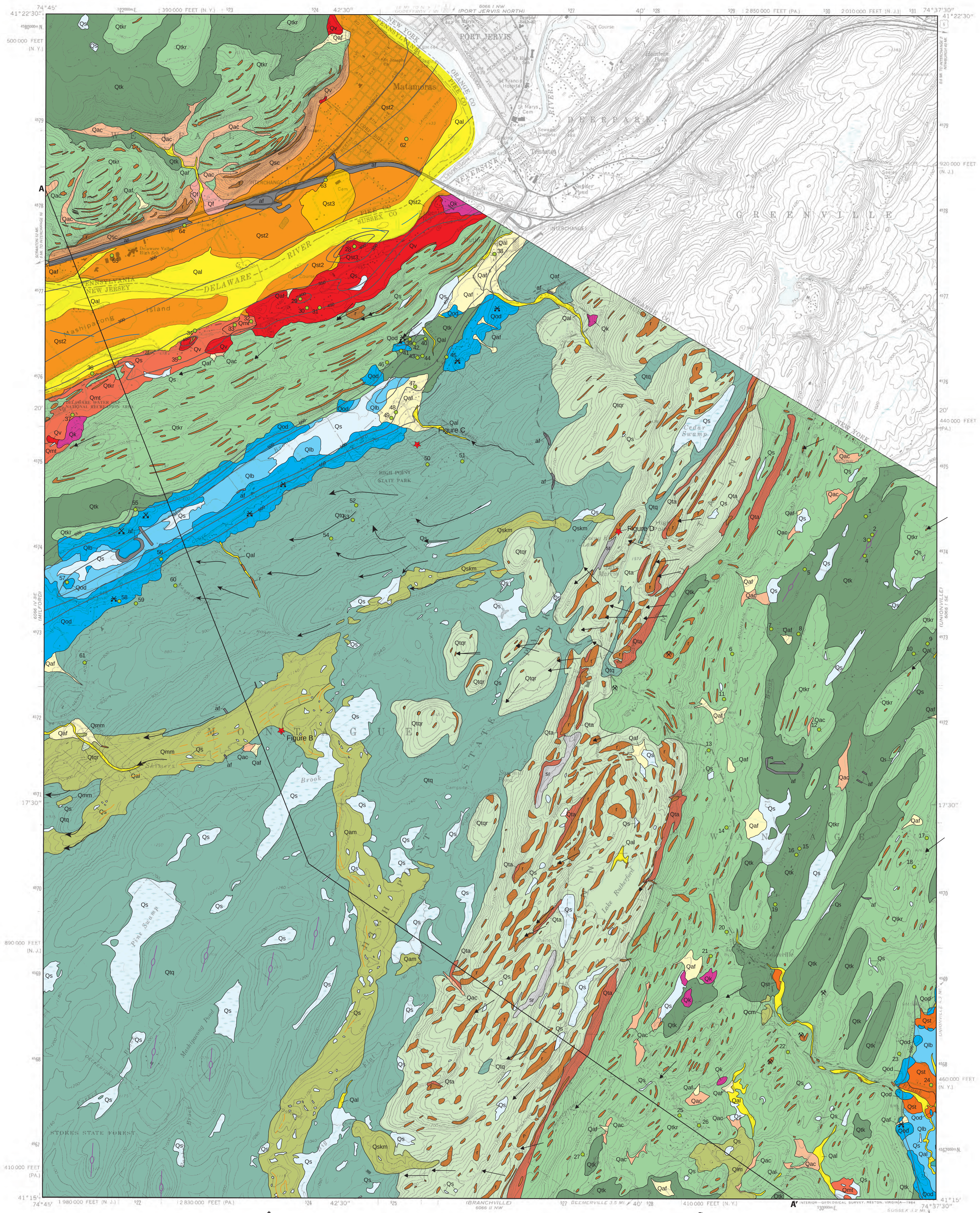
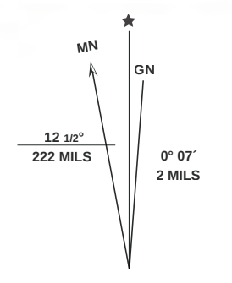
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATER RESOURCES MANAGEMENT
NEW JERSEY GEOLOGICAL AND WATER SURVEY

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

SURFICIAL GEOLOGIC MAP OF THE PORT JERVIS SOUTH QUADRANGLE,
SUSSEX COUNTY, NEW JERSEY AND PIKE COUNTY, PENNSYLVANIA
OPEN-FILE MAP OFM 99



Base from U.S. Geological Survey
Milford, 1957. Revised 1981



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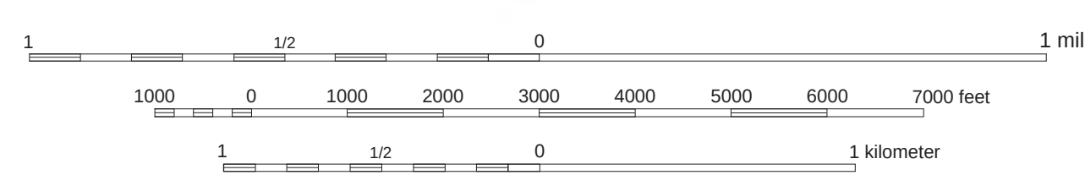


CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION

New Jersey surficial geology and Pennsylvania surficial geology in Delware Water Gap National Recreation Area mapped by Ron W. Witte, 1991 - 1995. Elsewhere, Pennsylvania geology modified from Sevon and others (1989). Research supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 99HQAG0141. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Government. Digital cartography by Ron Witte and GIS application by Mike Girard, New Jersey Geological and Water Survey.

SURFICIAL GEOLOGIC MAP OF THE PORT JERVIS SOUTH QUADRANGLE
SUSSEX COUNTY, NEW JERSEY AND PIKE COUNTY, PENNSYLVANIA

by

RON W. WITTE

2013

INTRODUCTION

Industrial, commercial, and residential expansion in New Jersey has promoted the increased use of surficial geologic data for land-use planning, for identification, management, and protection of ground-water resources, siting of solid-waste-disposal sites, locating and developing sources of geologic aggregate, and delineation of geologic hazards. Surficial deposits in the Port Jervis South quadrangle are lithologically diverse, cover most of the bedrock surface, and occur in many types of landscape settings. They include glacial drift of late Wisconsinan age, and alluvium, swamp and bog deposits, hillslope deposits, and wind-blown sediment laid down in postglacial time. Collectively, these deposits may be as much as 340 feet (104 m) thick and they form the parent material on which soils form. They are defined by their lithic characteristics, stratigraphic position, location, and further delineated by genetic and morphologic criteria. Geologic history, detailed observations on surficial materials, and a list of references are in the accompanying booklet.

DESCRIPTION OF MAP UNITS

Map units denote unconsolidated deposits more than 5 feet (1.5 m) thick. Color designations are based on Munsell Soil Color Charts (1975), and were determined from naturally moist samples.

Postglacial deposits

af

Artificial fill (Holocene) -- Rock waste, soil, gravel, sand, silt, and manufactured materials put in place by man. As much as 25 feet (8 m) thick. Not shown beneath roads, and railroads where it is less than 10 feet (3 m) thick. Primarily used to raise the land surface, construct earthen dams, and form a soild base for roads and railways.

Qal

Alluvium (Holocene) -- Stratified, moderately- to poorly-sorted sand, gravel, silt, and minor clay and organic material deposited by the Delaware River, Wallkill River and their tributaries. Locally bouldery. As much as 25 feet (8 m) thick. Includes planar- to cross-bedded gravel and sand, and cross-bedded and rippled sand in channel deposits, and massive and parallel-laminated fine sand, and silt in flood-plain deposits.

Qac

Alluvium and Colluvium, Undifferentiated - Stratified, poorly- to moderately-sorted, brown to yellowish-brown, gray sand, silt and minor gravel; as much as 20 feet (6 m) thick. Interlayered with, or overlying, massive to crudely-layered, poorly-sorted sand, silt, and minor gravel.

Qaf

Alluvial-fan deposits (Holocene and late Wisconsinan) -- Stratified, moderately to poorly sorted sand, gravel, and silt in fan-shaped deposits. As much as 35 feet (11 m) thick. Includes massive 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. Typically graded to postglacial terraces or the modern floodplain. More rarely graded to glacial outwash terraces. Most fans dissected by modern streams.

Qst Qst2 Qst3

Stream-terrace deposits (Holocene and late Wisconsinan) -- Stratified, well- to moderately-sorted, massive to laminated, and minor cross-bedded fine sand, and silt as much as 20 feet (6 m) thick, overlying planar to cross-bedded pebbly sand and gravel as much as 10 feet (3 m) thick in terraces flanking present and late postglacial stream courses. In Minisink Valley (Delaware River valley) deposits form two distinct terraces. The younger (**Qst2**) flanks recent and late postglacial stream courses and overlies early to late postglacial fluvial gravel and sand. It lies 20 to 35 feet (6 to 11 m) above the mean annual elevation of the Delaware River and chiefly consists of as much as 20 feet (6 m) of fine sand and silt overlying as much as 10 feet (6 m) of pebble gravel and sand. The older (**Qst3**) flanks late glacial and early postglacial stream courses and overlies glacial outwash and early postglacial fluvial sand and gravel. It lies 40 to 50 feet above the river and consists of as much as 10 feet of fine sand and medium sand.

Qs

Swamp and bog deposits (Holocene and late Wisconsinan) -- Dark brown to black peat, partially decomposed remains of mosses, sedges, trees and other plants, and muck underlain by laminated organic-rich silt and clay. Accumulated in kettles, shallow postglacial lakes, poorly-drained areas in uplands, and hollows in ground moraine. As much as 25 feet (8 m) thick. Locally interbedded with alluvium and thin colluvium.

Qsc

Shale-chip colluvium (Holocene and late Wisconsinan) -- Thin to thickly bedded, noncompact, poorly sorted light yellowish-brown (10YR 6/4) to brownish-yellow (10YR 7/6) or light olive-brown (2.5Y 5/2) framework supported, shale-chip gravel, containing as much as 80 percent unweathered to lightly weathered angular to subangular shale chips, and minor tabular pebbles and cobbles of siltstone, and sandstone. Interstitial material consists of silty sand. Forms aprons below cliffs and some steep slopes on the west side of Minisink Valley; as much as 20 feet (3 m) thick. Beds dip as much as 25° toward valley. In places the distal (downslope) beds are interlayered with wind-blown sand and alluvium. Graded to glacial and postglacial stream terraces in valley.

Qta

Talus deposits (Holocene and late Wisconsinan) -- Unsorted, nonstratified, angular boulders as much as 15 feet (4 m) long, cobbles, and smaller fragments of quartzite and quartz-pebble conglomerate forming aprons over rock and till at the base of bedrock cliffs and steep hillslopes on Kittatinny Mountain. As much as 20 feet (6 m) thick.

Glacial Deposits

Stratified Materials

Qv

Valley-train deposits (late Wisconsinan) -- Stratified, well- to moderately-sorted sand, boulder-cobble to pebble gravel, and minor silt deposited by meltwater streams in Minisink Valley from ice-recessional positions (fig. 2, in booklet) at and extending well beyond (more than five miles (8 km)) the stagnant glacier margin. As much as 100 feet (30 m) thick. The proximal part of the deposit consists of massive to horizontally-bedded and imbricated coarse gravel and sand, and planar to tabular and trough cross-bedded, fine gravel and sand in bars, and channel-lag deposits with minor cross-bedded sand in channel-fill deposits. Clasts generally are smaller downstream, sand is more abundant, and trough and planar cross-bedding, and graded beds are more common. Based on well records (table 1) overlies glacial lake deposits previously laid down in sediment-dammed proglacial lakes. In places overlain by nonlayered, well-sorted, very fine sand and fine sand presumed to be eolian; as much as 5 feet (2 m) thick. In Minisink Valley forms shingled sets of outwash terraces.

Qf

Outwash-fan deposits (late Wisconsinan) -- Stratified, well- to moderately-sorted sand, cobble-pebble gravel, and minor silt deposited by meltwater streams in fan-shaped deposits at the mouth of large tributaries in Minisink Valley. As much as 60 feet (18 m) thick. Includes massive to planar-bedded sand and gravel, and minor cross-bedded and channel-fill sand. Bedding generally dips towards the trunk valley by as much as 10°. Fan deposits are graded to valley-train deposits.

Qod

Glacial-lake delta deposits (late Wisconsinan) -- Stratified, sand, gravel, and silt deposited by meltwater streams in narrow proglacial lakes at and beyond the stagnant glacier margin. Includes well sorted sand and boulder-cobble to pebble gravel in planar to cross-bedded glaciofluvial topset beds that are as much as 25 feet (8 m) thick. Overlies and grades into foreset beds that dip 20° to 35° basinward and consist of well- to moderately-sorted, rhythmically-bedded cobble-pebble and pebble gravel and sand. These beds grade downward and outward into ripple cross-laminated and parallel-laminated, sand, silt and pebble gravel that dip less than 20°. Lower foreset beds grade into gently inclined prodelta bottomset beds of rhythmically-bedded, ripple cross-laminated to graded fine sand and silt with minor clay drapes. Thickness may be as much as 100 feet (30 m).

Deposits were laid down in glacial Lake Mill Brook and a narrow arm of glacial Lake Walkill. Many of the them are extensively kettled, showing deposition on and around stagnant ice. In places, topset beds may be extensively aggraded in their upstream sections.

Qlb

Glacial lake-bottom deposits (late Wisconsinan) -- Parallel-laminated, irregularly to rhythmically-bedded silt, clay, and very fine sand; and minor cross-laminated silt, fine sand, and minor clay deposited on the floor of glacial lakes chiefly by density currents and settling of fines. As much as 100 feet (30 m) thick.

Qmt

Meltwater-terrace deposits (late Wisconsinan) -- Stratified, well- to moderately-sorted sand, cobble-pebble to pebble gravel, and minor silt deposited by meltwater streams as terraces incised in valley-train, glacial lake delta deposits, and other meltwater-terrace deposits. As much as 20 feet (6 m) thick. Sediment and bedforms similar to the downstream, distal part of valley-train deposits. Includes bouldery strath terraces cut in till along meltwater stream courses in uplands. May also include the distal part of valley-train deposits where they have cut into older valley-train deposits downvalley.

Qk

Kame (late Wisconsinan) -- Stratified, well- to poorly-sorted sand, boulder- to pebble-gravel, silt, and interbedded flowtill in small collapsed hills and ridges overlying till. Presumed to be ice-hole and crevasse fillings. As much as 50 feet (15 m) thick. Attitude of bedding is highly variable.

Non-stratified Materials

Till (late Wisconsinan) -- Scattered patches of noncompact to slightly compact, bouldery "upper till" overlying a blanket-like compact "lower till" deposited chiefly on bedrock and locally some older pre-Wisconsinan surficial deposits. Includes two varieties:

Qtk Qtkr

1) 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 200 feet (61 m) thick. Locally overlain by thin, discontinuous, non-compact to slightly compact, poorly sorted, indistinctly layered yellow-brown (10YR 5/6-8), 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. Matrix is a varied mixture of unweathered quartz, rock fragments, and silt; minor constituents include feldspar and clay. Till derived chiefly from limestone, argillaceous limestone, shale, and sandstone from area west of Kittatinny Mountain. "r" denotes areas of till generally less than 10 feet thick (3 m) with few to some bedrock outcrops.

Qtq Qtqr

2) 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 (2.5Y5/4) and reddish-brown (5YR4/3) silty sand and sand containing 10 to 20 percent gravel. As much as 50 feet (15 m) thick. Locally overlain by thin, discontinuous, non-compact, 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. Matrix is a varied mixture of quartz, rock fragments, silt, minor feldspar, and clay. Till derived chiefly from quartzite, quartz-pebble conglomerate, and red sandstone on Kittatinny Mountain. "r" denotes areas of till generally less than 10 feet thick (3 m) with few to some bedrock outcrops.

Qam Qmm Qskm Qlm Qcm

Recessional moraine (late Wisconsinan) -- Unstratified to poorly stratified sand, gravel, and silt deposited at the active margin of the Kittatinny and Minisink Valley ice lobes. As much as 80 feet (24 m) thick. Consists 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. Overlies "lower till" in uplands and locally outwash in river valleys. Locally named Augusta (Qam), Montague (Qmm), Steeny Kill Lake (Qskm), Libertyville (Qlm), and Colesville (Qcm) moraines.

Bedrock

r

Bedrock -- Extensive outcrops, minor frost-shattered rock, talus, and sparse erratics.

sr

Bedrock -- Regolith; chiefly rock waste on steep hillslopes and ridge crests, minor talus, scattered erratics, and a few small outcrops.

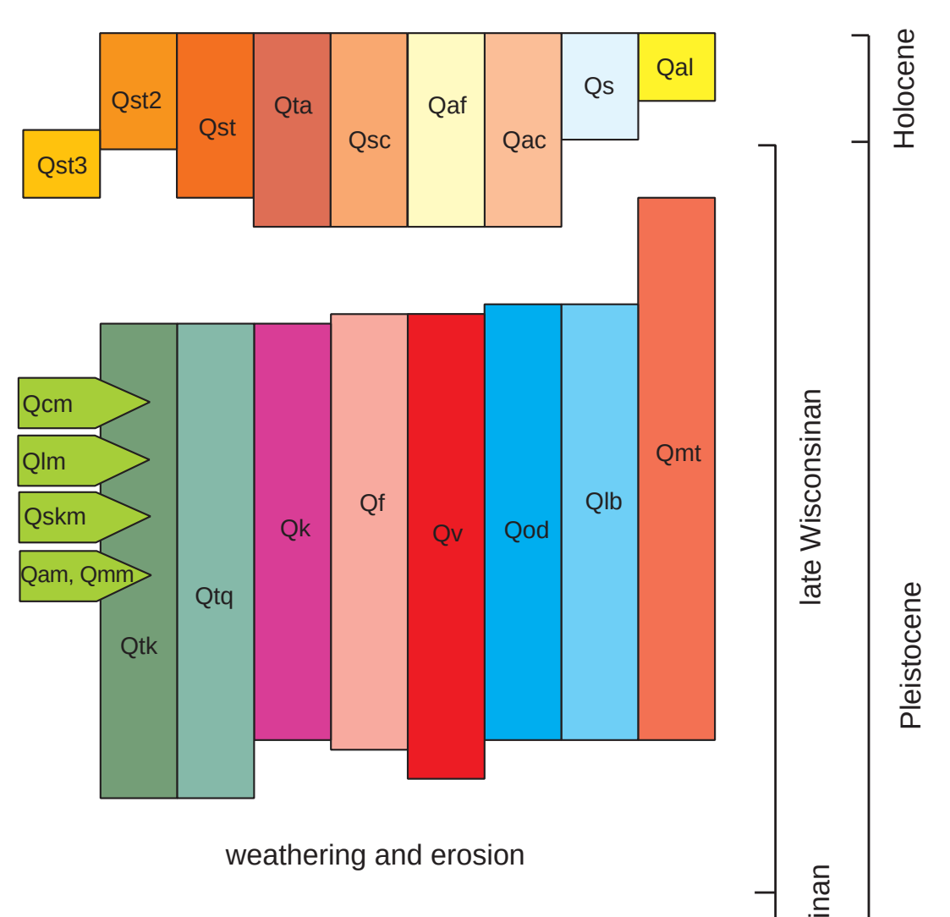
Table 1. Records of selected wells in the Port Jervis South quadrangle, Sussex County, New Jersey, and Pike County, Pennsylvania. The listed wells were drilled for private and public-water supply, and exploration. Wells listed with a NJDEP permit number are from the files of the Bureau of Water Allocation, Division of Water Resources, New Jersey Department of Environmental Protection. If the NJDEP permit number is not listed the well record is from Davis (1989) and noted in the table as "Pike" followed by an identification number that was used in the report. A few geologic records were compiled from New Jersey Geological Survey Permanent Notes, on file at the New Jersey Geological and Water Survey, PO Box 420, Trenton, New Jersey 08625. The location of wells listed with NJDEP permit number are based on property maps, and are generally accurate to 200 feet (S) and 500 feet (F) of their actual location. "cd" indicates thickness of unconsolidated material is based on casing length.

well number	NJDEP permit number	Location code	Discharge in gpm	Depth in feet	Driller's log
1	22-24721	S	20	0-90 90-150	sand, clay, and gravel overburden slate
2	22-13450	S	3	0-84 cd 84-498	sand and gravel overburden slate
3	22-23096	S	2	0-77 77-500	clay and gravel overburden slate
4	22-13057	S	2	0-72 cd 72-224	sand and gravel overburden slate
5	22-7322	F	8	0-31 cd 31-80	clay and gravel overburden slate
6	22-21125	F	3	0-8 8-175	clay overburden slate
7	22-25812	S	20	0-35 35-110	sand, clay, and gravel overburden slate
8	22-11599	S	5	0-51 51-186	casing depth slate
9	22-22422	S	6	0-30 30-247	clay and gravel overburden slate
10	22-19214	S	25	0-55 55-230	clay and gravel overburden slate
11	22-20326	F	15	0-15 15-131	clay and boulders shale
12	22-15986	S	3	0-57 57-260	casing depth slate
13	22-23541	S	2	0-10 10-350	clay overburden slate
14	22-15554	S	2	0-7 7-98	overburden shale
15	22-24202	S	25	0-176 176-275	sand, clay, and gravel overburden slate
16	22-24203	S	4	0-180 180-325	sand, clay, and gravel overburden slate
17	22-7887	F	2	0-21	casing depth
18	22-13972	F	1	0-22 22-500	casing depth slate
19	22-14074	S	6	0-54 cd 54-82	overburden shale
20	22-16408	F	18	0-22 22-70	casing depth slate
21	22-26177	S	none recorded	0-7 7-300	overburden shale
22	22-7989	F	8	0-20 cd 20-260	clay and gravel overburden slate
23	22-25023	S	5	0-12 12-322	clay and overburden shale
24	22-7360	F	12	0-67 cd 67-68	clay and gravel overburden slate
25	22-11705	F	3	0-30 cd 30-298	sand and gravel overburden slate
26	22-10296	F	20	0-21 cd 21-263	sand and gravel overburden slate
27	22-8410	F	18	0-23 cd 23-95	clay and gravel overburden slate
28	22-23488	S	8	0-28 28-65	clay and gravel overburden lime rock
29	22-20814	S	50	0-45 45-55 55-62	sand gravel shale
30	22-20944	S	6	0-100 100-188	sand shale
31	22-20945	S	15	0-92 92-145	sand shale
32	22-22169	S	20	0-32 32-125	sand limestone
33	22-25507	S	8	0-31 31-300	sand, clay, and gravel overburden slate
34	22-7271	F	30	0-65 cd 65-80	clay and gravel overburden limestone rock
35	22-21936	S	100	0-21 21-65 65-175	gravel and sand sand shale
36	22-25562	S	2	0-45 45-330	sandy loam and some gravel shale
37	22-24853	S	40	0-15 15-125	sandy loam black rock
38	22-12491	S	40	0-90 cd 90-122	sand and gravel overburden slate
39	22-26674	S	30	0-60 60-125	sand, clay, and gravel overburden slate
40	22-26054	S	20	0-90 90-150	sand, clay, and gravel overburden limestone
41	22-25422	S	30	0-69 69-225	sand, clay, and gravel overburden limestone
42	22-25824	S	8	0-110 110-160	sand, clay, and gravel overburden slate
43	22-19308	S	8	0-15 15-35 35-45 45-130	gravel and boulders sand and gravel boulders sand and gravel
44	22-18711	S	12	0-20 20-65 65-85 85-123	sand, clay, and water gray silt clay limestone
45	22-20584	S	30	0-105 105-200	sand and gravel overburden slate
46	22-21070	S	30	0-70 70-135	clay and gravel overburden slate
47	22-18713	S	20	0-20 20-50 50-80 80-148	large gravel and sand silt clay slate
48	22-24637	S	40	0-80 80-150	sand, clay, and gravel overburden red shale
49	22-21520	S	20	0-20 20-89 89-123	sand, gravel, clay, and boulders sand, gravel, and clay red rock
50	22-23324	S	15	0-136 136-275	clay and gravel overburden red slate
51	22-16232	S	2	0-15 15-50 50-80 80-100 100-135 135-141 141-148	gravel, clay, and water sand and boulders clay and sand hardpan with gravel hard-packed clay with gravel hardpan with water hardpan with gravel
52	22-25736	S	none recorded	0-15 15-166	overburden red rock
53	22-22215	S	3	0-50 50-64	clay and gravel overburden red slate
54	22-25491	S	30	0-51 51-125	sand, clay, and gravel overburden slate
55	22-24096	S	30	0-79 79-125	overburden limestone
56	22-23822	S	20	0-10 10-41 41-125	overburden boulders rock
57	22-13946	F	60	0-94	gravel
58	22-21871	S	12	0-10 10-105	overburden limestone
59	22-24573	S	12	0-12 12-125	loam red rock
60	22-25921	S	3	0-23 23-300	sand, clay, and gravel overburden slate
61	22-24488	S	4	0-61 61-275	sand, clay, and gravel overburden red slate
62	Pike - 223			0-84	alluvium and glacial outwash
63	Pike - 83			0-68	alluvium and glacial outwash
64	Pike - 13			0-68	alluvium and glacial outwash
65	Pike - 226			0-115	ice-contact stratified drift

EXPLANATION OF MAP SYMBOLS

——— — — —	Contact, dashed where approximately located or gradational.
←	Striation, measurement at tip of arrow.
—○—	Drumlin, line on crest, ellipse on summit.
←	Small meltwater channel.
⌣	Morainal ridge, line at crest.
925'	Glacial-lake spillway with estimated elevation of its floor.
⌒	Fluvial scarp, line lies at base of scarp and tics point upslope.
⌒	Alluvial channel scroll, line along channel axis.
⚒	Active sand and gravel pit.
⚒	Inactive sand and gravel pit.
⚒	Quarry.
⚒	Inactive quarry.
—550—	Bedrock surface contour - Shown where rock surface is buried beneath thick glacial sediment. Approximately located, indicates altitude of rock surface in feet above sea level. Contour interval is 50 feet. Hachures indicate closed depression.
● 12	Location of well or boring listed in Table 1 on this plate.
★	Location of photo, figures B, C, and D.

CORRELATION OF MAP UNITS



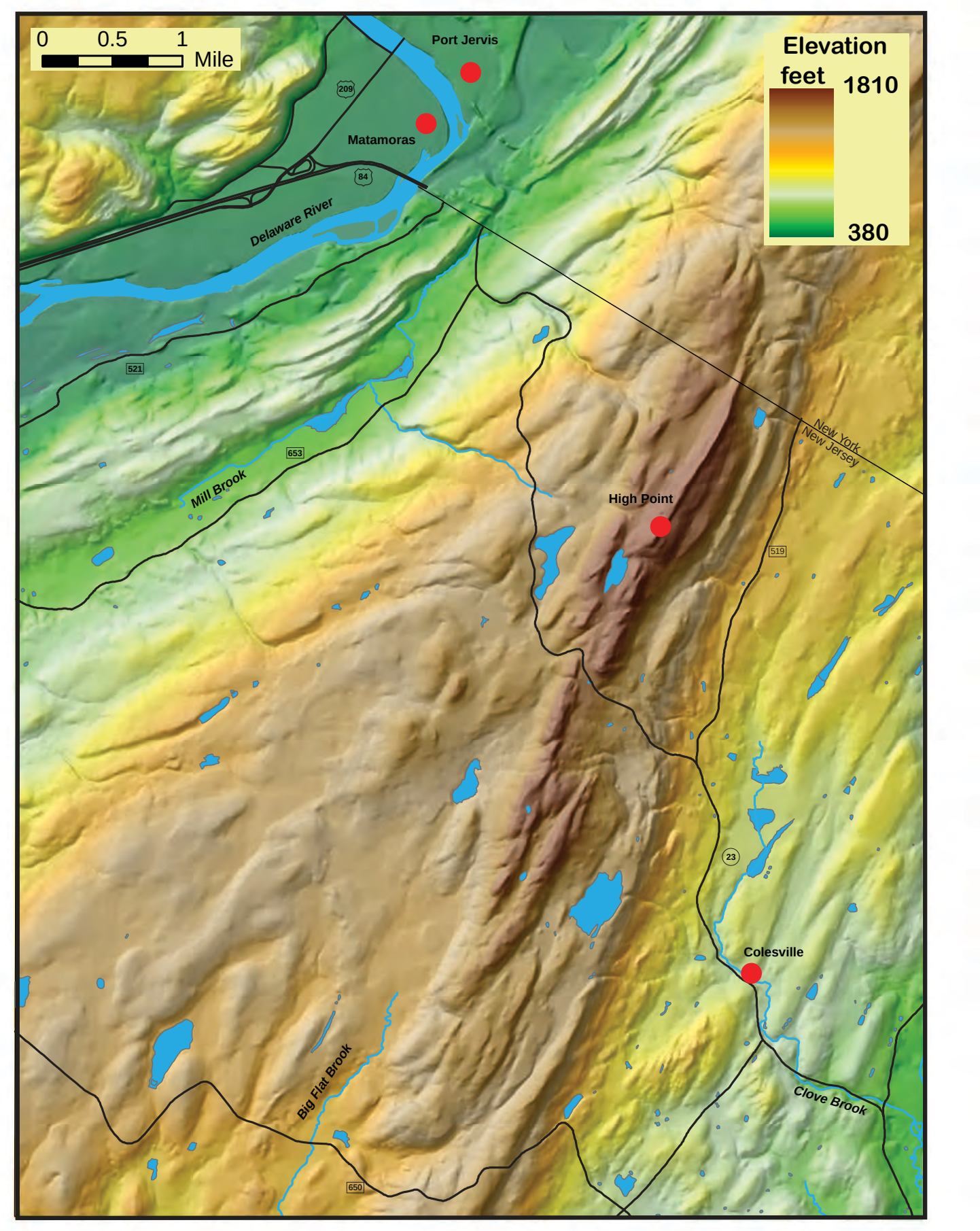
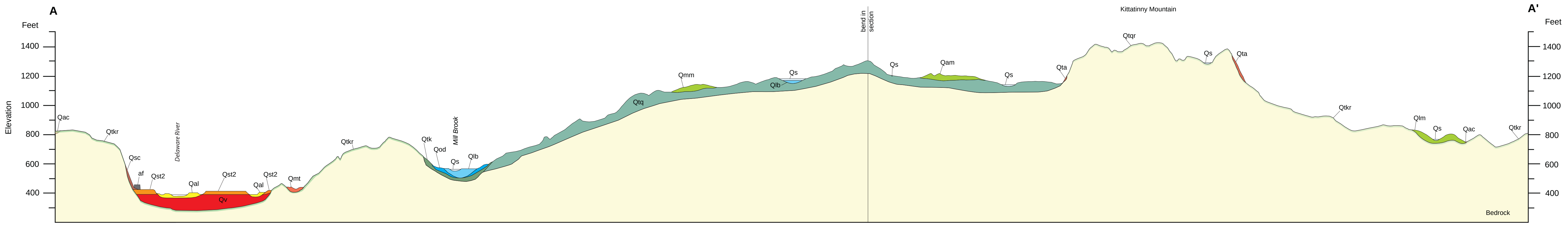


Figure A. Color-shaded relief map of the Port Jervis South quadrangle.

Figure B. "Our Swamp", High Point State Park, Sussex County, New Jersey. Formerly a shallow glacial lake dammed behind the Montague recessional moraine (Qmm).



Vertical exaggeration = 5x. Thin till (Qtkr, Qtqr) inferred to be less than 10 feet thick. Rock outcrops (r) are not shown on the section.

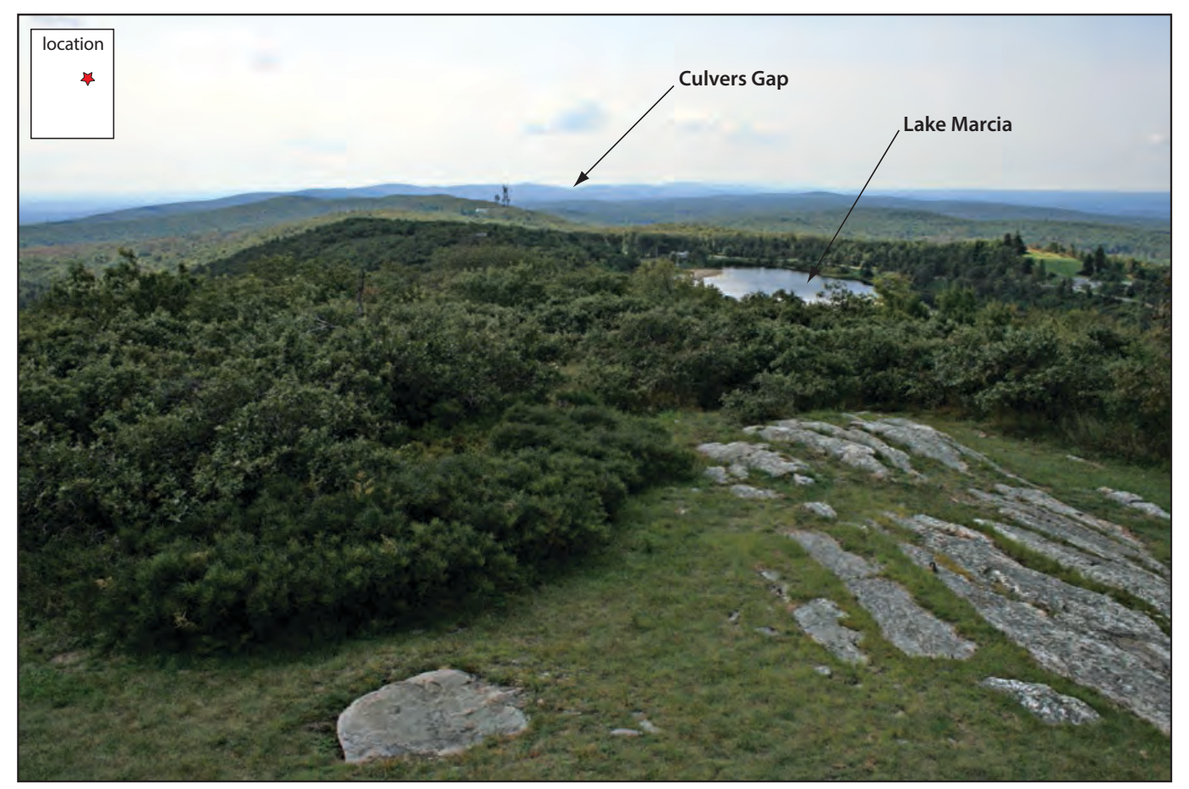


Figure D. Vista from High Point Monument, High Point State Park, Sussex County, New Jersey looking southwestward along the curving ridgeline of Kittatinny Mountain. The small notch along the ridge's midline is Culvers Gap, a wind gap cut by the ancestral Raritan or Delaware Rivers millions of years ago and prior to the onset of continental glaciation in North America.

Figure C. Brown quartzite-rich till overlying reddish-brown red sandstone rich till exposed along the face of a small slump located along the upper reach of Clove Brook, High Point State Park, Sussex County, New Jersey. The reddish-brown till, largely derived from the Bloomsburg Red Beds, represents a more southerly flow across Kittatinny Mountain. The brown till, largely derived from the Shawangunk Formation, represents a southwesterly to westerly flow. This change in till provenance is consistent other indicators of ice flow (drumlins, striae, erratic dispersal) that show a more regional southerly flow superceded by a southwesterly to westerly flow during deglaciation.

NEW JERSEY GEOLOGICAL AND WATER SURVEY
OPEN-FILE MAP OFM 99

SURFICIAL GEOLOGY OF THE PORT JERVIS SOUTH QUADRANGLE
SUSSEX COUNTY, NEW JERSEY AND
PIKE COUNTY, PENNSYLVANIA

by

Ron W. Witte

New Jersey Geological and Water Survey

State of New Jersey
Chris Christie, *Governor*
Kim Guadagno, *Lt. Governor*

Department of Environmental Protection
Bob Martin, *Commissioner*

Water Resources Management
Michele Siekerka, *Assistant Commissioner*

Geological and Water Survey
Karl Muessig, *State Geologist*

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

The mission of the New Jersey Department of Environmental Protection is to assist the residents of New Jersey in preserving, sustaining, protecting and enhancing the environment to ensure the integration of high environmental quality, public health and economic vitality.

NEW JERSEY GEOLOGICAL AND WATER SURVEY

The mission of the New Jersey Geological and Water Survey is to map, research, interpret and provide scientific information regarding the state's geology and ground-water resources. This information supports the regulatory and planning functions of DEP and other governmental agencies and provides the business community and public with information necessary to address environmental concerns and make economic decisions.

For more information, contact:
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http://www.njgeology.org/

Cover photo: Northwest vista from High Point, New Jersey, looking at the Delaware River between Port Jervis, New York (right) and Matamoras, Pennsylvania (left). Photograph by Ron W. Witte.

SURFICIAL GEOLOGY OF THE PORT JERVIS SOUTH QUADRANGLE, SUSSEX COUNTY, NEW JERSEY AND PIKE COUNTY, PENNSYLVANIA

Ron W. Witte

New Jersey Geological and Water Survey

INTRODUCTION

The Port Jervis South quadrangle is located in the glaciated part of the Appalachian Valley and Ridge physiographic province in Sussex County, New Jersey; Pike County, Pennsylvania; and Orange County, New York. The area is largely rural, its land covered by large tracts of forest in Delaware Water Gap National Recreation Area (DEWA), Stokes State Forest, and High Point State Park, New Jersey. Patchwork woodlands and cultivated fields lie in the fertile Minisink and Mill Brook Valleys. Port Jervis, New York, built along the banks of the Delaware and Neversink Rivers; and Matamoras, Pennsylvania, just across the Delaware River, are the two largest towns. Port Jervis started as a colonial settlement in the late 1600's. After the completion of the Delaware and Hudson Canal in 1828, it became a major hub in the transport of Pennsylvania anthracite to New York City and the many nearby cities and towns. During the mid-1800's Port Jervis became an important railroad town along a route linking Piermont, New York with Lake Erie.

The main geographic features are Minisink and Kittatinny Valleys, Wallpack Ridge, and Kittatinny Mountain (fig. 1). The Delaware River descends southeast from the Pocono Plateau to Port Jervis, where it makes a sweeping turn, flowing southwest through Minisink Valley. Directly downstream from Port Jervis it is joined by the Neversink River. In Kittatinny Valley Clove Brook flows southward to Papakating Creek, a tributary of the Wallkill River. The highest point in the quadrangle is on Kittatinny Mountain, 1803 feet (550 m) above sea level at High Point, New Jersey. The lowest point lies in the Delaware River where it flows south out of the quadrangle, approximately 390 feet (119 m) above sea level.

Surficial materials in the quadrangle consist of till and meltwater sediment deposited during the late Wisconsinan glaciation about 22,000 to 17,000 radiocarbon years ago (yr BP), and postglacial stream sediment, hillslope deposits, wind-blown sand, and swamp and bog deposits laid down in late glacial and postglacial time. These materials may be as much as 250 feet (76 m) thick, lie on bedrock, and form the parent material on which soils form. The glacial deposits correlate with the Olean Drift of northeastern Pennsylvania (Crowl and Sevon, 1980). Till typically lies on bedrock and in many places it is interspersed with numerous glacially-eroded bedrock outcrops. Thicker till forms drumlins, ground moraine, recessional moraine and aprons on north-facing hillslopes. Meltwater deposits were laid down at and beyond the glacier's margin in Minisink and Mill Brook Valleys and in glacial Lake Wallkill. The heads of outwash of these deposits and recessional moraines record retreat positions of the Minisink Valley and Kittatinny Valley ice lobes (fig. 2). The most extensive postglacial deposits lie in Minisink Valley and consist of alluvium deposited by the Delaware River. Elsewhere, organic soil, largely humus and peat, lies in the many bogs and swamps that dot the landscape.

PREVIOUS INVESTIGATIONS

The geology of surficial deposits in Sussex County, New Jersey was first discussed by Cook (1877, 1878, 1880) in a series of Annual Reports of the State Geologist. He included detailed observations on recessional moraines, age of drift, distribution and types of drift, and evidence of glacial lakes. Shortly thereafter, White (1882) described the glacial geology of Pike County, Pennsylvania, and a voluminous report by Salisbury (1902) detailed the glacial geology of New Jersey, region by region. The terminal moraine (fig. 2) and all glacial deposits north of it were interpreted to be products of a single glaciation of Wisconsinan age. Salisbury also noted that "in the northwestern part of the state, several halting places of ice can be distinguished by the study of successive aggradation plains in the valleys." Crowl and Sevon (1980), and Cotter and others (1986) indicated that the youngest glacial deposits in New Jersey and Pennsylvania are late Wisconsinan age. Crowl (1971) produced surficial geologic maps of Mininsink Valley and included detailed observations on its glacial history, and Sevon and others (1989) reported on the surficial geology of Pike County, Pennsylvania.

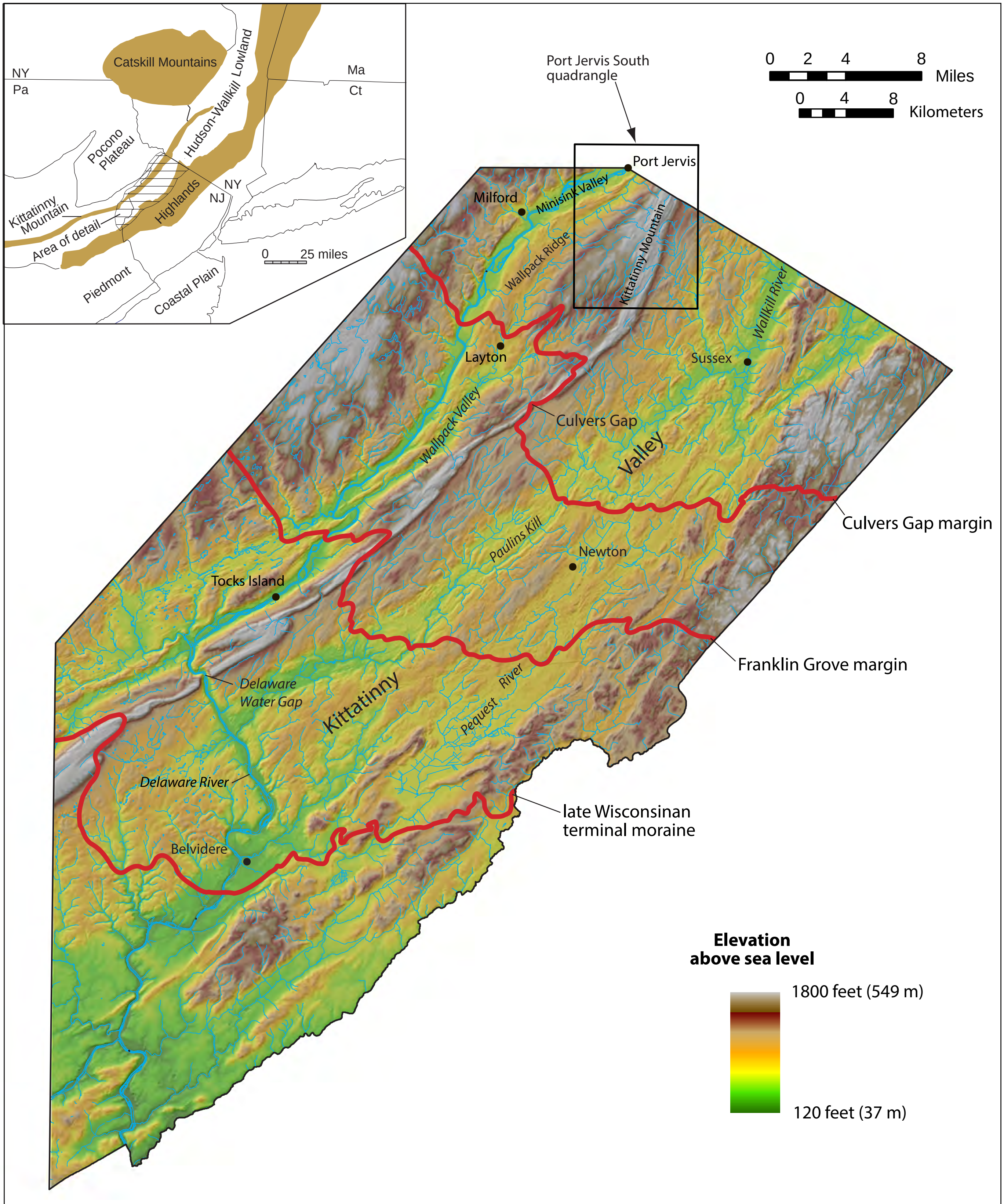

Figure 1. Physiography of northwestern New Jersey and northeastern Pennsylvania and location of the Port Jervis South quadrangle. Minisink Valley is a local geographic name for the Delaware River Valley from Delaware Water Gap to Port Jervis, New York.

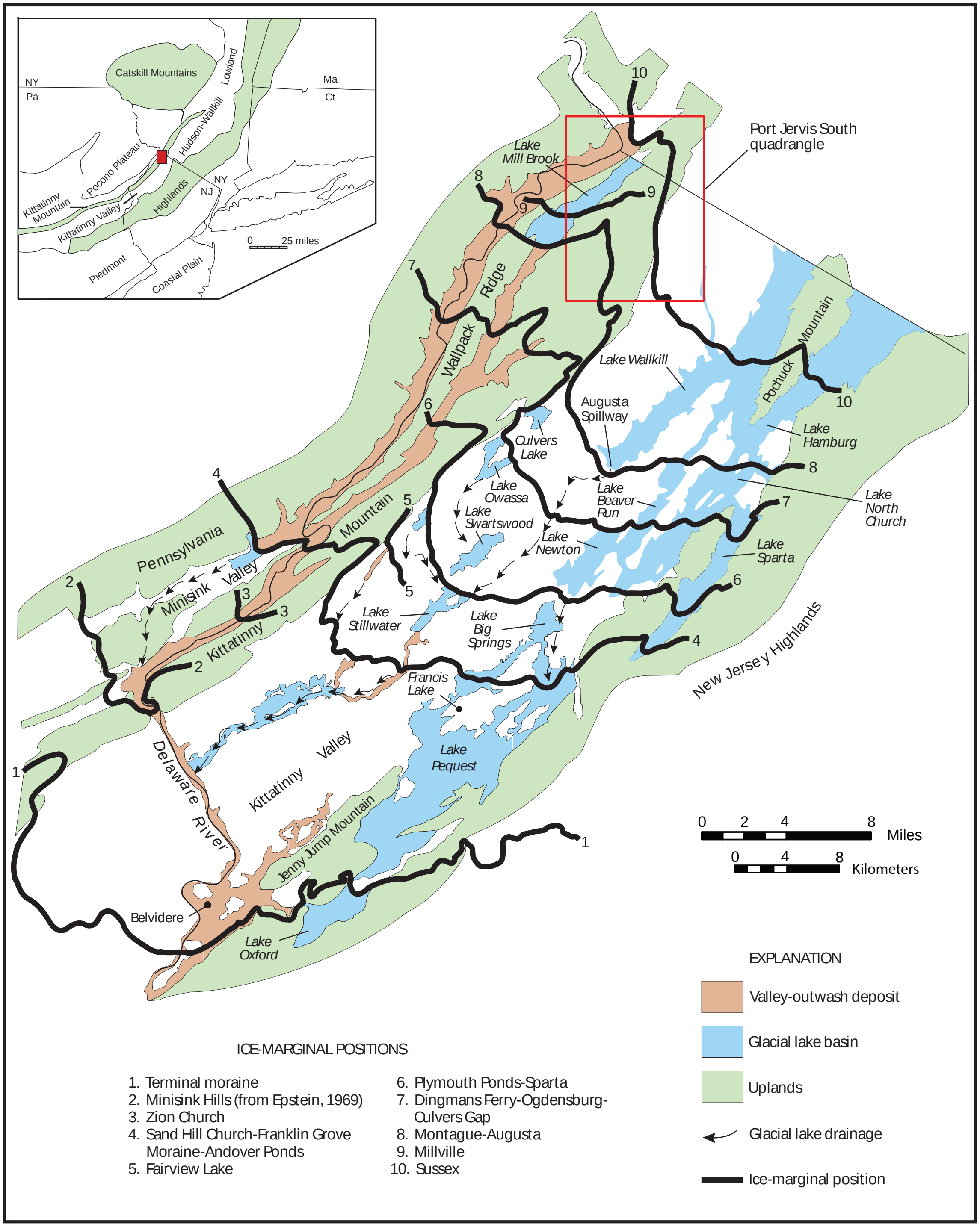

Figure 2. Late Wisconsinan ice margins of the Kittatinny and Minisink Valley ice lobes, and location of large glacial lakes, extensive valley-outwash deposits, and Port Jervis South 7.5-minute topographic quadrangle. Modified from data by Crowl (1971), Epstein (1969), Minard (1961), Ridge (1983), and Witte (1997).

Recessional moraines in Kittatinny Valley were originally identified by Salisbury (1902), and latter remapped by Herpers (1961), Ridge (1983), and Witte (1997). The Ogdensburg-Culvers Gap and Augusta moraines (fig. 2) were traced on Kittatinny Mountain by Herpers (1961), and Minard (1961), and later remapped by Witte (1997), and Stone and others (2002). In Minisink and Wallpack Valleys, the Dingmans Ferry and Montague moraines (fig. 2) were identified by Salisbury (1902), Minard (1961), and Crowl (1971), and later remapped and correlated to the Ogdensburg-Culvers Gap and Augusta moraines by Witte (1997). The Millville and Steeny Kill Lake moraines were identified by Witte (1997).

See Witte (1997, 2001a, 2001b, 2008) and Witte and Epstein (2004, 2012) for detailed discussions on the glacial and postglacial history of northwestern New Jersey.

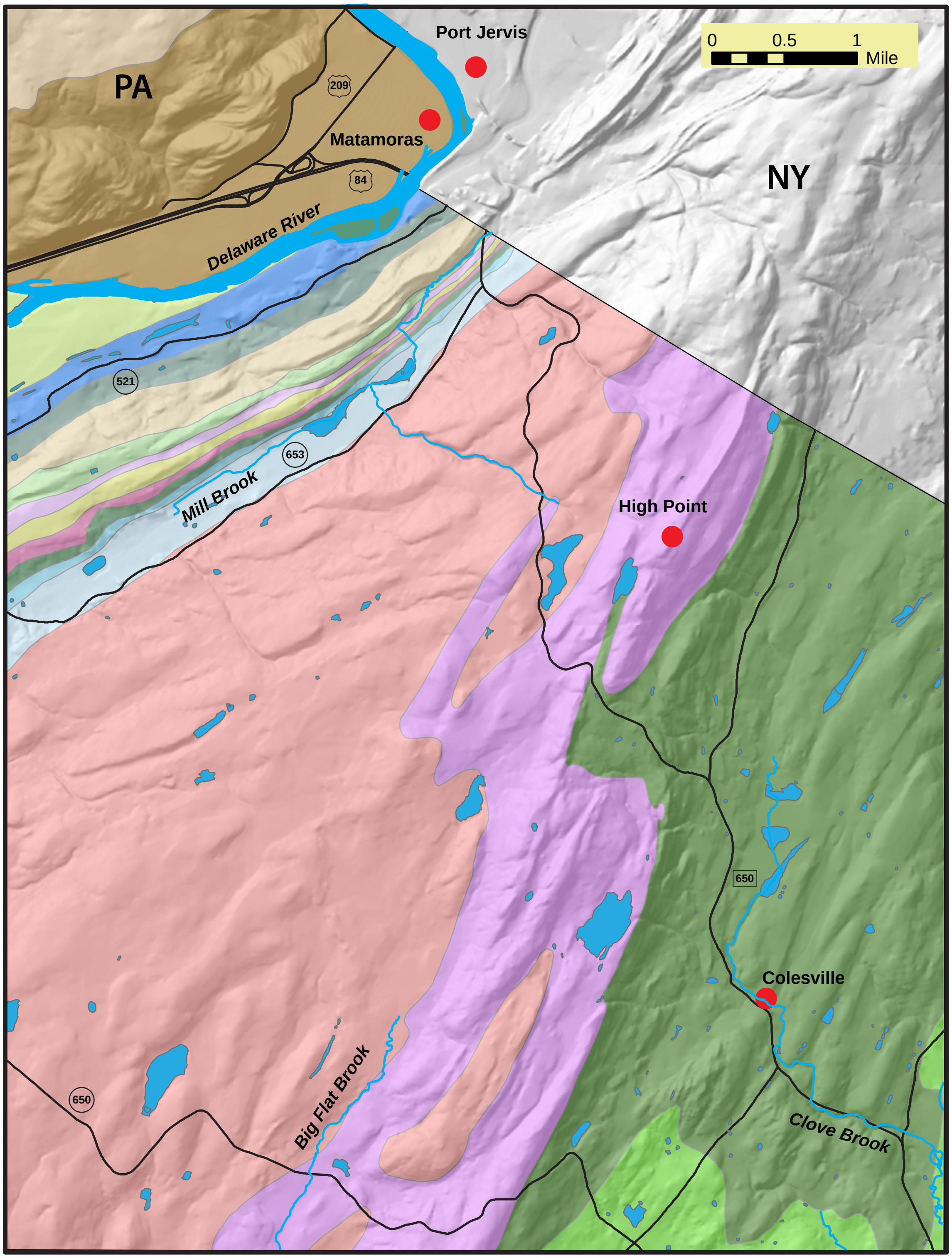

Figure 3. Simplified bedrock geologic map of the Port Jervis South quadrangle in New Jersey and Pennsylvania. Correlation to bedrock formations discussed in text. Bedrock map for New Jersey modified from Drake and others (1996), and for Pennsylvania modified from Sevon and others (1989).

Explanation

🟧 Trimmers Rock Formation

🟫 Mahantango Formation

🟨 Marcellus Shale

🟦 Onondaga Limestone

🟩 Schoharie Formation

🟫 Esopus Formation

🟩 Oriskany Group

🟪 Port Ewen Shale

🟨 Minisink Limestone and New Scotland Formation

🟥 Kalkberg Limestone, Coeymans Limestone, and Manlius Limestone

🟩 Rondout and Decker Formations

🟦 Bossardville Limestone

🟦 Poxono Island Formation

🟥 Bloomsburg Red Beds

🟪 Shawangunk Formation

🟩 Martinsburg Formation High Point Member

🟩 Martinsburg Formation Ramseyburg Member

PHYSIOGRAPHY AND BEDROCK GEOLOGY

The Port Jervis South quadrangle lies mostly in the Delaware River watershed (fig. 1). Downstream from Port Jervis, New York, the Delaware flows southwestward through Minisink Valley following the readily eroded Onondaga Limestone and Marcellus Shale. The western side of the valley is bordered by a 300-foot-high escarpment consisting of the Mahantango Shale. Tributaries typically flow at right angles to the Delaware and are deeply incised, flowing over rock before entering the trunk valley. Waterfalls are common, mostly the products of knickpoint retreat due to glacial widening and deepening of Minisink Valley. Multiple knickpoints, and abandoned and notched falls along the creek's lower course hint of multiple glaciations (Witte, 2001c, Witte, 2012).

In New Jersey, Mill Brook flows northeastward in a small strike valley and joins the Neversink River at Tristates, New York. It is separated from Minisink Valley by Walpack Ridge, a narrow, 300-foot-high interfluve mostly underlain by siltstone and fine-grained sandstone.

Kittatinny Mountain is underlain by the Shawangunk Formation, which consists of quartz-pebble conglomerate, and quartzite, and the Bloomsburg Red Beds, which consists of red sandstone, and red shale (fig. 3). The mountain forms a very long ridge that extends southwestward from the Shawangunk Mountains in New York through New Jersey into Pennsylvania. In many places its steep southeast face forms a nearly continuous escarpment. In a few places the continuity of the mountain is broken by wind gaps. The largest of these is Culvers Gap (fig. 1) and it marks the former site of a large river that abandoned its course some time during the Late Tertiary (Witte and Epstein, 2004). The mountain is rugged, chiefly consisting of uneven, narrow- to broad-crested, strike-parallel ridges. Rock outcrops are very abundant, exhibiting extensive glacial scour and plucking. The high ridge area of the mountain is underlain by the Shawangunk Formation, whereas the hills and slopes to the west are underlain by Bloomsburg Red Beds, covered in most places by thick glacial drift. Relief here may be as much as 300 feet (91 m), and the surface is marked by rolling topography of gentle to moderate slopes chiefly formed on drumlins and ground moraine. Big Flat Brook and its many tributaries flow southwestward toward Wallpack Valley.

Kittatinny Valley is a broad northeast-to-southwest-trending lowland underlain by dolomite, limestone, slate, siltstone, and sandstone; all Cambrian to Ordovician in age (fig. 3). In the quadrangle the valley is underlain only by shale, siltstone, and sandstone of the Martinsburg Formation. Outcrops are abundant and the landscape typically consists of rolling hills of moderate to steep slopes, and strike-parallel ridges streamlined by glacial erosion. Kittatinny Valley and the east-facing slope of Kittatinny Mountain are in the Wallkill River drainage basin.

PREGLACIAL DRAINAGE

The overall drainage pattern of the study area probably has not significantly changed from the middle Pleistocene to the present. A discussion of Culvers Gap and the river that formerly flowed through it is in Witte and Epstein (2004), and a discussion of waterfalls and multiple glaciations in Minisink Valley is in Witte (2001c, 2012). In Kittatinny Valley, Clove Brook, a tributary of the north-flowing Wallkill River, follows a barbed drainage course suggesting that it may have been a tributary of the Paulins Kill. During the late Wisconsinan glaciation, outwash in the upper part of the Papakating Valley (a tributary to the Wallkill River) blocked drainage southward to Paulins Kill (Witte, 2008). After deglaciation, these streams, which were originally in the Paulins Kill watershed, rerouted and became part of the Wallkill River watershed.

GLACIAL EROSION

Erosional features of the late Wisconsinan glaciation include polished, striated, and plucked bedrock outcrops, and streamlined bedrock forms called *roche moutonnées*. The many unweathered and lightly weathered bedrock outcrops show that most of the preglacial soil and weathered rock have been removed by glacial erosion. Talus and shale-chip colluvium, products of mass wasting (chiefly by frost shattering) are postglacial age (younger than 17,000 yr BP). Direct evidence of erosion by earlier glaciations (Illinoian, pre-Illinoian) has been removed by weathering during interglacial times and late Wisconsinan glacial erosion. Erosion during at least three glaciations has deeply scoured the floor of Minisink Valley and cut back its walls, especially on its western side where the Marcellus and Mahantango Formations were readily eroded. Because ice flow was generally southward down the Minisink's axis, erosion here was much greater than it was in its tributaries, which were oriented obliquely to glacial flow. Witte and Stanford (1995) have estimated as much as 150 feet of valley-bottom scour in the Minisink during the last two glaciations (late Wisconsinan, and Illinoian) and Braun (1989) has suggested that as much as 450 feet (150 m) of land may have been removed in eastern Pennsylvania by glacial erosion.

GLACIAL DEPOSITS

Till

Till typically covers the bedrock surface and it is distributed widely throughout the quadrangle. It is generally less than 20 feet (6 m) thick, and its surface expression is mostly controlled by the shape of the bedrock surface. Extending through this cover are numerous bedrock outcrops that show evidence of glacial erosion. Thicker, more continuous till smooths bedrock irregularities and may completely mask them. Very thick till forms drumlins, aprons on north facing hillslopes, recessional moraine, and ground moraine. It also fills narrow preglacial valleys, especially those oriented transverse to glacier flow.

Till is typically a compact sandy-silt to silty-sand containing as much as 20 percent pebbles, cobbles, and boulders. Clasts are subangular to subrounded, faceted, and striated, and clast fabrics indicate a preferred long-axis orientation that is generally parallel to the regional direction of glacier flow. Presumably this material is lodgement till. Overlying this lower 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. This material appears to be ablation till and flowtill, but it has not been mapped separately due to its scant distribution and poor exposure. Also, cryoturbation and bioturbation have altered the upper few feet of till, making it less compact, reorienting stone fabrics, and sorting clasts.

Till has been divided into two types. They are informally named lowland (Qtk) and upland (Qtq) till; their lithology based largely on the direction of ice flow over different suites of local source rocks. Lowland till (Qtk) is chiefly derived from slate, graywacke, dolostone, and limestone underlying Kittatinny Valley; and limestone, shale, limey shale, and sandstone underlying the Minisink and Wallpack Valleys, and Wallpack Ridge. Upland till (Qtq) is chiefly made up of materials derived from quartzite, quartz-pebble conglomerate, and red sandstone and shale underlying Kittatinny Mountain. On Kittatinny Mountain a reddish-colored till, derived primarily from the red sandstone and shale of the Bloomsburg Red Beds, is locally visible underlying a yellowish-brown till chiefly derived from the quartzite and quartz-pebble conglomerate of the Shawangunk Formation (fig. C on map). This relationship results from changes in the direction of ice flow during deglaciation (Witte, 1997).

Drumlins

Drumlins occur throughout the study area in two different settings. The first one consists of multiple drumlins on Kittatinny Mountain in an area of very thick and widespread till. Well records and seismic refraction data (unpublished data on file at the N.J. Geological and Water Survey, Trenton New Jersey) indicate that the overburden here is typically thicker than 100 feet (30 m), and most of the drumlins lack a bedrock core. The second setting consists of single drumlins or small sets in areas of thin till. These drumlins are in Kittatinny Valley, and well records and rock outcrops near them suggest that many have a bedrock core. Pre-Wisconsinan glacial deposits have not been observed in the study area. However, Stanford and Harper (1985) indicated that some drumlins in Kittatinny Valley, southeast of the Port Jervis South quadrangle, have cores that consist of weathered, older till.

Moraines

Morainal deposits include the Montague (Qmm), Augusta (Qam), Steeny Kill Lake (Qskm), Libertyville (Qlm), and Colesville (Qcm) moraines. The Montague and Augusta moraines mark a major recessional position of the Kittatinny Valley and Minisink Valley lobes (fig. 2, position 8). Following a similarly parallel course to the Ogdensburg-Culvers Gap moraine (fig. 2), the Augusta moraine follows a continuous northwest course to where it abuts the Montague moraine one mile west of Sawmill Pond, High Point State Park. From here the Montague moraine traces a nearly continuous course from the quadrangle into Wallpack Valley where it splits into two distinct ridges abruptly ending near the village of Montague (Witte, 2012). The moraine does not continue across Minisink Valley, and it has not been observed in Pennsylvania. However, it may be correlative with ice-contact outwash in the Sawkill Creek drainage basin in Pennsylvania (Witte, 2012).

The Steenykill Lake moraine is correlative with the Millville moraine (Witte, 2012), both delineating a minor recessional position of the Minisink Valley sublobe (fig. 2, position 9). The Colesville moraine represents a minor recessional position of the Kittatinny Valley ice lobe.

The Libertyville moraine, which is located near the village of Libertyville in Kittatinny Valley, has been correlated eastward to a large ice-contact delta near the town of Sussex, and westward to the head of a valley-train deposit in Minisink Valley, near the village of Tristates, New York. Collectively they delineate the Sussex margin (fig. 2, position 10).

The recessional moraines are as much as 65 feet (20 m) thick and 2500 feet (762 m) wide, although most morainal segments are less than 1000 feet (305 m) wide. Their surfaces are bouldery, and they consist of poorly compacted stony till and minor beds of stratified sand, gravel, and silt. The moraines generally have asymmetrical cross sections and their distal slopes are the steepest. Their distal margins are sharp, whereas the innermost margins are indistinct. The outermost parts of the moraines are generally marked by single or parallel sets of ridges that are as much as 25 feet (8 m) high, 150 feet (46 m) wide, and 2000 feet (610 m) long (fig. 4). Most are less than 500 feet (152 m) long. Many may have been formerly continuous, but were disconnected when buried ice melted and the ridge collapsed. Sets of ridges are separated by elongated depressions that are as much as 20 feet (6 m) deep below their rim, 100 feet (30 m) wide, and 300 feet (91 m) long. The depressions parallel the ridges, and many contain organic deposits. Irregularly-shaped depressions also occur; these are as much as 40 feet (12 m) deep, as much as 500 feet (152 m) wide, and probably were caused by melting of ice blocks. The innermost parts of the morainal segments have fewer ridges, fewer elongated depressions, and are marked by knob-and-kettle rather than ridge-and-kettle topography. In areas where segments abut thick and widespread till, the moraines are generally larger, more continuous, and have more fully developed moraine-parallel ridges than those abutting thin patchy drift.

The course of the end moraines delineates the lobate margins of the Kittatinny and Minisink Valley ice lobes, and shows the strong influence of regional and local topography (fig. 2). Lines drawn perpendicular to their courses typically parallel nearby striations and indicate that ice was active at or very near the glacier margin. Also, well logs show that the Augusta moraine overlies ice-contact deltaic outwash, where it crosses the Papakating Creek Valley (Witte, 1997 and 2008). This suggests the moraine was laid down following a readvance. Although, the extent of the readvance is unknown, it was probably only a minor one based on the pattern of ice recession defined for Kittatinny Valley by Ridge (1983), and Witte (1988, 1991, and 1997).

The lobate course of the end moraines, their morphology, and evidence of glacial readvance suggests they were formed by 1) the pushing or transport of debris and debris-rich ice by the glacier at its margin, and 2) penecontemporaneous and postdepositional

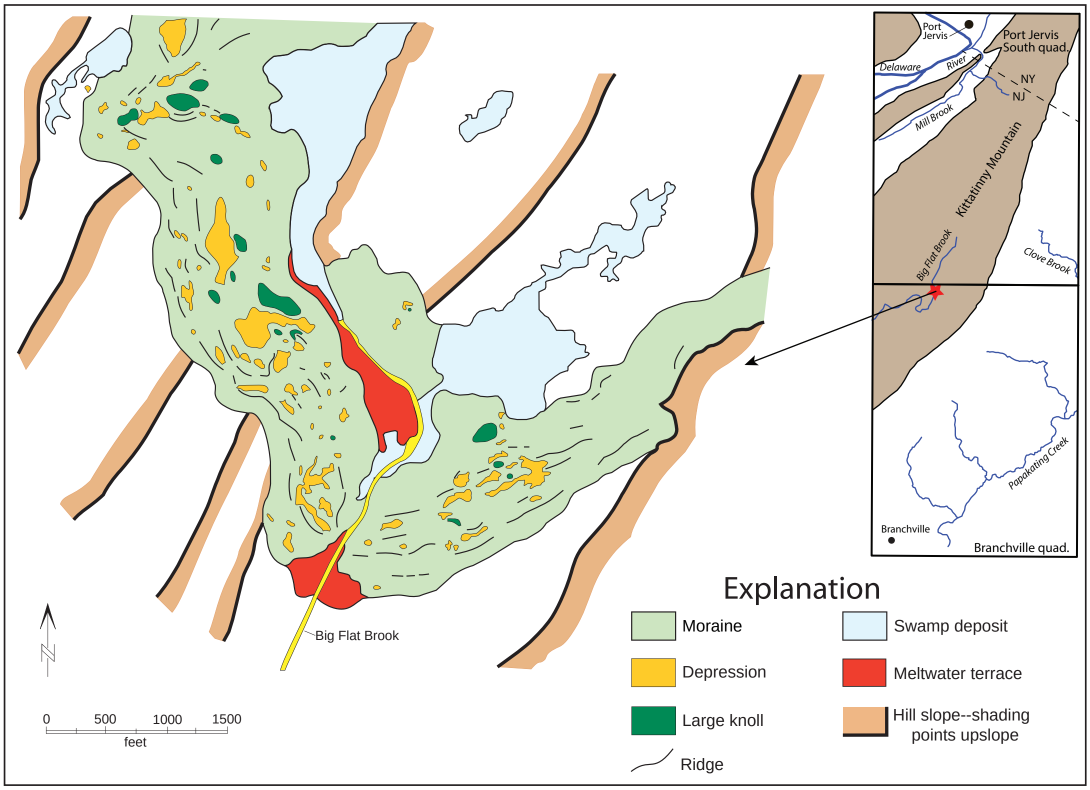

Figure 4. Morphology of the Augusta moraine (Qam); a Late Wisconsinan recessional moraine on Kittatinny Mountain, High Point State Park, Sussex County, New Jersey. This part of the moraine lies just south of the Port Jervis South quadrangle (Witte, 2008). It is used to illustrate morainal topography common to recessional moraine in the study area.

sorting and mixing of material by mass movement, chiefly resulting from slope failure caused by melting ice, and saturation and collapse of sediment. The source and mechanism of sediment transport to the glacier's margin is unclear. Most of the morainal material is of local origin, possibly transported to the margin in basal debris bands or shear planes (Koteff and Pessl, 1981).

Deposits of glacial meltwater streams

Sediment carried by glacial meltwater streams was chiefly laid down at and beyond the glacier margin in valley-train deposits (Qv), outwash-fan deposits (Qf), and ice-contact deltas (Qod). Smaller quantities of sediment were deposited in meltwater-terrace deposits (Qmt), and a few kames (Qk). Most of this material was transported by meltwater through glacial tunnels to the glacier margin, and by meltwater streams draining deglaciated upland areas adjacent to the valley (Witte, 1988; Witte and Evenson, 1989). Sources of sediment include till and debris from beneath the glacier and in the basal dirty-ice zone, and 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-train (Qv), outwash-fan (Qf), meltwater-terrace deposits (Qmt), and delta topset beds (Qod). These sediments include cobbles, pebbles, sand, and minor boulders laid down in stream channels; and sand, silt, and pebbly sand in minor overbank deposits. Sediment laid down near the glacier margin in valley-train deposits, and delta topset beds typically includes thick, planar-bedded, and imbricated coarse gravel and sand, and minor channel-fill deposits that consist largely of cross-stratified pebbly sand and sand. Downstream, the overall grain size typically decreases, sand is more abundant, and crossbedded and graded beds are more common. Outwash-fan deposits consist of gently inclined beds of planar to cross-bedded sand and gravel that form large fan-shaped deposits (similar to alluvial fans), at the mouth of tributary valleys. These deposits were laid down beyond the glacier margin, and are graded to the surface of the valley-outwash deposits that lie in the trunk valley.

Glaciolacustrine sediments were laid down by meltwater streams in ice-contact and non-ice-contact deltas (Qod), and lake-bottom deposits (Qlb); all deposited in proglacial lakes. 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.

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

Kames (Qk) consist of a varied mixture of stratified sand, gravel, and silt interlayered with flowtill. In many places they lie above local base-level controls indicating they were probably laid down in an ice crevasse, ice-walled sink, or moulin within the stagnant glacier margin. In other places they may include small, extensively collapsed ice-contact deltas.

POSTGLACIAL DEPOSITS

Wind-blown sediment

In a few places, thin deposits of very fine sand (not shown on map due to their scant distributionn) lie at the base of Wallpack Ridge's northwest-facing slope. They extend up the hillslope a short distance as a very thin wedge-shaped sheet, generally concealing the contact between glacial outwash in the valley and till on the adjacent hillslope. No other wind-blown deposits have been recognized in the quadrangle, and wind-blown silt (loess) if present has been incorporated in the upper part of the soil.

Hillslope-sediment

Thin deposits of shale-chip colluvium (Qsc) lie at the base of cliffs formed by the Mahantango Shale in Minisink Valley. This material includes shale-chip gravel with very little matrix material, and sandy-silty shale chip diamicton that consists of a mixture of weathered rock, till, and soil.

Thick deposits of talus (Qta), chiefly made up of blocks of conglomerate and quartzite, form an extensive apron of rock debris on the southeast face of Kittatinny Mountain, and at the base of a few cliffs higher on the mountain.

Organic deposits

Swamp and bog deposits (Qs) are numerous in the quadrangle. They formed in glacially-scoured bedrock basins and kettles in outwash and moraine that previously contained shallow lakes, in glacial lakes that persisted into the Holocene, in abandoned stream channels on alluvial plains, and in poorly-drained areas in ground moraine. These deposits typically consist of peat, underlain by silty peat and minor mineral detritus, which in turn is underlain by organic-rich clay and silt. In some places the basal section consists of postglacial deposits of lacustrine silt and clay. In Kittatinny Valley, peat is largely of the reed and sedge type, and peat deposits on Kittatinny Mountain and in Minisink Valley are typically of woody origin, or consist of mixed wood and sedge peat (Waksman and others, 1943).

Stream deposits (modern alluvium, stream-terrace deposits, and alluvial-fan deposits)

Alluvium (Qal) is chiefly late Holocene in age and includes both channel (sand and gravel), and overbank (sand and silt) deposits laid down by streams that form narrow, sheet-like deposits on the floors of modern valleys. Channels, channel scarps and levees are commonly preserved on flood plains along the larger rivers. In Minisink Valley the modern flood plain is marked by a terrace that lies as much as 12 feet (4 m) above the mean-annual elevation of the Delaware River. This terrace forms all or parts of the lower islands in the river and it also forms narrow terraces that flank its present course. Stream-terrace deposits (Qst) include both channel and flood-plain sediment. They lie 5 to 35 feet (2 to 11 m) above the modern flood plain and below the level of meltwater-terrace deposits. In Minisink Valley they may be grouped into two distinct sets (fig. 5, profile C-C'). The youngest (Qst2) lies between 20 to 35 feet (6 to 11 m) above the mean-annual elevation of the river and consists of as much as 15 feet (4m) of overbank fine sand and silt overlying cobble-pebble gravel and sand. The underlying gravel and sand are channel-bar and point-bar deposits, and in places strath terraces of a postglacial river. The Qst2 deposits typically form broad terraces that flank the present course of the river. The highest parts of a terrace lie next to the Delaware River and typically form a levee. In a few places the levee is well developed and forms a low ridge that is as much as 8 feet (2 m) high. More commonly; however, the levee is the highest point on a gently inclined surface that slopes away from the river to the valley wall. At the base of the valley wall, the terrace is marked by a back-channel, which in some places contains swamp deposits. In many places, multiple levees, and channel scrolls are preserved, especially where the terrace lies on a large inside bend of the river. The 15 foot (5 m) range in elevation of the terrace throughout the valley is due in part to as much as 8 feet (2 m) of relief on the terrace, and parts of the terrace have been lowered by erosion as the river cut down to its modern level. It is also possible that the Qst2 terrace may consist of several levels as shown by Wagner (1994). However, without better elevation control, it is difficult to correlate these terrace subsets on a regional scale. The differing levels may also be related to local riparian conditions and channel morphology of the postglacial Delaware River. Archaeological investigations in the Delaware River valley upstream from Delaware Water Gap (Stewart, 1989) indicate that the base of the Qst2 terrace may be as old as 11,000 yr BP, and the upper 1 foot (< 1 m) has been dated to historic times. This indicates that the Qst2 terrace is Holocene age and has been largely built up over time by vertical accretion. However, in a few places, channel scrolls preserved on some of the deposits, and the course of the Delaware River indicate the terrace has also been built by lateral accretion.

The oldest stream-terrace deposits in Minisink Valley (Qst3) lie 40 to 48 feet (12 to 15 m) above the mean annual elevation of the river and typically consist of as much as 10 feet (3 m) of overbank fine and medium sand overlying glacial outwash. In places this material has been eroded, revealing the underlying outwash. The Qst3 terraces are typically smaller than, and flank, the younger Qst2 deposits. In some places they lie completely surrounded by Qst2 deposits. No dates are available for the Qst3 terrace, but based on the age of the Qst2 terrace, it is late Wisconsinan age and it may represent a transition between glaciofluvial and postglacial fluvial environments.

Alluvial fan deposits (Qaf) are scattered throughout the quadrangle. They form fan-shaped deposits that lie at the base of hillslopes at the mouths of gullies, ravines, and tributary valleys. Sediment is highly varied and is derived chiefly from local surficial sediment eroded and laid down by, streams draining adjacent uplands. Most alluvial fans are entrenched by modern streams. This suggests that most are

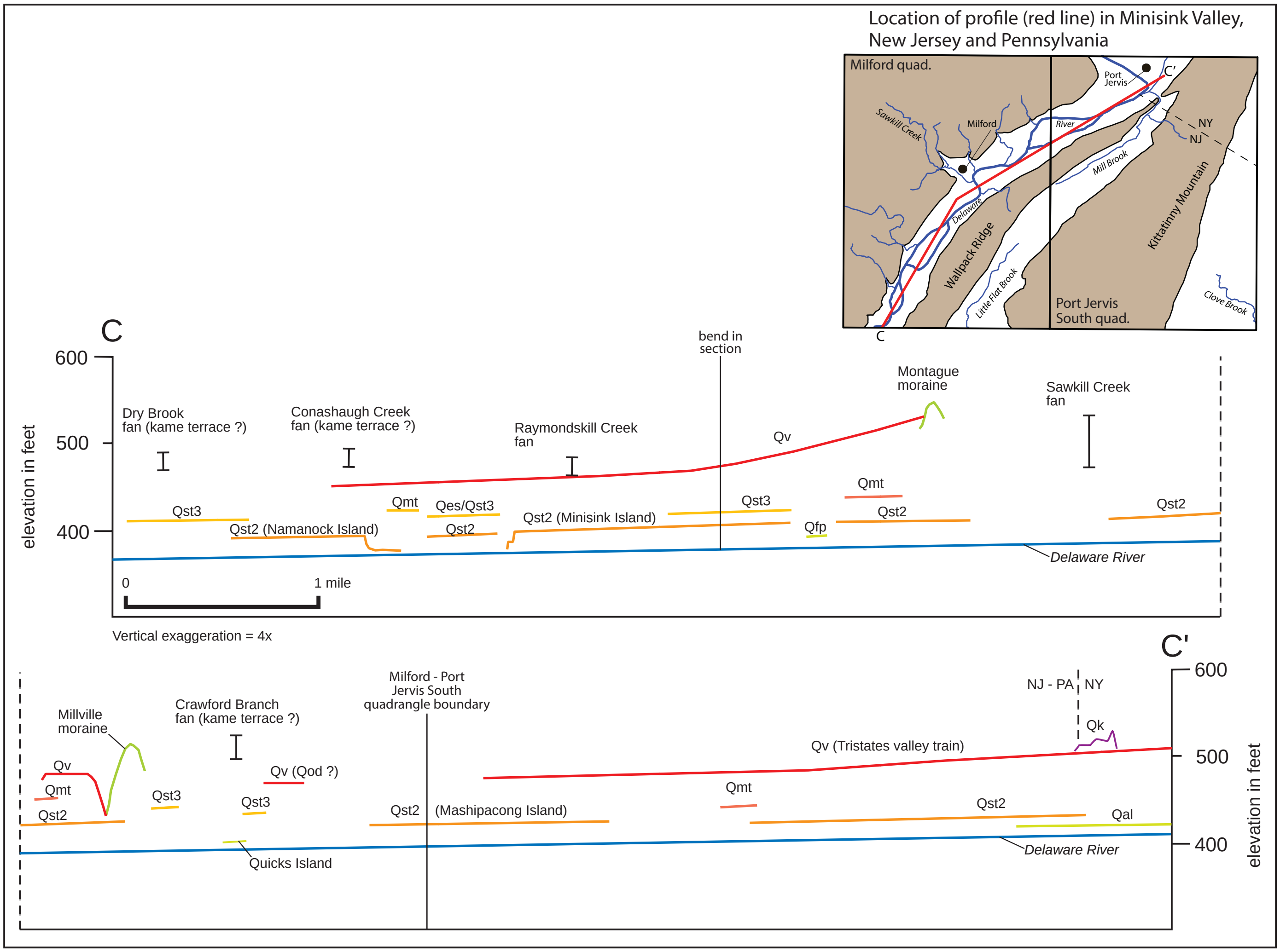

Figure 5. Longitudinal profiles of glacial outwash and postglacial alluvial terraces in Minisink Valley, Milford and Port Jervis South quadrangles. Profiles constructed by projecting elevation and contacts to a center line drawn up Minisink Valley. Additional elevation data determined from 1:4800 (5-foot contour interval) topographic maps constructed for the Delaware Water Gap National Recreation Area, and measurements using a hand level. List of units: Qv - valley-train deposit, Qmt - meltwater-terrace deposit, Qk - kame, Qst3 - abandoned Pleistocene flood plain, Qst2 - abandoned Holocene floodplains, Qal - modern flood plain. The range in elevation shown for the outwash fans represents the distal and proximal parts of their plains projected perpendicular to the section. Figure modified from Witte (2001b).

probably of late Wisconsinan and early Holocene age when climate, sediment supply, and amount and type of hillslope vegetation were more favorable for their deposition.

GLACIAL HISTORY

Glacial Advance and Changes in the Direction of Regional Ice Flow

The late Wisconsinan advance of ice into Minisink Valley and the upper part of Kittatinny Valley is obscure because glacial drift and striae that record this history have been eroded or were buried. If the ice sheet advanced in lobes as suggested by the lobate course of the Terminal Moraine (fig. 2); then its initial advance was marked by lobes of ice moving down these valleys. 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, and ice flow turned to the southwest. In this scenario the course of the Terminal Moraine in Minisink and Kittatinny Valleys was controlled by ice flowing from the Hudson Wallkill lowland. Connally and Sirkin (1986) suggested that the Ogdensburg-Culvers Gap moraine represents or nearly represents the terminal late Wisconsinan position of the Hudson-Champlain lobe based on changes in ice flow noted by Salisbury (1902) in the vicinity of the moraine. Ridge (1983) proposed that 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, and its flow was constrained by the southwesterly trend of the valley. Analyses of striae, drumlins, and the distribution of erratics in the upper part of Kittatinny Valley and adjacent Kittatinny Mountain support Ridge's view (Witte, 1997). These data further indicate that by the time the Ogdensburg-Culvers Gap moraine was formed, ice flow in Kittatinny Valley had turned completely to the southwest with extensive lobation at the margin.

Radiocarbon dating of basal organic material cored from Budd Lake by Harmon (1968) yielded a date of 22,890 +/- 720 yr BP (I 2845), and a concretion sampled from sediments of Lake Passaic by Reimer (1984) that yielded a date of 20,180 +/- 500 yr BP (QC 1304) suggests that the age of the late Wisconsinan terminal moraine is about 22,000 to 20,000 yr BP. Basal organic material cored from a bog located on the side of Jenny Jump Mountain approximately 3 miles (4.8 km) north of the terminal moraine by D. H. Cadwell (written commun., 1996) indicates a minimum age of deglaciation at about 19,340 +/- 695 yr BP (GX-4279). Similarly, basal-organic material from Francis Lake in Kittatinny Valley, which lies approximately 8 miles (12.9 km) north of the terminal moraine indicates a minimum age of deglaciation at about 18,570 +/- 250 yr BP (SI 5273) (Cotter, 1983). Because the lake lies approximately 3 miles southeast of the Franklin Grove moraine, this age is also probably a minimum date for that feature. Exactly when the ice margin retreated out of the New Jersey part of Kittatinny Valley is also uncertain. A concretion date of 17,950 +/- 620 yr BP (I 4935) from sediments of Lake Hudson (cited in Stone and Borns, 1986) and estimated ages of 18,000 yr B.P. for the Ogdensburg-Culvers Gap moraine, and 17,210 yr BP for the Wallkill moraine by Connally and Sirkin (1973) suggest ice had retreated from New Jersey by about 17,500 yr BP.

Style and Timing of Deglaciation: Regional Overview

The recessional history of the Laurentide ice sheet is well documented for northwestern New Jersey and parts of eastern Pennsylvania. Epstein (1969), Ridge (1983), Cotter and others (1986), and Witte (1988, 1991, 1997) showed that the margins of the Kittatinny and Minisink Valley lobes retreated systematically with minimal stagnation.

Based on the morphosequence concept of (Jahns, 1941), which was modified by Koteff and Pessl (1981) as a framework to describe deglaciation in New England, many ice-recessional positions have been delineated in Kittatinny Valley by mapping glacial heads-of-outwash (Ridge, 1983; Witte, 1988, 1997). In addition, moraines, and interpretation of glacial lake histories, based on correlative relationships between elevations of delta topset-foreset contacts, former glacial-lake-water plains, and lake spillways, provide a firm basis for reconstruction of the ice-recessional history of the Kittatinny and Minisink Valley ice lobes. Recessional deposits are discussed in reference to deposition at the margin of the Kittatinny Valley lobe or the Minisink Valley lobe. Locally, the two lobes wasted back synchronously, although regionally the Minisink lobe retreated more rapidly (Witte, 1997).

Kittatinny Valley

Retreat of the Kittatinny Valley lobe from the Augusta margin resulted in the initial formation of Lake Wallkill in Papakating Creek Valley (fig. 2). Initially, Lake Wallkill's spillway was over the Augusta Moraine. Eventually the sluiceway was lowered by fluvial erosion into the underlying gravel and sand of an ice-contact delta that had previously filled in the Paulins Kill Valley south of the position now marked by the moraine. Erosion continued until bedrock was reached, and the level of the lake stabilized. The present elevation of this threshold (fig. 5), located south of the moraine and called here the Augusta spillway, is estimated to be 495 feet (151 m) above sea level. The interval antedating the formation of the Augusta stage is here called the Frankford Plains phase of Lake Wallkill. Based on the elevation of topset foreset contacts of deltas built into the lake, this phase lasted until the Kittatinny Valley lobe retreated from the Sussex margin (Witte, 2008).

The next major ice retreatal position in the upper part of Kittatinny Valley was the Sussex margin (fig. 2), and it is delineated by a large ice-contact delta near Sussex, a small end moraine near Libertyville, and smaller ice-contact deltas in Lake Hamburg (Stanford and Harper, 1985). Glacial Lake Wallkill deposits in the quadrangle consist of small ice-contact deltas laid down after the glacier margin had retreated from the Sussex margin. They lie in the Clove Brook Valley, which at the time of deglaciation contained an arm of Lake Wallkill (fig. 2). Deltaic deposits typically reach an elevation of 545 feet above sea level, which is similar to the Sussex delta.

Lake Wallkill continued to expand northward until ice uncovered the northern end of the Skunnemunk Mountains, and a lower outlet, that now lies at an elevation of 365 feet (111 m) above sea level, was uncovered on a drainage divide between the Wallkill River and Moodna Creek (Adams, 1934; Connally and others, 1989). At this time the Augusta spillway was abandoned, and in the upper part of the Wallkill River valley thin stream-terrace deposits were laid down on the newly exposed floor of Lake Wallkill. Subsequently, the former lake basin became tilted due to isostatic rebound (Koteff and Larsen 1989), and a shallow lake flooded the upper part of the valley in postglacial time. Elsewhere in Kittatinny Valley, a few small, collapsed meltwater deposits are mapped as kames (Qk). Most of these appear to have been laid down in crevasses or ice-walled ponds within the stagnant glacier margin. Because of their small size and unknown origin most are not correlated with an ice-retreatal position.

Kittatinny Mountain

Outwash deposits are absent in this area, largely because the floor of most valleys here have steep gradients. Valley floors are typically covered by boulder and cobble lags, left after meltwater eroded matrix material from till. In many places meltwater channels are cut deeply into thick till, and a few, such as those northwest of the Steeny Kill Lake moraine, may mark the former lobate edge of the glacier margin. Others are in front of the recessional moraines. Most of the material eroded from these upland channels was transported to Mill Brook Valley and deposited in glacial deltas.

Mill Brook Valley

Meltwater deposits in Mill Brook Valley consist of ice-contact deltas and lake-bottom deposits laid down in Lake Mill Brook. This lake expanded northeastward following the retreating Minisink Valley lobe. Several meltwater channels cut down in the Shimers Brook deposits mark places where Lake Mill Brook discharged southwestward, generally following a line of small ice-block depressions. Deltaic deposits generally border the valley walls and are collapsed. The main axis of the valley contains a few lacustrine-fan deposits, lake-bottom deposits, and till. The elevation of the non-collapsed part of the deltas rises from 665 feet (203 m) above sea level at the southern end of the lake basin to 685 feet (209 m) at its northern end. Based on the distribution of the deposits, the small size of the lake's basin, and evidence for minimal postglacial erosion, stagnant ice may have occupied a large part of the lake basin. However, the elevation of the deltas indicates they were laid down in a lake whose elevation was controlled by a spillway over the Shimers Brook deposits.

Lake Mill Brook lasted until the margin of the Minisink Valley lobe retreated northward from Duttonville, uncovering a gap in the northernmost part of Wallpack Ridge, and the lake drained into Minisink Valley.

Minisink Valley

Glacial outwash in Mininsink Valley consists of valley train (Qv), outwash fan (Qf), and meltwater terrace deposits (Qmt). Valley-train deposits are remnants of an extensive valley train that rises from approximately 460 feet (140 m) near the village of Millville to 510 feet (155 m) at its head near the village of Tristates. These outwash remnants form discontinuous, narrow terraces that are typically attached to the valley wall. They have flat surfaces that slope gently downvalley, and have steep sided erosional escarpments that lie against the younger meltwater terrace, stream terrace, and alluvial deposits that cover the lower parts of the valley floor. Based on projected longitudinal profiles of terraces in the valley and an increase in grain size upstream, the outwash appears to have been laid down from an ice recessional position just upstream from the New Jersey border (fig. 2, ice margin 10).

On the Pennsylvania side of Minisink Valley, a small outwash fan (Qf) lies at the mouth of an unnamed tributary of the Delaware River. This deposit reaches an elevation of 610 feet (186 m) above sea level and it was laid down by a meltwater stream draining the upper reaches of the tributary, and it is graded to the surface of the valley-train deposits in Minisink Valley. Meltwater terraces (Qmt) in Minisink Valley are chiefly strath terraces that were cut down in valley-train deposits by meltwater streams emanating from sources upstream from the Tristates margin. These deposits are as much as 15 feet (5 m) thick and they largely consist of material eroded and reworked from the adjacent and upstream parts of valley-outwash deposits, and till that covers the lower part of valley slopes. These terraces generally have flat surfaces, which in places are cut by later meltwater channels, and they range in elevation from 440 feet (134 m) near the moraine to 410 feet (125 m) downvalley (fig. 5).

Records of wells in Minisink Valley (table1) indicate that in places silt, very fine sand, and clay underlie the coarse gravel and sand of the valley-train deposits, as has been indicated for other parts of Minisink Valley (Witte and Epstein, 2012). Although outcrops have not been observed of this material, it seems that this sediment consists of distal-deltaic and lake-bottom deposits laid down in short-lived proglacial lakes that formed between heads-of-outwash downvalley and the retreating glacier margin.

Summary of deglaciation

The ice-retreatal positions marked by end moraines, the heads-of-outwash of ice-contact deltas, and valley-train deposits indicate that the margins of the Kittatinny Valley and Minisink Valley lobes retreated in a systematic manner, chiefly by stagnation-zone retreat, to the northeast. Two ice-marginal positions, the Augusta and Sussex margins (Witte, 1997), mark major recessional positions of the ice lobes, and a third, the Millville margin marks a minor recessional position (fig. 1). Meltwater deposits consist chiefly of ice-contact deltas laid down in Lake Wallkill, Lake Mill Brook, and several other smaller, unnamed glacial lakes. In Minisink Valley and part of Wallpack Valley valley-train deposits extended many miles downstream from heads-of-outwash deposited at the Augusta and Sussex margins. Subsurface data indicate that these coarse-grained glaciofluvial deposits overlie sand and silt presumably of glaciolacustrine origin. This suggests that proglacial lakes may have formed in the narrow south-draining valleys when meltwater became ponded behind heads-of-outwash and recessional moraine. Meltwater-terrace deposits also show that many parts of older valley-train deposits were eroded as the meltwater stream adjusted itself to a longer course.

POSTGLACIAL HISTORY

Northwestern New Jersey is estimated to have been deglaciated by 17,500 yr BP, based on the oldest Francis Lake radiocarbon date (Cotter, 1983). Meltwater continued to flow down Minisink Valley until the glacier margin retreated out of the Delaware River drainage basin and into the Susquehanna drainage basin about 14,000 yr BP (estimated from Ozvath and Coates, 1986).

The postglacial landscape immediately following deglaciation was cold, wet, and windswept. This harsh climate and sparse vegetation enhanced erosion of the land by streams, and by mass wasting of material on slopes. Mechanical disintegration of exposed bedrock by frost shattering was extensive. On Kittatinny Mountain, frost-rived blocks of conglomerate and quartzite as large as 20 feet form an apron of thick talus below cliffs. In Minisink Valley, deposits of shale-chip colluvium mantle the lower part of cliffs and steep hillslopes along the Delaware River. In areas of lower relief, boulder fields formed at the base of slopes where rocks were transported by soil creep. Other fields were formed where meltwater left a lag deposit consisting of the heavier rocks, and a few others may have been concentrated and deposited by the glacier. In places boulders moved by frost heave form crudely-shaped circles and larger areas of polygonal-patterned ground.

The many swamps and poorly drained areas in the quadrangle are typical of glaciated landscapes. Upon deglaciation, surface water, which had in preglacial time flowed in a well-defined network of streams, became trapped in the many depressions, glacial lakes and ponds, and other poorly drained areas created during the last glaciation. Several studies of bogs and swamps in northwestern New Jersey and northeastern Pennsylvania have established a dated pollen stratigraphy that nearly extends to the onset of deglaciation (Cotter, 1983). Paleoenvironments, interpreted from pollen analysis, show a transition from tundra with sparse vegetal cover, to open parkland of sedge and grass with scattered arboreal stands that consisted largely of spruce. From about 14,000 to 11,000 yr BP, the regional pollen sequence records the transition to a dense, closed boreal forest that consisted largely of spruce and fir blanketing the uplands. This was followed by a period (11, 000 to 9,700 yr BP) in which pine dominated. These changes in pollen spectra and percentages record the continued warming during the late Pleistocene and transition to a temperate climate. About 9,400 yr BP, oak and other hardwoods began to populate the landscape, eventually displacing the conifers and marking the transition from a boreal to a mixed-hardwoods temperate forest. Throughout the Holocene the many shallow lakes and ponds remaining from the ice age slowly filled with decayed vegetation, subsequently forming bogs and swamps. These organic-rich deposits principally consist of peat, muck, and minor rock and mineral fragments. Mastodon remains, excavated from Shotwell Pond in nearby Stokes State Forest (Jepsen, 1959), show the presence of these large mammals on Kittatinny Mountain during the close of ice age.

Late Wisconsinan glacial and postglacial fluvial history is well preserved in Minisink Valley where events unfolded in 4 phases (Witte, 2001b). Phase 1 was a period of valley filling when glacial stream deposits were laid down at the margin of the Minisink Valley lobe. At times the glacier's margin remained stationary and outwash built up in front of it and extended many miles downstream. Phase 2 marks the later stages of deglaciation when ice had retreated into the upper part of the Delaware Valley. It is a period of erosion in the valley and further development of meltwater-terrace deposits as the meltwater stream lowered into the valley fill. Phase 3 marks the onset of stream-terrace deposition and presumably started when the ice sheet retreated from the Delaware River drainage basin, and stream discharge diminished substantially. An interval of extensive lateral erosion and deposition on the valley floor followed as the main channel of the river began to meander. The Qst3 terrace is a relic of this phase and it represents the oldest flood-plain deposits preserved in the valley. Phase 4 marks renewed downcutting and extensive vertical and lateral accretion of overbank deposits. During the Holocene these flood-plain deposits built up to as much as 35 feet (11 m) above the modern river. This interval appears to have been initiated by 1) rebound of the Earth's crust, which commenced around 14,000 yr BP (Koteff and Larsen, 1989), and 2) the onset of warmer climate, such that deeper rooted and more extensive vegetation reduced sediment load in the drainage basin.

SURFICIAL ECONOMIC RESOURCES

The most important natural resource in the quadrangle, other than ground water, is stratified sand and gravel. Most of it is in valley train deposits (Qv), and ice-contact deltas (Qod). Sediment is also used as aggregate, subgrade fill, select fill, surface coverings, and decorative stone. Shale chip colluvium (Qcs) and weathered slate makes excellent subgrade material. The location of sand and gravel pits and quarries is shown on the geologic map. All are currently inactive except for occasional use by the land owner. Till may be screened and used for fill and subgrade material, and large cobbles and small boulders have been used for building stone. Peat and muck from swamp deposits may be used as a soil conditioner.

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