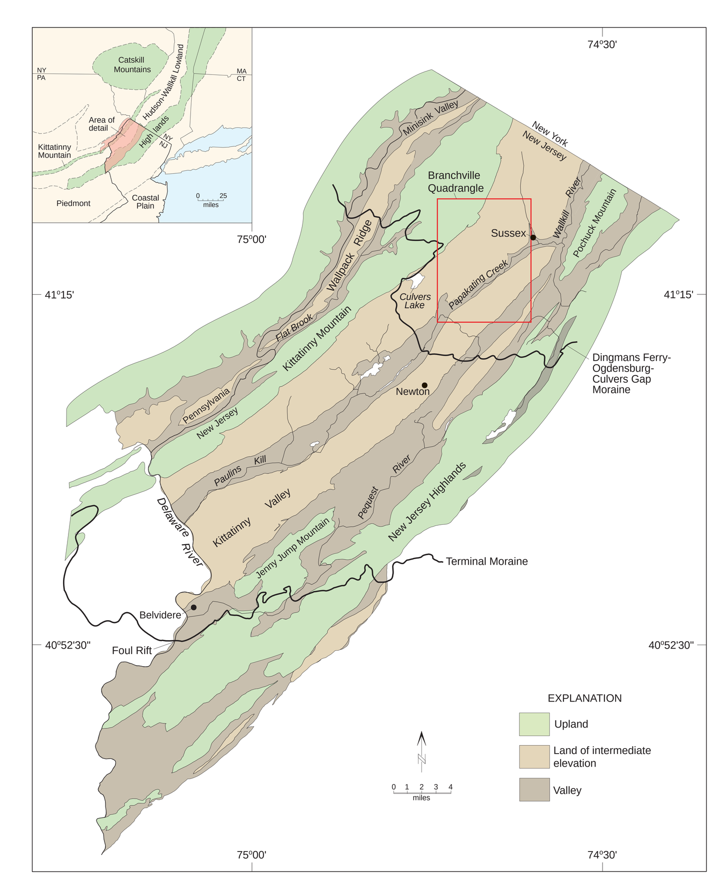


Figure 1. Physiography of northwestern New Jersey and northeastern Pennsylvania, and location of the Branchville quadrangle. Kittatinny Valley is a local geographic name for the southwest continuation of the Hudson-Wallkill lowland.

INTRODUCTION

The Branchville quadrangle lies within the glaciated Valley and Ridge Physiographic Province in Sussex County, northern New Jersey (fig. 1). Most of it lies in Kittatinny Valley, except its northwest corner, which covers part of Kittatinny Mountain. The land is largely rural, marked by patches of woodlands and cultivated fields in Kittatinny Valley and large tracts of forested land on Kittatinny Mountain. A drainage divide between the Delaware and Hudson Rivers runs through the southern part of the quadrangle. The highest point is on Kittatinny Mountain, 1653 feet above sea level and the lowest point lies along Papakating Creek, approximately 395 feet above sea level.

Surficial materials in the quadrangle include glacial drift, alluvium, colluvium, talus, lacustrine sediment, and swamp deposits of late Pleistocene and Holocene age. Collectively, they may be as much as 175 feet thick, lie on bedrock, and form the parent material for soil. The glacial deposits are late Wisconsinan age and are correlative with the Olean drift (Crowl and Sevon, 1980) in northeastern Pennsylvania. Till typically lies directly on bedrock, and is generally less than 20 feet thick. In many areas it is interspersed with many bedrock outcrops. Thicker till forms drumlins, ground moraine, and aprons on north-facing hillslopes. Meltwater sediment, laid down at and beyond the glacier margin, lies in stream valleys through which Beaver Run, Papakating Creek, and Big Flat Brook now flow. The heads-of-outwash of these deposits, and the Augusta, Ogdensburg-Culvers Gap, and Libertyville moraines mark ice-retreatal positions and minor readvances of the Kittatinny Valley lobe.

The identification of meltwater deposits, and delineation of ice-retreatal positions is based here on the morphosequence concept of Koteff and Pessl (1981). A morphosequence is "... a body of stratified drift laid down layer upon layer by meltwater at and beyond the margin of the glacier, with deposition controlled by a specific base level." Meltwater deposits are grouped into six types of morphosequences (fig. 2). Their distribution provides a firm basis for morphostratigraphic analysis of glacial retreat, a clearer understanding of regional and local ice flow patterns, and the correlation of glacial events within a regional context.

BEDROCK GEOLOGY AND PHYSIOGRAPHY

Kittatinny Valley (fig. 1) is a broad northeast-trending lowland chiefly underlain by dolomite, limestone, slate, siltstone, and sandstone; all of Cambrian to Ordovician age. Dolomite and limestone (fig. 3) underlie the valleys through which Beaver Run and Paulins Kill flow. Relief here is generally less than 100 feet; the rock surface is marked by knobby, irregular topography of moderate to steep slopes. The more resistant beds, which contain chert, and thin quartzite, form narrow strike-parallel ridges. Rock outcrops here are very abundant; the rock surface, although lightly weathered, is marked by glacial scour and plucking. Elsewhere, Kittatinny Valley is underlain by slate, siltstone, and sandstone (fig. 3). Except for Papakating Valley, the more resistant rock underlies areas of higher elevation. Relief is as much as 300 feet; the rock surface is marked by rolling topography of moderate to steep slopes. The rock surface has been streamlined by glacial erosion, which is accentuated by long strike-parallel ridges. A narrow area of rugged, knobby topography, at the base of Kittatinny Mountain, forms the highest point in the valley. It is underlain by nepheline syenite that is Late Ordovician age (fig. 3).

Kittatinny Mountain forms a continuous ridge from the Shawangunk Mountains in New York southwestward through New Jersey into Pennsylvania. It is underlain by quartz-pebble conglomerate, and quartzite of Silurian age (fig. 3). These rocks are the most resistant to weathering, and they are the major ridge-formers in the study area. Relief is as much as 500 feet; the rock surface marked by undulatory, narrow- to broad-crested, strike-parallel ridges of moderate to steep slopes. The southeast face of the mountain forms a nearly continuous escarpment that is as much as 300 feet in height. Rock outcrops are abundant, and many exhibit extensive glacial scour. The area northwest of Kittatinny Mountain is included here as part of the mountain. It is underlain by red shale and sandstone of Silurian age (fig. 3). The rock surface is completely covered by thick glacial drift. Relief here may be as much as 300 feet; the surface is marked by rolling topography of gentle to moderate slopes.

The Wallkill River drains about 70 percent of the quadrangle. Its main tributaries include Papakating Creek, West Branch of Papakating Creek, and Beaver Run. Paulins Kill drains the southwest part of the quadrangle; its tributaries include Paulins Kill and Dry Brook. Kittatinny Mountain chiefly lies in the Flat Brook drainage basin; the largest stream here is Big Flat Brook. Both Paulins Kill and Big Flat Brook flow southwestward toward the Delaware River.

PREVIOUS INVESTIGATIONS

Glacial deposits in Sussex County, New Jersey were discussed by Cook (1877, 1878, and 1880) in the Annual Report of the State Geologist. He included observations on recessional moraines, ages of glacial drift, distribution and kinds of drift in Kittatinny Valley, and evidence of glacial lakes. A voluminous report by Salisbury (1902) detailed the entire glacial geology of New Jersey, region by region. The Terminal Moraine and all drift north of it were interpreted to be products of a single glaciation of Wisconsinan age. Salisbury recognized kames, kame terraces, deltas and moraines in Papakating Creek and Wallkill River valleys, and although he realized that some of these deposits define ice-retreatal positions, he did not document them within a larger chronostratigraphic framework. Most stratified deposits were thought to have been laid down as crevasse fillings, or deltas in small, short-lived proglacial lakes. Based on the collapse morphology of the meltwater deposits, their position on the sides of the valley, and exposed bedrock and till in the valley bottom, it was thought that stagnant ice had occupied much of Papakating Valley during deglaciation. Large glacial lakes in the upper Wallkill Valley were also overlooked, in part because isostatic rebound due to the melting of the Laurentide ice sheet was not yet recognized.

Fairchild (1912) alluded to glacial lakes in Wallkill Valley, and Adams (1934), Connally and Sirkin (1973), Connally and others (1989), and Stanford and others (1998) suggested a single former glacial lake consisting of several stages. The highest and oldest stage, which Adams termed the 500-foot lake, was controlled by a spillway at the head of Papakating Valley near Augusta. The lake's outlet lies at an elevation of 495 feet above sea level, and it straddles a drainage divide between Paulins Kill and Papakating Creek. Adams envisioned glacial meltwater in the upper Wallkill Valley, especially in Papakating Valley, flowing through a system of ice-contact lakes, crevasse passageways and supraglacial valleys to the Augusta divide. The open waters of the 500-foot lake only occupied the wide parts of the Wallkill Valley near the New Jersey-New York border. A later stage, which Adams (1934) called the 400-foot lake, was created when a drainage divide between Wallkill River and Moodna Creek located east of Middletown, New York, was uncovered by melting stagnant ice. Connally and Sirkin (1973) further added that a series of local ice-contact lakes occupied the upper Wallkill Valley before the formation of the 500-foot lake, and that a lower and final stage, called the 230-foot lake, was created when a low divide near Wallkill, New York was uncovered. Other investigations in the area include a surficial map by Spencer and others (1908), an engineering soil survey by Minard and others (1954), identification of recessional moraines on Kittatinny Mountain by Minard (1961), a short study of glacial stagnation by Herpers (1961), surficial geology of the Hamburg quadrangle by Stanford and others (1998), and a Soil Conservation Service soil report by Fletcher (1975).

GLACIAL DEPOSITS

Till

Till typically covers the bedrock surface and it is distributed widely throughout the quadrangle. It is generally less than 20 feet thick, and its surface expression is controlled by the shape of the underlying bedrock surface. Extending through this cover are many bedrock outcrops that show evidence of glacial erosion. Thicker, more continuous till subdues bedrock topography, and in places completely masks it. Very thick till forms drumlins, aprons on north-facing hillslopes, and ground moraine. It also fills narrow preglacial valleys, especially those oriented transversely to glacier flow.

Till is a poorly-sorted, compact, massive, silty sand containing as much as 20 percent pebbles, cobbles, and boulders. Clasts are subangular to subrounded, and many are faceted and striated. Presumably this material was deposited at the glacier's base. Overlying this compact till is a thin, discontinuous, noncompact, poorly sorted silty sand to sand containing as much as 35 percent pebbles, cobbles, boulders, and interlayered with lenses of sorted sand, gravel, and silt. Overall, clasts are more angular and clast fabrics lack a preferred orientation, or have a weak orientation that is oblique to the regional direction of glacier flow. (Witte, 1988) This material was presumably deposited from the glacier's surface. It was not mapped separately due to its scant distribution and poor exposure. Cryoturbation and colluviation have also altered the upper few feet of till making it less compact, reorienting stone fabrics, and sorting clasts.

Till has been divided lithologically into three types; each reflecting a different suite of local source rocks. These are: (1) Qkmq, derived chiefly from quartzite and quartz-pebble conglomerate of the Shawangunk Formation, (2) Qkms, derived chiefly from red shale and red sandstone of the High Falls Formation, and (3) Qkv, derived chiefly from slate, siltstone and sandstone of the Martinsburg Formation, and dolomite of the Kittatinny Supergroup. Units Qkmq and Qkms lie on Kittatinny Mountain and only unit Qkmq crops out in the quadrangle. This vertical stacking, shown in profile C-C', is based on exposures in the adjoining Port Jervis South and Culvers Gap quadrangles. Farther to the southwest, in the Flatbrookville quadrangle, Qkms is at the surface, and in places its base lies directly on conglomerate and quartzite. The areal distribution of these two tills is consistent with reconstructed regional ice flow patterns that show ice flowed southward over Kittatinny Mountain, and later southwestward as ice thinned during deglaciation (Witte, 1988, 1991a; Ridge, 1983). The third variety of till, Qkv, lies only in Kittatinny Valley.

Drumlins are widespread in the quadrangle; their long axes parallel the region's southwesterly topographic grain, except on Kittatinny Mountain where they trend more directly south. Some drumlins have bedrock cores (table 1, wells 37 and 51), whereas others consist entirely of till (wells 28, 34, 44, 46). Stratified sand and gravel beneath thick till (table 1, wells 21, 39, 44, 46) suggest proglacial outwash may have been laid down, and subsequently covered by till, during the advance of the late Wisconsinan ice sheet. Other areas of thick till include aprons on north-facing hillslopes that are as much as 65 feet thick (table 1, on Plate 2, wells 58, 18).

A very thick continuous sheet of till covers the northwest part of the quadrangle on Kittatinny Mountain, and extends into adjoining Culvers Gap, Milford, and Port Jervis South quadrangles. Well records and seismic refraction data (on file at the N.J. Geological Survey) show that it is as much as 200 feet thick. The unusual thickness of glacial drift here suggests that it may have been deposited during multiple glaciations. Although pre-Wisconsinan drift has not been observed in the quadrangle, exposures of older, weathered till beneath late Wisconsinan till were described by Stanford and others (1998) in the adjacent Hamburg quadrangle. Profile C-C' shows the possible distribution of pre-Wisconsinan drift (unit Qig).

Many records of wells drilled in Papakating Creek and Beaver Run valleys list sand and gravel, and silt and clay, directly overlying bedrock (profile A-A', and table 1). The absence of reported till here may be due to overgeneralized driller's logs, or it may have been eroded by subglacial meltwater. Based on its distribution elsewhere in the quadrangle, a thin layer of till is believed to mantle most bedrock in the valleys.

Ice-Marginal Deposits

Morainal deposits in the quadrangle make up the Ogdensburg-Culvers Gap, Augusta, and Libertyville moraines (fig. 4). Both the Ogdensburg-Culvers Gap and Augusta moraines are traceable across Kittatinny Mountain where the former joins the Dingmans Ferry moraine and the latter joins the Montague moraine (Witte, 1991a). The Libertyville moraine appears correlative with the Sussex delta and smaller ice-contact deltas that lie further east in Kittatinny Valley (Stanford and others, 1998). These moraines mark three former recessional positions of the Kittatinny Valley ice lobe (fig. 4). The moraines are estimated to be as much as 65 feet thick, and as much as 2500 feet wide. On Kittatinny Mountain, northwest of its main ridge, morainal segments are nearly continuous except where they have been eroded by meltwater and postglacial streams. Along the main ridge of Kittatinny Mountain and in Kittatinny Valley they are much more discontinuous. The distribution of correlative segments defines lobate ice-marginal positions that reflect both regional and local topographic control.

Cross-sectional topographic profiles of morainal segments are asymmetric; their outer slope is generally steepest. The geologic contact between the outermost margin of morainal segments and adjacent surficial materials is sharp and well defined; whereas the contact of the innermost margin with adjacent surficial materials is generally gradational and poorly defined. The moraines are bouldery, and they chiefly consist of poorly compacted, stony till with minor water-laid sand, gravel, and silt. Lithology of morainal materials is generally similar to that of local till and outwash deposits. Typical morphology of the morainal segments is shown in figure 5. Their outermost margin is marked by single ridges and parallel sets of ridges that are as much as 25 feet high, 150 feet wide, and 2000 feet long; most are less than 500 feet long. They generally parallel the course of the morainal segment, and many ridges appear to have been formerly continuous; they were subsequently broken by collapse of underlying material. These features may be morainal push-ridges based on their size, continuity, parallel course, and location along the outermost morainal margin. Elongated depressions that are as much as 20 feet deep below their rim, 100 feet wide, and 300 feet long separate sets of ridges. They parallel the ridges, and many contain swamp deposits. Irregular-shaped depressions also occur; these are as much as 40 feet deep, and as much as 500 feet wide. The innermost margins of the morainal segments have fewer ridges, fewer elongated depressions, and are marked by knob-and-kettle rather than ridge-and-kettle topography.

In Kittatinny Valley, ridge-and-kettle topography is generally absent on morainal segments that cross subvalleys, such as Papakating Creek valley, Moraines are also not as continuous and generally smaller than those that cross Kittatinny Mountain. These morphologic differences between "upland" and "valley" moraines may be related to thickness and distribution of drift adjacent to the morainal segments, with thicker and better developed segments formed down ice from thick till deposits. It is also likely that stagnant ice at the glacier's margin may have limited moraine formation. This seems especially true in Kittatinny Valley where the glacier's margin crossed river valleys.

The Augusta moraine in Papakating Valley lies on outwash (profile A-A'; table 1, well 57), and the Ogdensburg/Culvers Gap moraine, where it crosses the Paulins Kill and Wallkill Valleys also lies on outwash (Witte, 1991a). This suggests that the moraines were deposited during a readvance, indicating that stagnant ice at the glacier's margin may have varied considerably in width during deglaciation.

The composition and morphology of recessional moraines in Kittatinny Valley (Witte, 1991a) suggest they were formed by 1) the pushing of debris and debris-rich ice by the glacier at its margin, and 2) penecontemporaneous and postdepositional sorting and mixing of material by mass movement, chiefly resulting from slope failure caused by saturation and collapse of sediment over melting ice. The source and mechanism of sediment transport is unclear. Most of the morainal material is of local origin, but it is not known whether the glacier was simply reworking drift at its margin or carrying sediment to its margin by some type of "dirt-machine" process as suggested by Koteff and Pessl (1981). Inwash is probably not a viable mechanism because the larger deposits lie on mountain or ridge tops.

Deposits of Glacial Meltwater Streams

Sediment carried by meltwater streams was laid down at and beyond the glacier in valley-outwash and terrace deposits, ice-contact deltas, fluviodeltas, lacustrine-fan deposits, lake-bottom deposits, and ice-channel fillings. These glacial landforms are grouped into morphosequences based on their depositional and geographic setting, contemporaneity, specific base-level control, and texture. Most stratified sediment was transported by meltwater through glacial tunnels to the glacier margin, and by meltwater streams draining ice-free upland areas beside the valley (Witte, 1988; Witte and Evenson, 1989). Sources of sediment include: 1) till and debris eroded beneath the glacier, 2) debris eroded from the basal "dirty-ice" zone, and 3) till and reworked outwash in upland areas. Debris carried to the margin of the ice sheet by direct glacial action was minor.

Glaciofluvial sediments were laid down by meltwater streams in valley-outwash, meltwater-terrace deposits, and delta topset beds. These sediments include cobbles, pebbles, sand, and minor boulders laid down in stream channels, and sand, silt, and minor pebbly sand in overbank deposits. Sediment laid down near the glacier margin in valley-outwash deposits, and delta-topset beds typically includes thickly bedded, imbricated, planar coarse gravel and sand, and minor channel-fill deposits that consist largely of cross-stratified sand. Downstream sand is more abundant, and crossbedded and graded beds are more common.

Mapped Glaciofluvial Morphosequences

Fluvial sequence (fig. 2a) Qpdu consists of valley-outwash deposits laid down along the upstream reaches of Dry Brook and Papakating Creek valleys. These deposits are now terrace remnants of outwash and collapsed outwash eroded by postglacial streams. In Dry Brook valley, Qpdu deposits are graded to the outwash surface of Qpk14; other Qpdu deposits are graded to delta-plain surfaces of sequences Qwk1a, or the former water level of glacial Lake Wallkill.

Meltwater-terrace deposits (Qmt) lie in Paulins Kill and Big Flat Brook valleys, and in tributary valleys of Papakating Creek. These make up terraces incised in sequences Qpk13 and Qpk14, when local base level down-valley became lower because of erosion. In uplands, bouldery lag deposits were formed by meltwater winnowing fines from till. These are also mapped as meltwater-terrace deposits.

DEPOSITS OF GLACIAL LAKES

Glaciolacustrine sediments were laid down by meltwater streams in ice-contact deltas, lacustrine-fan deposits, and lake-bottom deposits in proglacial lakes that were temporarily dammed in the north-draining Wallkill River valley, and the south-draining Paulins Kill valley. Their distribution, texture, sedimentary facies, and morphology were controlled by the depth and shape of the lake basin, extent of stagnant ice, local base-level control, and sediment source.

Deltas consist of topset beds of coarse gravel and sand overlying foreset beds of fine gravel and sand. Near the meltwater feeder stream, foreset beds are generally steeply inclined (25° to 35°) and consist of thick to thin rhythmically-bedded fine gravel and sand. Farther out in the lake basin these sediments grade into less steeply dipping foreset beds of graded, ripple cross-laminated, parallel-laminated sand and fine gravel with minor silt drapes. These in turn grade into gently dipping bottomset beds of ripple cross-laminated, parallel-laminated sand and silt with clay drapes.

The basins of glacial Lake Wallkill and Lake Beaver Run (fig. 4) are not completely filled with deltaic sediment, and generally have exposed lake-bottom deposits that may contain varves. Lacustrine-fan deposits are common; some of these are buried by lake-bottom or deltaic sediment and others rise above the lake-bottom plain. The glacial lake basin receiving the West Branch deposits was generally filled by deltaic sediment where not occupied by stagnant ice, and exposed lake-bottom deposits are rare.

Typically, deltas consist of many individual lobes that prograde outward from the delta front across the lake floor, thinning and widening with distance (Gustavson, and others, 1975). Because lake basins in Paulins Kill valley were very narrow and small, they filled with deltaic deposits and were subsequently covered by a thick wedge of glaciofluvial sand and gravel that extended from valley wall to valley wall.

Unlike deltas, lacustrine-fan deposits lack topset beds; they were deposited at the mouth of glacial tunnels that generally exited the glacier near the floor of the lake basin. Some of these deposits may have also been laid down in cavities within the marginal area of the ice sheet. Lacustrine fans also become progressively finer grained basinward. However, near the former tunnel mouth, sediments may be coarser grained and less sorted because of high sedimentation rates and little chance for sorting. If the tunnel remained open and the ice front remained stationary, the fan eventually may have built up to lake level and formed a delta.

Lake-bottom deposits consist of laminated, rhythmically bedded silt, clay, and very fine sand that has progressively settled out from suspension, and sand and silt carried by turbidity currents in the lake basin. These deposits grade laterally into bottomset beds of deltas and lacustrine-fan deposits.

Mapped Glaciolacustrine Morphosequences

Lacustrine ice-marginal sequences (fig. 2c) include deltas Qwk1 through Qwk3, Qbr1 and Qbr2, and Qwb1 through Qwb4. These deltas were laid down in small, shallow glacial lake basins partly on top of and against stagnant ice, and against valley walls. They generally have irregular shapes, and are partially collapsed.

Fluviolacustrine sequences (fig. 2d) include fluviodeltas Qwk1a (Frankford Plains delta), Qwk4 (McCoys Corner delta), and Qwb5. These deltas were chiefly laid down by meltwater streams emanating from tributary valleys. They are generally triangular in form if laid down in larger lake basins, have fluvial deposits that extend up tributary valleys from the main part of the delta, and only have minor collapse features.

Ice-marginal lacustrine-fluvial sequences (fig. 2f) include units Qpk13, and Qpk14. These deposits filled small sediment-dammed lakes in the narrow Paulins Kill valley south of Branchville. They share similar morphology as valley-outwash deposits of fluvial sequences. However, beneath the thick wedge of fluvial sediments lie deltaic and lacustrine sediments. The proglacial lakes in these basins were temporarily dammed by older sequences and moraine downvalley. Local base-level controls were generally the floors of erosional channels cut down in these valley-fill materials. Sequences in this depositional setting commonly overlap.

(Continued on Plate 2)

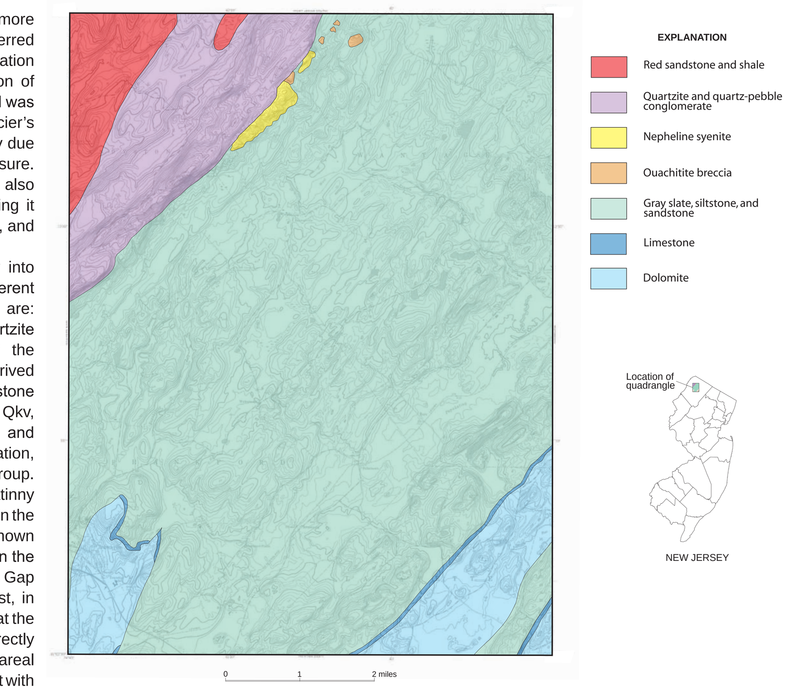


Figure 3. Simplified bedrock geologic map of the Branchville Quadrangle (modified from Drake and others, 1996).

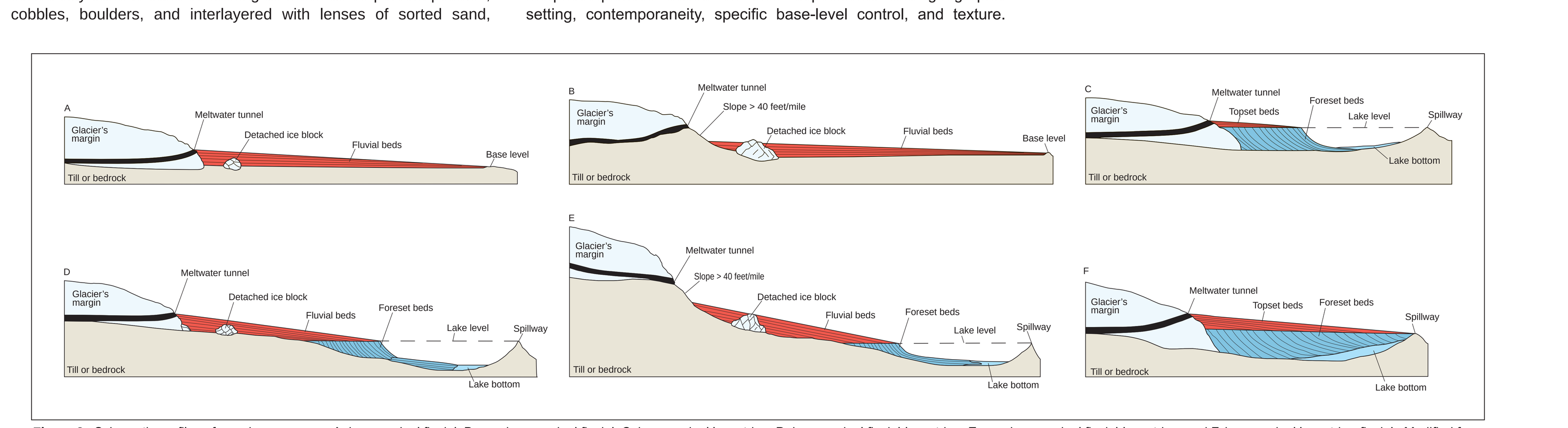


Figure 2. Schematic profiles of morphosequences; A, ice-marginal fluvial, B, non-ice-marginal fluvial, C, ice-marginal lacustrine, D, ice-marginal fluvial-lacustrine, E, non-ice-marginal fluvial-lacustrine, and F, ice-marginal lacustrine-fluvial. Modified from Koteff and Pessl, 1982, figure 1, p. 7.

DEPARTMENT OF ENVIRONMENTAL PROTECTION
LAND USE MANAGEMENT
NEW JERSEY GEOLOGICAL SURVEY

SURFICIAL GEOLOGIC MAP OF THE BRANCHVILLE QUADRANGLE,
SUSSEX COUNTY, NEW JERSEY
GEOLOGIC MAP SERIES GMS 08-2

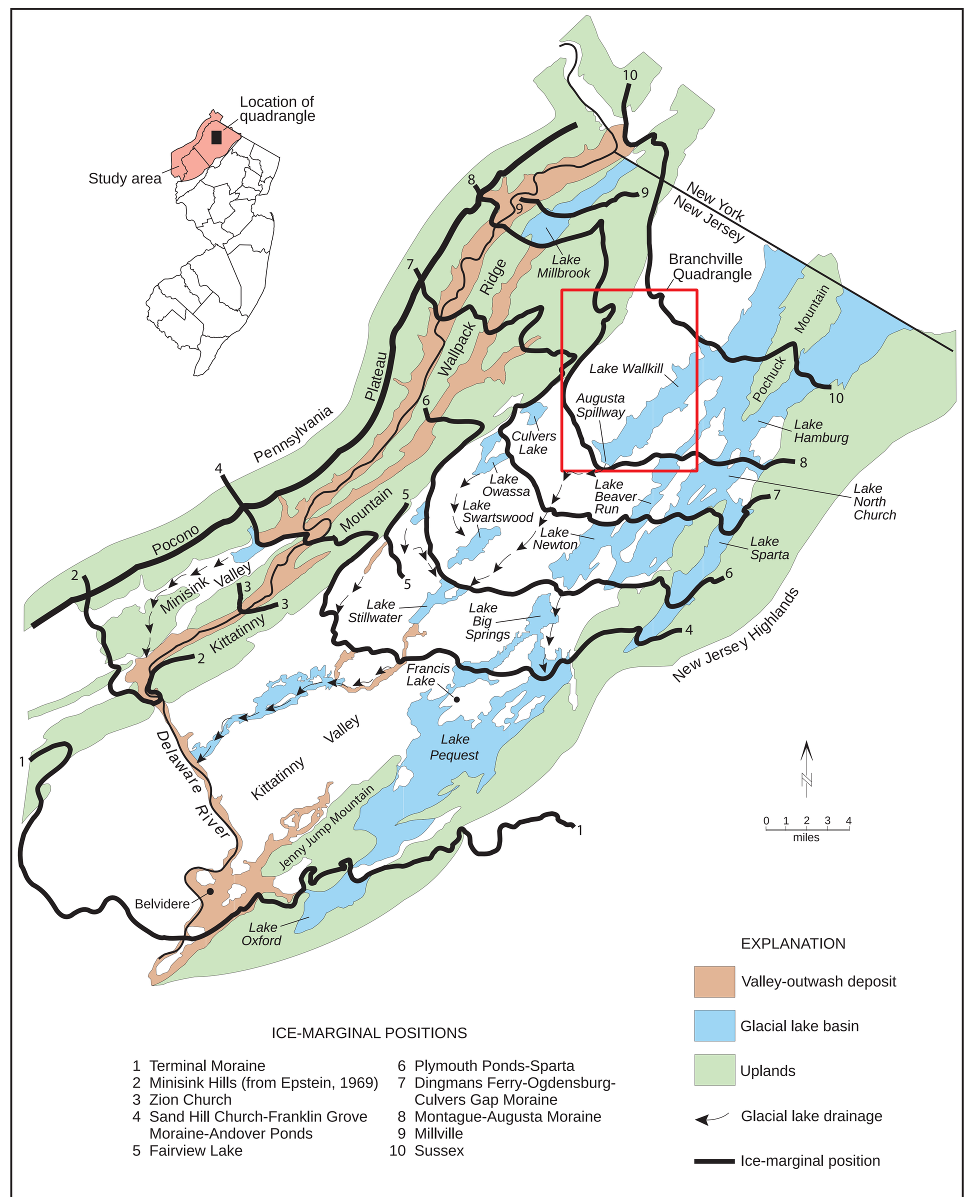


Figure 4. Late Wisconsinan ice-marginal positions of the Kittatinny and Minisink Valley ice lobes, and location of large glacial lakes, extensive valley-outwash deposits, and the Branchville 7.5 minute topographic quadrangle, in northwestern New Jersey, and northeastern Pennsylvania. Modified from Witte, 1991a.

(Continued from Plate 1)

QUATERNARY HISTORY

The distribution and weathering characteristics of glacial drift in northwestern New Jersey (Salisbury, 1902; Witte and Stanford, 1995, and Stone and others, 2002) show that continental ice sheets covered this area at least three times during the Pleistocene epoch. Erosional features of only the late Wisconsinan glaciation are preserved. They include polished and striated bedrock surfaces, plucked bedrock outcrops, streamlined bedrock forms, and roche moutonnées.

Subsurface bedrock contours in Papakating Creek valley show that preglacial streams flowed to the northeast. However, the barbed drainage pattern of Papakating Creek's tributaries suggest that the valley was formerly drained by a southwestward flowing preglacial stream. Reversal in drainage direction from southwest to northeast perhaps occurred when glacial erosion shifted the drainage divide between the Wallkill and Paulins Kill southward, or when southwest drainage was blocked by glacial deposits.

The Laurentide ice sheet in the late Wisconsinan reached its maximum extent in New Jersey approximately 21,000 yrs. B.P. (Harmon, 1968; Reimer, 1984; Cotter and others, 1986). Its southerly limit is marked by a terminal moraine (fig. 4), except in a few places where the glacier advanced as much as a mile farther south. The initial advance of ice into Kittatinny Valley is obscure because glacial drift and striae that record this history have been eroded or lie deeply buried. If the ice sheet advanced in lobes as suggested by the lobate course of its terminal moraine, then its initial advance was marked by lobes of ice moving down the Kittatinny and Minisink Valleys. The chronology of each advancing lobe is unclear. Sevon and others (1975) suggested that ice from the Ontario basin first advanced southward into northeastern Pennsylvania and northwestern New Jersey. Later, ice from the Hudson-Wallkill lowland, which initially had lagged behind, overrode Ontario ice. Therefore, the course of the terminal moraine in Minisink and Kittatinny Valleys reflects ice flow from the Hudson-Wallkill lowland. Ridge (1983) proposed an alternative view: a sublobe of ice from the Ontario basin overrode Kittatinny Mountain and flowed southward into Kittatinny Valley. Southwestward flow occurred only near the glacier margin where ice was thinner. Witte (1988, 1991a) modified Ridge's model to better account for ice flow in the upper part of Kittatinny Valley, and on Kittatinny Mountain. During its maximum extent, ice flowed southward over Kittatinny Mountain into Kittatinny Valley except near the glacier margin where ice was thin and its flow was constrained by the southwesterly trend of the valley. This flow direction suggests that glacial ice did not originate solely from Ontario or Hudson-Champlain sources. During deglaciation ice near the glacier margin thinned, and local topography exerted greater control on the direction of ice flow and for a longer distance inward from the glacier margin. In Kittatinny Valley this resulted in the formation of a more pronounced valley-ice flow system by the time the Ogdensburg-Culvers Gap Moraine had been deposited.

Striae in the Branchville quadrangle show that regional ice flow during deglaciation was southwestward along the axis of Kittatinny Valley. Westward oriented striae, and the occurrence of nepheline-syenite and graywacke-sandstone erratics on Kittatinny Mountain, also indicate that ice flow at the glacier's margin was divergent, an indication of well-defined ice lobation.

STYLE OF DEGLACIATION

Models describing ice dynamics and sedimentation at or near glacier margins are generally based on two contrasting styles of deglaciation, either regional stagnation or systematic retreat. Detailed mapping in the southern part of Kittatinny Valley by Ridge (1983) and Witte (1988, 1991b) showed that deglaciation from the late Wisconsinan terminal moraine was systematic and varied from stagnation-zone retreat to oscillatory retreat of an active ice margin. Accordingly, deglaciation of the Branchville quadrangle was characterized by the systematic northeastward retreat of the Kittatinny Valley ice lobe. This interpretation is based on the distribution of morphosequences and moraines, and correlative relationships between elevations of delta topset-foreset contacts, former glacial lake water plains, and lake spillways. Systematic retreat is due to an increased rate of melting at the glacier's margin or decrease in "new" ice from the accumulation zone. A common component of this style of retreat is a narrow zone of stagnant ice at the glacier margin that melts back contemporaneously with the active ice. Termed "stagnation zone retreat" it was first described by Currier (1941), and Jahns (1941) and later modified by Koteff and Pessl (1981) to describe glacial retreat in New England. The stagnant ice zone is generally less than 2 miles wide (Koteff and Pessl, 1981), and it may vary widely with time and location along the glacier's margin. If little or no stagnant ice occurs at the glacier's margin, then the ice is active here, and oscillation of the margin is more common.

In contrast, Adams (1934), Herpers (1961), and Connally and others (1989) suggested that deglaciation occurred by downwasting and regional stagnation, or valley ice-tongue stagnation. Their interpretations involve the recognition of major esker systems, massive crevasse-fill deposits, inversion ridges, and dead-ice sinks.

DEGLACIATION

The recessional history of the Laurentide ice sheet is well documented for northwestern New Jersey and northeastern Pennsylvania. Epstein (1969), Ridge (1983), Cotter and others (1986), and Witte (1988, 1991a) showed that the margin of the Kittatinny and Minisink Valley lobes retreated systematically with minimal stagnation. Radiocarbon dating of organic material cored from Francis Lake by Cotter (1983) shows a minimum age of deglaciation of 18,750 yr. B.P.

Reconstruction of the deglacial chronology is based on the morphosequence concept of Koteff and Pessl (1981), which permits delineation of heads-of-outwash that mark ice-retreatal positions. Besides these positions, the distribution of moraines, and the interpretation of glacial lake histories, based on correlative relationships between elevations of delta topset-foreset contacts, former glacial-lake-water plains, and lake spillways, provides a firm basis to reconstruct the ice-recessional history of the Kittatinny Valley lobe.

The distribution of morphosequences and moraines shows that late Wisconsinan deglaciation of Kittatinny Valley was characterized by the systematic northeastward retreat of the margin of the Kittatinny Valley ice lobe into the Wallkill Valley (Ridge, 1983; Witte, 1988, 1991a). Minor readvances are marked by the Ogdensburg-Culvers Gap and Augusta Moraines, and possibly the Libertyville Moraine. During retreat, proglacial lakes developed successively in basins dammed by the glacier, and in valleys dammed by recessional meltwater deposits, moraines, and stagnant ice (fig. 4).

The oldest recessional deposit is the Ogdensburg-Culvers Gap Moraine (Qom), which has been tentatively assigned a terminal age of 18,250 yrs. B.P. based on work by Sirkin and Minard (1972), Connally and Sirkin (1973), Cotter (1983), and Witte (1988). The moraine marks a minor readvance of the margin of the Kittatinny Valley lobe (Witte, 1991a).

The oldest meltwater deposits make up ice-marginal lacustrine-fluvial sequence Qpk13 in the upper Paulins Kill Valley. Qpk13 was laid down in a proglacial lake ponded by older recessional meltwater deposits and the Ogdensburg-Culvers Gap Moraine downvalley (Witte, 1988; 1991b). Sequence Qpk14, also an ice-marginal lacustrine-fluvial sequence, filled in a proglacial lake in the Augusta-Branchville area. This lake had been dammed by the Qpk13 deposits downvalley. Part of the sequence at Branchville consists of meltwater sediment that was transported downstream in the Culvers Creek valley in the adjoining Culvers Gap quadrangle, and part of it was transported from Papakating Creek and Dry Brook valleys.

The Augusta Moraine (Qam) was deposited during the later stages of deposition of sequence Qpk14. The moraine in Papakating Creek valley overlies stratified sand and gravel of sequence Qpk14 (profile A-A'; table 1, well 57), which shows it was deposited after a readvance of the Kittatinny Valley lobe. The extent of the readvance is unknown; however, based on the deglaciation history of Kittatinny Valley (Ridge, 1983; Witte, 1988), it was probably minor.

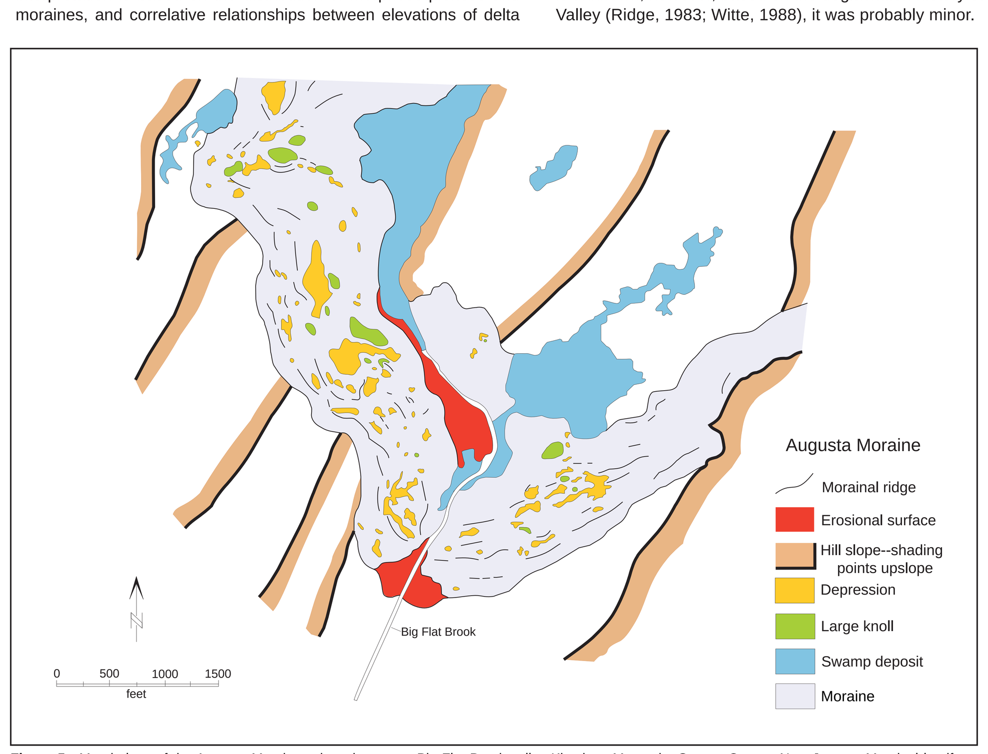


Figure 5. Morphology of the Augusta Moraine, where it crosses Big Flat Brook valley Kittatinny Mountain, Sussex County, New Jersey. Morainal landform elements collectively define areas of ridge-and-trough, and knob-and-kettle topography.

The retreat of the margin of the Kittatinny Valley ice lobe from the Augusta Moraine resulted in the formation of glacial Lake Wallkill in Papakating Creek valley (fig. 4). Initially, the lake's spillway was over morainal deposits of the Augusta Moraine. As the size of the lake and its drainage basin increased during retreat of the ice lobe, discharge increased and the spillway was eroded into the underlying coarse gravel and sand of sequence Qpk14. Eventually a narrow deep channel was cut through the sequence by the outflowing stream. Erosion of the channel continued until bedrock was reached, and the level of the lake stabilized. Present elevation of this threshold, called here the Augusta spillway, is approximately 495 feet above sea level. The period preceding the formation of the stable spillway is here called the Frankford Plains phase of glacial Lake Wallkill. Based on the estimated elevation of topset-foreset contacts of deltas built into the lake, this period of lowering lake level lasted at least until after the deposition of sequence Qwk3.

Ice-marginal lacustrine sequence's Qwk1 through Qwk3 delineate three minor ice-retreatal positions in Papakating Creek valley. These deposits were laid down sequentially in the lake as the margin of the ice lobe retreated to the northeast. The Frankford Plains (Qwk1a) and McCoy's Corner deltas (Qwk4) are fluvial-lacustrine sequences laid down by meltwater carrying sediment downstream along tributary valleys now occupied by Papakating Creek and its West Branch. The Frankford Plains delta is tentatively correlated with sequences Qwk2 and Qwk3. This delta postdates sequence Qwk1, based on an exposure (table 2, sec. no. 3) northeast of Northrup that shows pebble gravel and sand foresets of Qwk1a overlying collapsed cobble pebble gravel and sand foresets of Qwk1.

The many sand and gravel deposits (Qwklf) in the valley that lie below the projected water plane of glacial Lake Wallkill are lacustrine fan deposits or collapsed deltaic sediment. Their distribution suggests that deposition may have been nearly continuous as the margin of the ice lobe retreated. Till and bedrock on the floor of the lake basin, and the glacial lake-bottom and ice-contact slopes of many deltas and lacustrine-fan deposits, show that stagnant ice occupied part of the lake basin. However, in general ice was not present in large amounts and it wasted back synchronously with the margin of the Kittatinny Valley lobe. Altitudes of delta plains, and estimated topset-foreset contacts (profile A-A') suggest that base-level control for the Frankford Plains phase of glacial Lake Wallkill was a spillway cut in the Augusta Moraine and underlying sequence Qpk14. Later the elevation of the lake was controlled by the stable Augusta spillway.

Contemporaneous with deposition of glacial Lake Wallkill sequences was the deposition of fluvial sequences (unit Qpdu) along the upper reaches of Papakating Creek and Dry Brook, and deltaic sequences in an unnamed tributary valley near Wykertown (unit Qwtu). Heads-of-outwash are rare in these sequences; an indication that these deposits may be largely non-ice marginal.

Synchronous with retreat of the Kittatinny Valley ice lobe in the upper part of Paulins Kill valley was the formation of glacial Lake Beaver Run (fig. 4). This lake formed in a small south-draining valley dammed by the Lafayette delta (Witte, 1988). Its spillway, underlain by till, is situated at the south end of the lake basin near Lafayette in the Newton East quadrangle. Its floor has also been further lowered by postglacial stream action. Unit Qbr1 (Harmonyvale delta) is part of an ice-marginal lacustrine sequence laid down in these sequences laid down in the valley. Surfaces of these deltas correspond with the elevations of local outlets uncovered by the retreating margin of the Kittatinny Valley ice lobe. Eventually, the lake drained through the Wallkill River. The delta straddles a drainage divide between the Paulins Kill and Wallkill drainage basins.

Sequence Qbr2 and uncorrelated Beaver Run deposits (Qbru) in the Beaver Run valley mark deposition in a small proglacial lake dammed behind sequence Qbr1 (Harmonyvale delta). The level of this lake was controlled by a spillway over the Harmonyvale delta, now at an elevation of 575 feet. As the ice front retreated northward in Beaver Run valley, the lake lowered to a level controlled by a spillway 0.5 miles north of Harmonyvale. This spillway, now at an elevation of 550 feet, lies on a drainage divide between Beaver Run and Papakating Creek drainage basins. As the margin of the Kittatinny Valley lobe retreated further northward, this lower lake expanded into the Wallkill Valley near Hamburg and has been named glacial Lake Hamburg by Stanford and others (1998).

In the West Branch of Papakating Creek valley, several small proglacial lakes formed after the margin of the Kittatinny Valley ice lobe retreated into the West Branch drainage basin and meltwater became ponded in small basins that drained toward the glacier. West Branch deposits (Qwb1 through Qwb4) are ice-marginal lacustrine sequences laid down in these successively lower lakes. Altitudes of delta surfaces correspond with the elevations of local outlets uncovered by the retreating margin of the Kittatinny Valley ice lobe. Eventually, meltwater drained away from the West Branch valley after the main part of the West Branch valley became free of ice. Qwb5 deposits are part of a fluvial-lacustrine sequence laid down in the valley. Elevations of the deposits show that the West Branch valley was still dammed by ice or drift near Woodbourne. Meltwater deposition continued in the West Branch drainage basin until the margin of the ice lobe retreated into the Clove Brook drainage basin.

Meltwater deposits in the Flatbrook drainage basin (units Qfbu) have been observed in only a few locations. One deposit lies near the head of a small north-draining valley. Based on the similarity between its elevation and a spillway on a local drainage divide to the south, it may be a small ice-marginal delta laid down in a proglacial pond. Other Qfbu deposits include uncorrelated glaciofluvial outwash laid down in Big Flat Brook valley.

The youngest meltwater deposits are in the northeastern part of the quadrangle, east of Libertyville. Here an ice-marginal delta, sequence Qcb1, filled part of a small north-draining basin. The deposit is extensively collapsed, and is graded to a threshold at its south end. Qwku deposits in the northeast corner of the quadrangle are part of an uncorrelated lacustrine sequence deposited in Clove Brook valley. Surface elevations indicate that they were laid down in Lake Wallkill, which had expanded upvalley as the margin of the Kittatinny Valley ice lobe retreated to the northeast.

MAJOR ICE-RETREATAL POSITIONS

Two ice-retreatal positions had been previously identified in the study area; these are marked by the Ogdensburg-Culvers Gap and Augusta moraines (fig. 4). The mapping of morphosequences has delineated many more such positions, making it possible to develop a detailed deglaciation chronology.

The correlation of ice-retreatal positions and their associated morphosequences is based on: 1) the greater continuity of morphosequences along these margins, 2) similar development in size of the sequences as related to their respected drainage basins and sediment sources, 3) similarity in shape with reconstructed ice margins associated with moraines and recessional positions defined in previous studies, 4) inferred recessional positions based on location of ice dams in glacial lake basins, and sediment source for non-ice-marginal sequences. Based on the above criteria three major ice-retreatal positions have been delineated. The first is marked by sequences Qwk1, and Qbr1. These sequences are also tentatively correlated with the North Church delta (Stanford and others, 1998) which is approximately 2 miles east of the Harmonyvale delta in the Hamburg quadrangle. The second position is marked by sequences Qwk2 and Qbr2, and the third by the Libertyville moraine and sequence Qcb1. The last position is tentatively correlated with the Sussex delta, which lies 2 miles northeast of McCoys Corner in the Hamburg quadrangle (Stanford and others, 1998). These ice-marginal positions appear to mark periods of prolonged or increased meltwater deposition and ice-margin stability, possibly controlled by climate or change in ice regimen.

Many sequences do not seem to have correlative deposits in adjacent or nearby depositional basins, or correlations are very speculative. Therefore, other factors presumably influenced their development such as: topography and its effect on ice-margin stability, rate of ice margin retreat, discharge points for meltwater along the margin of the ice lobe, availability of debris sources, deglaciation of adjacent upland drainage basins, and changes in local base levels.

POSTGLACIAL DEPOSITS AND HISTORY

Postglacial deposits in the study area include alluvial fan, stream-terrace, and swamp deposits, alluvium, talus, and colluvium. Extensive alluvium lies along Papakating Creek and its tributaries, and also Paulins Kill and Big Flat Brook. Swamp deposits occur throughout the area in former glacial-lake basins, kettles, in small glacially-scoured rock basins in upland areas, and along streams. Talus and colluvium as much as 25 feet thick (estimated) lie on the lower part of the southeast-facing escarpment of Kittatinny Mountain. Small, thin deposits of talus and colluvium located at the base of smaller cliffs, hillslopes, and convergent slopes are not mapped.

It is estimated that the Branchville quadrangle was uncovered by ice approximately 18,000 yr. B.P. based on the oldest Francis Lake date (Cotter, 1983). Meltwater from Lake Wallkill continued to flow down the Paulins Kill Valley until a lower spillway was uncovered in the mid-Wallkill Valley and the lake drained into the Hudson Valley. This occurred about around 17,000 yr. B.P., based on the estimated age of the Pellets Island moraine in Wallkill Valley (Connally and Sirkin, 1986). In the upper part of the valley thin stream-terrace deposits were laid down on the exposed floor of Lake Wallkill. Following this period of deposition the northern end of the former lake basin was elevated relative to its southern end due to isostatic rebound, which is estimated to have started by 14,000 yrs B.P. (Koteff and Larsen, 1989). Eventually, a shallow lake flooded the upper part of the valley in late glacial to early Holocene time. The lake eventually became filled with swamp deposits and later alluvium laid down by the Wallkill River during the latter part of the Holocene. Also, following the onset of rebound, streams in south-draining valleys began a renewed period of incision, and further eroded glacial valley-fill materials.

Initially, cold and wet conditions, and sparse vegetative cover enhanced erosion of hillslope material by solifluction, soil creep, and slope wash. Mechanical disintegration of rock outcrops by freeze-thaw also provided additional sediment. Some of this material forms extensive aprons of talus at the base of cliffs on Kittatinny Mountain. A few small boulder fields were formed where boulders, transported downslope by creep, accumulated at the base of hillslopes and in front of boulder-shaped stone furrows, and other boulder concentrations formed by glacial transport and meltwater erosion, were further modified by freeze and thaw, their stones reoriented to form crudely-shaped stone circles. Gradually as the climate warmed, vegetation spread and was succeeded by types that further limited erosion. Between 14,250 and 11,250 yr. B.P. (Cotter, 1983) lacustrine sedimentation, which had been dominated by clastic material, changed to that dominated by organic material. This transition represents a warming of the climate such that subaquatic vegetation could be sustained. Also during this time the paleoenvironment changed from tundra to a boreal forest dominated by spruce and hemlock. Based on the Francis Lake pollen record (Cotter, 1983), oak and mixed hardwood forests started to dominate the landscape around 9700 yr. B.P.

The Holocene is marked by the overall amelioration of the climate. Shallow lakes and ponds slowly filled with swamp deposits, and flood plains developed along stream courses. The formation of flood plains was episodic; marked by periods of extensive alluviation, and followed by lengthy periods of nondeposition and soil formation. Presumably these cycles were a response to wetter and dryer, and warmer and cooler climates.

SURFICIAL ECONOMIC RESOURCES

The most important natural resource in the quadrangle is stratified sand and gravel; most of which lies in glacial deltas. Sediment may be used as aggregate, subgrade fill, select fill, surface coverings, and decorative stone. Shale-chip colluvium (Qcs) and weathered slate makes an excellent subgrade material. The location of all sand and gravel pits and quarries is shown on Plate 1, a terse description of materials found in some of these pits is listed in table 2, and the lithology of the pebble fraction of selected till and meltwater deposits is listed in table 3. All pits are currently inactive except for occasional use by the land owner. Till may be used for fill and subgrade material, and large cobbles and small boulders may supply building stone. Humus and marl from swamp deposits may be used as a soil conditioner.

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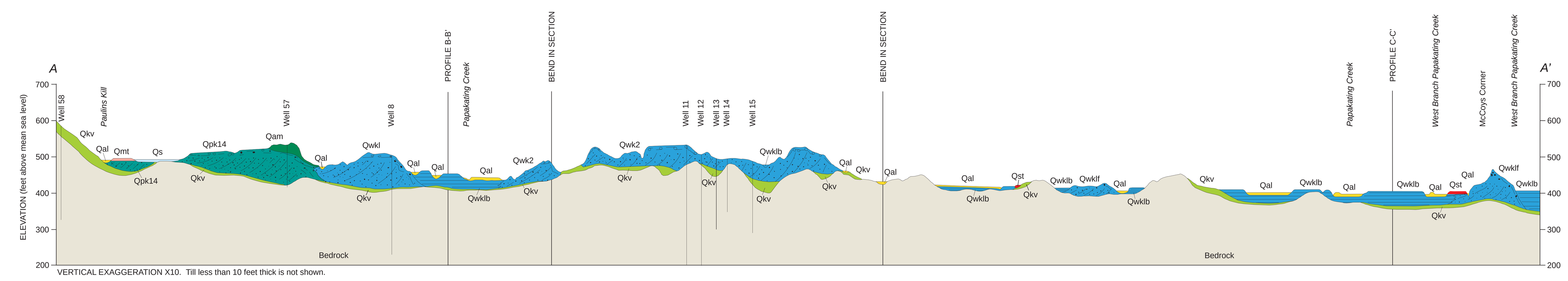
TABLE 2. Abbreviated description of materials observed in sand and gravel pits, excavations, and soil-test pits.

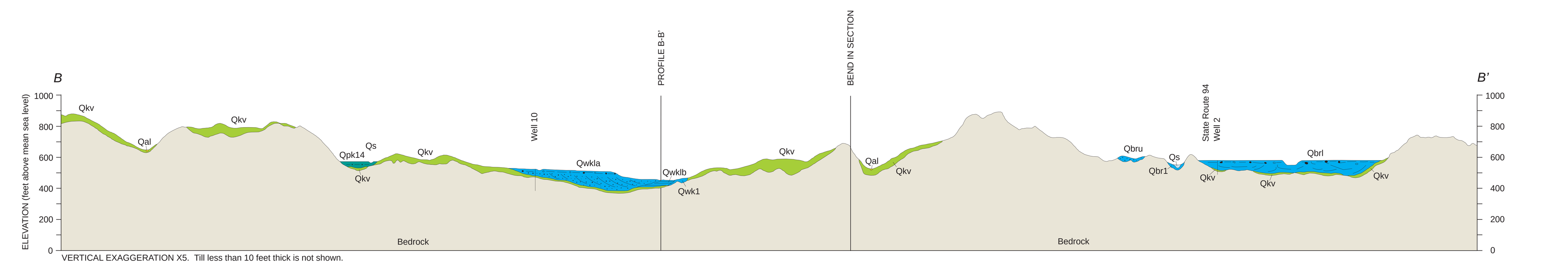
Section No.	Unit	Description
1	Qwk1	3 feet pg and s topset beds / > 15 feet pg and s, pbs, and s foreset beds.
2	Qwk1a	10 feet pg and s topset beds / 4 feet pbs and s foreset beds.
3	Qwk1a /Qwk1	> 20 feet pg and s, pbs, and fs foreset bed > 5 feet cpg and s collapsed foreset beds interlayered with flowtill.
4	Qwk2	> 10 feet of highly collapsed pg and s, pbs, s and m foreset beds interlayered with flowtill / > 5 feet laminated, crossbedded s and m with dropstones interlayered with cpg and s, and pg and s sediment-grain flow deposits.
5	Qwklf	> 20 feet pg and s, pbs, s, and m foreset beds inter-layered with flowtill.
6	Qwklf	> 10 feet cpg, pg and s, pbs, and s foreset beds.
7	Qbr1	> 30 feet of very poorly exposed, collapsed cg, cpg and sand foreset beds.
8	Qrbu	> 10 feet cs to fs foreset beds, topset beds have been removed by excavation.
9	Qrb2	> 40 feet pg and s, pbs, s, and m foreset beds.
10	Qwk4	> 15 feet collapsed cs to fs foreset beds interlayered with pg and s sediment-grain flow deposits.
11	Qwtu	> 15 feet collapsed pg and s, pbs, and s foreset beds.
12	Qwk2	3 to 4 feet cpg and s topset beds / > 25 feet pg and s, pbs, s, and m foreset beds.
13	Qwk2	> 30 feet pg and s, pbs, and s foreset beds interlayered with flowtill.
14	Qwbu	Poorly sorted, crudely stratified cg, cpg and s interlayered with flowtill.
15	Qwb2	2 feet cpg and s topset beds / > 40 feet cpg, pg and s, pbs, and s foreset beds, partially collapsed.
16	Qwb2	> 15 feet crudely stratified cg, cpg, pg and s (collapsed foreset beds?) / 1.5 feet compact clayey silty till / slate.
17	Qwbu	> 8 feet massively bedded cg, cpg, pg and sand glacio-fluvial deposits, slightly collapsed.
18	Qwb4	2 feet of poorly compacted sandy silty flowtill / > 15 feet pg and s, and pbs foreset beds.
19	Qwb4	massive bcg and s topset beds as much as 8 feet thick / > 15 feet pg and s, pbs, and s foreset beds, partially collapsed.
20	Qwb4	3 feet pg and s topset beds / 10 feet pbs and s foreset beds.
21	Qwb4	> 10 feet cpg, pg and s, pbs and s foreset beds inter-layered with flowtill and poorly sorted sediment-grain flow deposits and poorly sorted sediment-grain flow deposits.

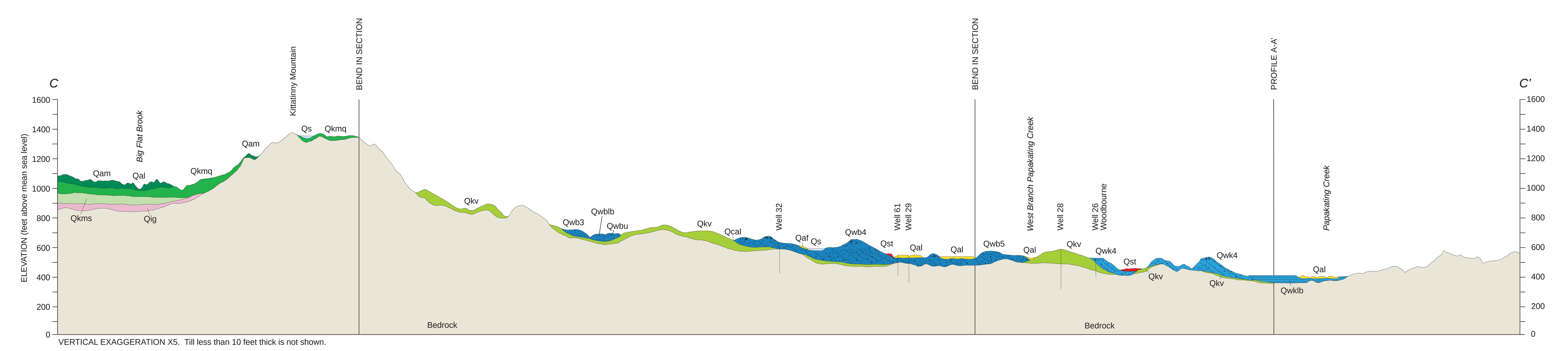
Key to abbreviations:
bcg -- boulder-cobble gravel, cg -- cobble gravel, cpg -- cobble-pebble gravel, pg -- pebble gravel, pbs -- pebbly sand, cs -- coarse sand, fs -- fine sand, s -- sand, m -- silt, / -- overlies, > -- more than, ? -- unit interpretation uncertain.

TABLE 3. Lithology of pebbles from glacial deposits in the Branchville Quadrangle, Sussex County, New Jersey. Percentage is based on 100 to 150 pebbles, one to three inches in diameter, collected at a depth of at least four feet.

Sample	Surficial deposit	Percentage							
		gneiss and granite	dolomite, limestone, and chert	slate and graywacke	sandstone	quartzite and conglomerate	red sandstone	syenite and lamprophyre	vein quartz
1	Qwbu	0	0	58	39	3	0	0	0
2	Qm	0	0	58	38	2	0	1	0
3	Qkv	1	2	13	81	3	0	0	0
4	Qwb2	2	0	26	59	4	0	0	0
5	Qwbu	1	0	45	54	1	0	0	0
6	Qwb2	3	2	58	24	11	0	2	1
7	Qwb4	4	2	41	42	9	2	1	1
8	Qcb1	0	30	69	0	1	0	0	0
9	Qkv	2	2	40	53	2	1	0	0
10	Qwb4	0	0	64	35	1	0	0	0
11	Qwb4	0	0	56	33	11	1	0	0
12	Qwk4	0	0	66	25	7	1	0	0
13	Qwtu	0	3	66	25	4	0	1	1
14	Qwklf	2	2	76	16	4	0	0	1
15	Qwklf	0	0	81	11	5	2	0	0
16	Qwk2	0	0	76	21	4	0	0	0
17	Qbr2	0	2	80	13	2	1	1	1
18	Qbr2	1	46	32	12	7	1	0	1
19	Qbru	0	3	83	9	4	0	0	1
20	Qbru	0	57	27	13	3	0	0	0
21	Qbr1	0	67	19	7	6	0	0	2
22	Qbru	0	3	80	15	3	0	0	0
23	Qbru	0	1	94	3	2	0	0	0
24	Qwk1a	0	2	65	28	4	1	0	1
25	Qwk1	1	1	83	7	9	0	0	0
26	Qam	2	0	62	24	9	2	0	1
27	Qkv	2	1	47	45	4	1	1	0
28	Qkv	0	0	60	25	11	1	3	0







Well no.	Surface altitude (feet)	NJDEP well permit no.	Depth (feet)	Driller's Log	Yield (gpm)	Stratigraphic correlation
1	570	22-8948	0-15	overburden, sand, clay		Qbr1
			-53	sand, clay		Qbr1 & Qbrlb
			-122	black, white limestone	45	OCk
2	585	22-5776	0-74	clay and sand		Qbr1
			-86	limestone	45	OCk
3	580	22-14487	0-17	boulder		Qbr1
			-43	heavy gravel		Qbr1
			-59	gravel, clay		Qkv
			-79	limestone	40	OCk
4	575	22-18849	0-90	sand, clay, gravel overburden		Qbr1/ Qkv ?
			-174	limestone	20	OCk
5	580	22-12139	0-22	sand, gravel		Qbr1
			-65	limestone	15	OCk
6	560	22-21831	0-18	sand, gravel		Qwku
			-173	shale	10	Om
7	590	22-20855	0-45	clay and gravel overburden		Qkv
			-325	slate rock	20	Om
8	505	22-22077	0-95	clay and gravel overburden		Qwk1
			-275	slate rock	15	Om
9	515	22-21258	0-22	sand and gravel		Qwk1
			-222	shale bedrock	3	Om
10	525	22-21276	0-43	gravel and sand		Qwk1a/Qkv
			-145	shale	20	Om
11	530	22-19412	0-61	clay and gravel		Qwk2/Qkv?
			-550	slate	15	Om
12	510	22-22282	0-32	clay and gravel overburden		Qwk2
			-500	slate rock	3	Om
13	495	22-22284	0-51	sand, clay gravel		Qwk2/Qkv
			-198	slate	5	Om
14	495	22-21453	0-18	sand and gravel		Qwk2
			-145	shale bedrock	25	Om
15	485	22-20337	0-65	sand and gravel		Qwk2/Qkv
			-290	shale	10	Om
16	415	22-11048	0-80	sand and gravel overburden	100	Qwklf
			-82	slate		Om
17	455	22-13020	0-60	sand and gravel overburden		Qwk4a
			-477	slate	100	Om
18	660	22-19119	0-65	clay and gravel overburden		Qkv
			-199	slate	6	Om
19	525	22-20339	0-30	overburden with gravel, sand, and water		Qpk14
			-273	limestone	5	OCk
20	520	22-3214	0-14	boulders & stones		Qal/Qpk14
			-52	clay and stones		Qpk14/ Qkv?
			-170	hard gray rock	350	OCk ?
21	570	22-2379	0-25	hardpan & boulders		Qkv
			-50	hardpan, boulders, and gravel		Qkv
			-65	gravel & very fine		proglacial sand
			-95	limestone	25	OCk
22	530	22-21109	0-18	overburden with gravel		Qpk14
			-273	limestone	15	OCk
23	585	22-21625	0-86	clay and gravel overburden		Qkv
			-147	lime rock	6	OCk
24	580	22-21976	0-70	clay and gravel overburden		Qwk1a/ Qkv
			-300	slate rock	4	Om
25	480	22-25610	0-15	sand, clay and gravel overburden		Qkv
			-150	slate rock	8	Om
26	525	22-4852	0-90	clay and gravel		Qwk4a/ Qkv
			-130	slate rock	9	Om
27	560	22-20635	0-65	clay and boulders		Qkv
			-330	shale	2	Om
28	590	22-22803	0-115	clay and gravel overburden		Qkv
			-275	slate rock	5	Om
29	550	22-19819	0-68	sand and gravel overburden		Qal/ Qwb5
			-185	slate rock	50	Om
30	615	22-13621	0-133	sand and gravel overburden		Qwb4
			-275	slate rock	3	Om
31	610	22-20387	0-81	sand and gravel	10	Qwb4
			-122	shale		Om
32	645	22-14874	0-64	sand and gravel overburden		Qwb4
			-224	slate rock	25	Om
33	635	22-22627	0-96	clay and stones		Qkv
			-260	shale	10	Om
34	645	22-26132	0-105	sand, clay and gravel overburden		Qkv
			-250	slate rock	8	Om
35	650	22-16804	0-115	sand and gravel overburden		Qkv
			-149	slate rock	30	Om
36	730	22-22642	0-32	sandy loam		Qkv
			-300	shale bedrock	4	Om
37	775	22-5640	0-40	clay and gravel overburden		Qkv
			-257	slate rock	4	Om
38	695	22-7990	0-150	clay and gravel overburden		Qal/ Qkv
			-222	slate rock	1	Om
39	710	22-7819	0-155	overburden to coarse gravel	14	Qkv/ proglacial outwash
40	650	22-15091	0-33	sand and gravel overburden		Qkv
			-112	slate rock	12	Om
41	680	22-11195	0-71	sand and gravel overburden		Qkv
			-123	slate rock	6	Om
42	665	22-22471	0-100	clay and gravel overburden		Qcb1/ Qkv
			-300	slate rock	2	Om
43	710	22-7318	0-25	clay overburden		Qwb3/Qkv?
			-210	slate rock	15	Om
44	935	22-8756	0-132	sandy hardpan to coarse gravel	7	Qkv/ outwash?
45	790	22-9406	0-30	sand, gravel and clay overburden		Qkv
			-207	slate rock	5	Om
46	725	22-5029	0-110	clay and gravel overburden (gravel well)	6	Qkv/ proglacial outwash ?
47	735	22-14952	0-50	sand and clay		Qkv
			-133	slate	3	Om
48	730	22-26215	0-15	sand, clay and gravel overburden		Qkv
			-225	slate rock	7	Om
49	750	22-18933	0-21	clay and gravel overburden		Qkv
			-525	slate	5	Om
50	710	22-20487	0-81	clay and boulders		Qkv
			-147	bedrock shale	5	Om
51	890	22-22961	0-30	clay and gravel overburden		Qkv
			-325	slate rock	10	Om
52	925	22-20982	0-38	clay and sand		Qkv
			-222	gray shale	4	Om
53	845	22-20014	0-2	overburden		Qkv
			-85	clay and gravel		Qkv
			-95	brown shale		Om
			-225	blue shale	9	Om
54	850	22-21502	0-42	clay and gravel overburden		Qkv
			-350	slate rock	2	Om
55	665	22-21827	0-18	clay overburden		Qkv
			-98	shale bedrock	10	Om
56	665	22-21068	0-5	overburden		Qkv
			-22	clay and gravel		Qkv
			-32	big gravel & water		proglacial outwash
			-223	blue shale	5	Om
57	530	NJGS obs well 7	0-23	poorly compact, stony diamicton interlayered with gravel and sand		Qam
			-35	cobble gravel inter-layered with pebble gravel		Qpk14
			-50	pebbly sand, sand interlayered with pebble gravel		
			-65	fine gravel and fine sand		
			-90	pebbly sand to sand to clayey silt		
			-110	gray clayey silt		Qpklb
			-115	dary gray siltstone		Om
58	570	22-21457	0-30	clay and hardpan		Qkv
			-260	slate	5	Om
59	800	22-20743	0-68	sand and gravel		Qkv
			-423	shale	10	Om
60	550	22-7485	0-60	clay and gravel overburden		Qal/ Qwb5
			-136	slate rock	9	Om

TABLE 1. The listed wells were drilled for private and public water supply, monitoring and exploration. Wells listed with a NJDEP permit number are from the files of the Bureau of Water Allocation, Division of Water Resources, New Jersey Department of Environmental Protection. Well locations are based on tax-parcel maps. Well locations plotted on Plate 1 are generally accurate to within 200 feet of their actual location. Yield listed as gallons per minute. Suffixes used: number after meltwater deposit refers to a morphosequence, (lf) indicates a lacustrine fan, (u) indicates uncorrelated morphosequence, and (lb) indicates lake-bottom deposit. Altitude of wells estimated from contours on base map. Slash (/) indicates that unit on left side lies over unit to the right, and question mark (?) indicates uncertain stratigraphic correlation.

Explanation of deposit abbreviations used in Table 1.

Qal - alluvium
Qwk - glacial Lake Wallkill
Qbr - glacial Lake Beaver Run
Qpk - upper Paulins Kill Valley
Qwb - West Branch Papakating Creek
Qam - Augusta Moraine
Qkv - till (Kittatinny Valley)
OCk - Kittatinny Limestone
Om - Martinsburg Formation