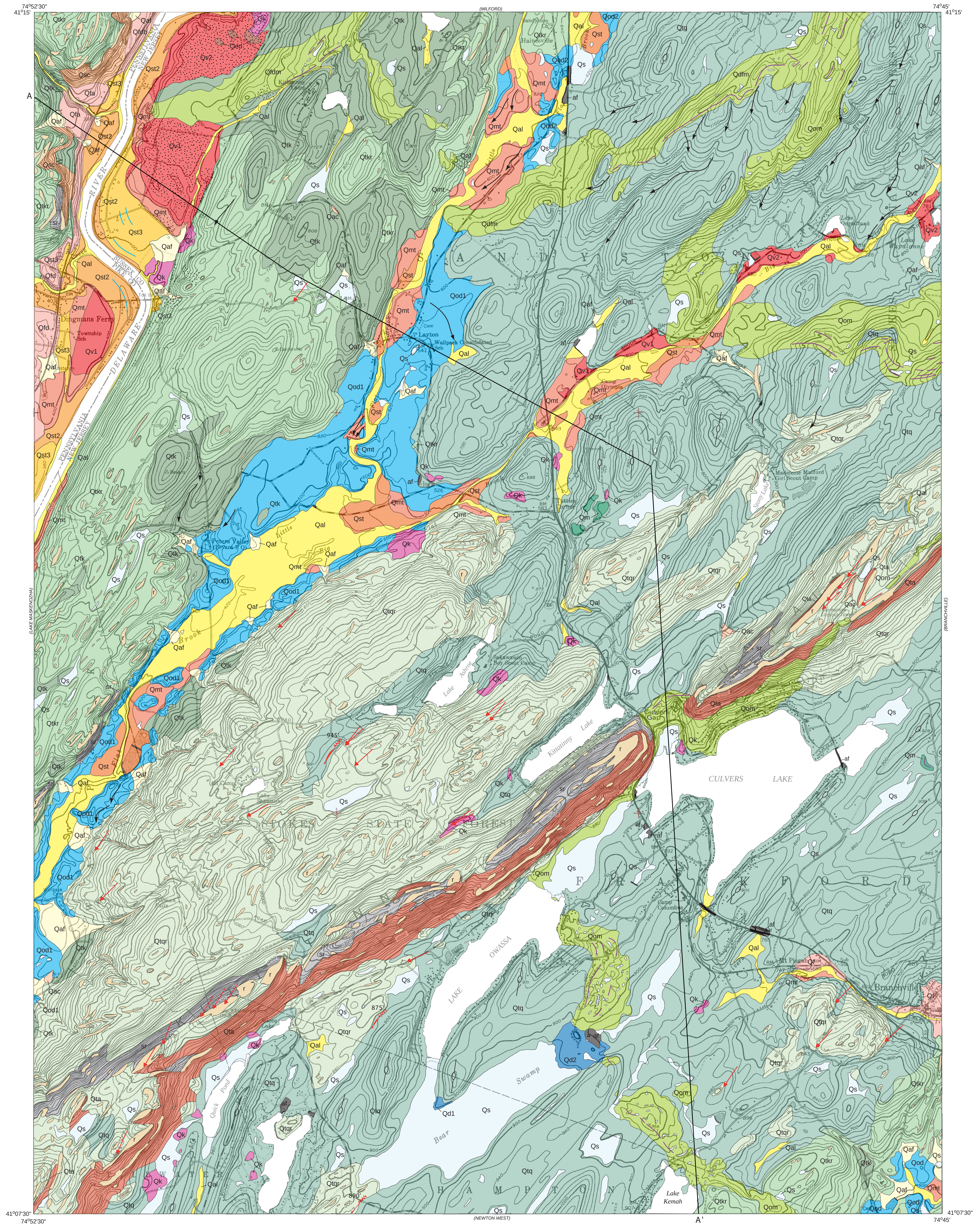
DEPARTMENT OF ENVIRONMENTAL PROTECTION
LAND USE MANAGEMENT
NEW JERSEY GEOLOGICAL SURVEY

SURFICIAL GEOLOGIC MAP OF THE CULVERS GAP
QUADRANGLE, SUSSEX COUNTY, NEW JERSEY
GEOLOGIC MAP SERIES GMS 04-1, Plate 1 of 2



Base from U.S. Geological Survey, 1954
Photorevised, 1971
GIS application and digital cartography by Ron W. Witte

SCALE 1:24000

1 1/2 0 1 mile
1000 0 1000 2000 3000 4000 5000 6000 7000 feet
1 1/2 0 1 kilometer

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Geology mapped 1985 - 1991
Reviewed by John Peper, U.S. Geological Survey
John Inners, Pennsylvania Geological Survey
Karl Muessig, Richard Dalton, Dave Pasicznyk,
New Jersey Geological Survey

SURFICIAL GEOLOGIC MAP OF THE CULVERS GAP QUADRANGLE NEW JERSEY - PENNSYLVANIA

BY

RON W. WITTE [1] AND JACK B. EPSTEIN [2]

2005

[1] New Jersey Geological Survey
[2] U. S. Geological Survey

INTRODUCTION

Industrial, commercial, and residential expansion in New Jersey and Pennsylvania have 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 Culvers Gap quadrangle are lithologically diverse, cover most of the bedrock surface, and are found 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 on the landscape, 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. Numbered stream-terrace deposits indicate relative ages of units based on heights of terraces in valley. Lower numbers indicate younger deposits. Numbered meltwater deposits indicate relative age of units based on morphosequence model of Koteff and Pessl (1981). Lower numbers represent older deposits.

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 (8m) thick. Not shown beneath roads and railroads where it is less than 10 feet (3m) thick. Primarily used to raise the land surface, construct earthen dams, and form a solid 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 and its tributaries. Locally bouldery. As much as 25 feet (8m) 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.

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. 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 in terraces flanking present and late postglacial stream courses. As much as 20 feet (6 m) thick. Overlies glacial and postglacial fluvial, planar to cross-bedded pebbly sand and gravel; as much as 10 feet (3 m) thick. 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 and medium sand. Subscript "a" indicates elevation of terrace is slightly lower than similar nearby terraces. This lower substage has not been shown to be correlative throughout Minisink Valley at map scale. The lower elevation may be due to erosion or differences in local depositional conditions.

Qs

Swamp and Bog deposits (Holocene and late Wisconsinan) -- Dark brown to black, 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 (8m) thick. Locally interbedded with alluvium and thin colluvium.

Qta

Talus deposits (Holocene and late Wisconsinan) -- Unsorted, nonstratified, angular boulders as much as 15 feet (4m) 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 (6m) thick.

Qac

Alluvium and Colluvium undifferentiated (Holocene and late Wisconsinan) -- Stratified, thinnly bedded, moderately to poorly sorted sand, silt, and minor gravel in thin sheets laid down on the floors of small upland tributaries and the lower parts of adjacent slopes. Interlayered with and overlying silty to silty-sandy diamicton (interpreted as a mass-flow deposit). Locally shaly. As much as 15 feet (5 m) thick.

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.

Qed

Sand dunes (late Wisconsinan) -- Well sorted, thinnly bedded, yellowish-brown (10YR 5/4) and brown (10YR 5/3) fine sand and very fine sand in low mounds and ridges on outwash deposits in Minisink Valley. As much as 10 feet thick (3 m).

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 at and extending well beyond (greater than five miles (8 km)) the glacier's margin (fig. 1, on this plate). 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, where sand is more abundant, and trough and planar cross-bedding, and graded beds are more common. Based on well records (Table 2) 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. Number after unit label indicates relative age of unit in valley. Lower numbers represent older deposits.

Qfd Qfa Qfdb

Outwash-fan deposits (uncorrelated), Dingmans Creek Fan, Adams Creek Fan, Dry Brook Fan (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 (18m) 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.

Qd Qod

Glacial-lake delta deposits (late Wisconsinan) -- Stratified sand, gravel, and silt deposited by meltwater streams in 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 (8m) 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 (30m). Number following unit label indicates relative age of unit in glacial lake basin. Lower numbers represent older deposits.

Qd deposits were laid down in glacial Lake Owassa, Kittatinny Valley (fig. 1, on this plate). Numbered units refer to successively younger ice-contact deltas laid down in glacial Lake Owassa. Qod deposits were laid down in narrow sediment-dammed proglacial lakes in Paulins Kill and Wallpack Valleys. Deposits are extensively kettled, and in long lake basins, topset beds are extensively aggraded in their upstream sections. Numbered units refer to successively younger valley-outwash deltas laid down in Wallpack Valley.

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 (30m) thick. In subsurface only, form thick deposits beneath Qs deposits and modern lakes in glacial Lake Owassa basin, Kittatinny Valley. Thin deposits presumed to be in subsurface in Paulins Kill, Wallpack, and Minisink Valleys.

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 (6m) 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 (15m) thick. Attitude of bedding is highly variable.

Nonstratified 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, noncompact 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 slate, graywacke, dolomite, and minor limestone bedrock in Kittatinny Valley, and limestone, argillaceous limestone, shale, and sandstone bedrock in Minisink Valley.

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 (2.5Y 5/4) and reddish-brown (5YR 4/3) silty sand and sand containing 10 to 20 percent gravel. As much as 50 feet (15m) 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. 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 bedrock on Kittatinny Mountain.

Subscript "r" denotes areas of till generally less than 10 feet thick (3 m) with some bedrock outcrops.

Qom Qdfm

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 (24m) 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 Ogdensburg-Culvers Gap (Qom) and Dingmans Ferry (Qdfm) moraine.

Qm

Recessional Moraine (Late Wisconsinan) — Unstratified to poorly stratified sand, gravel, and silt. As much as 30 feet (9m) thick. Consist of poorly compact, stony till, silty-sandy compact till, and minor lenses and layers of water-laid sand, gravel, and silt, in small, uncorrelated, hummocky transverse ridges.

Pre-Wisconsinan glacial deposits

Qi?t

Pre-Wisconsinan drift (Illinoian ?) -- Unstratified to poorly stratified sand, gravel, and silt; presumably Illinoian till. Shown only in subsurface on cross-section beneath late Wisconsinan drift.

Bedrock

r

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

sr

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

Explanation of Map Symbols

Contact, dashed where inferred.

Striation, measurement at tip of arrow. The letter y denotes a younger striation based on crosscutting relationships.

Drumlin, denotes long axis.

Small meltwater channel.

Large meltwater channel.

Large kettle in glacial outwash or moraine. Smaller kettles on moraines are not shown. Tics on downslope side.

Morainal ridge.

925' Glacial-lake spillway with estimated elevation of its floor.

Fluvial scarp, line lies at base of scarp; tics point on upslope side.

Alluvial channel scroll.

Active sand and gravel pit.

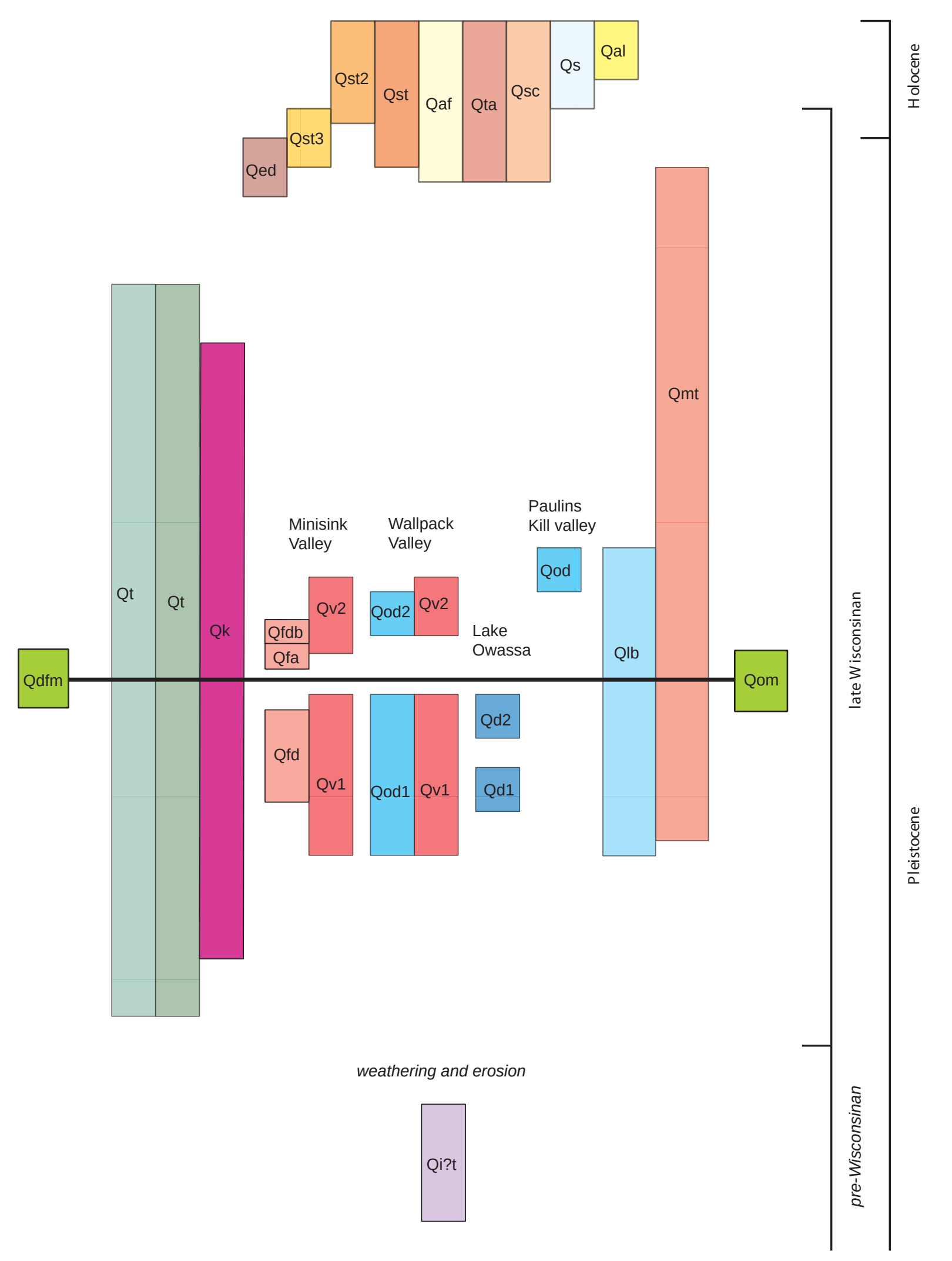
Inactive sand and gravel pit.

Quarry.

Inactive quarry.

Thin sheet of eolian sand (less than 5 feet thick).

Correlation of Map Units



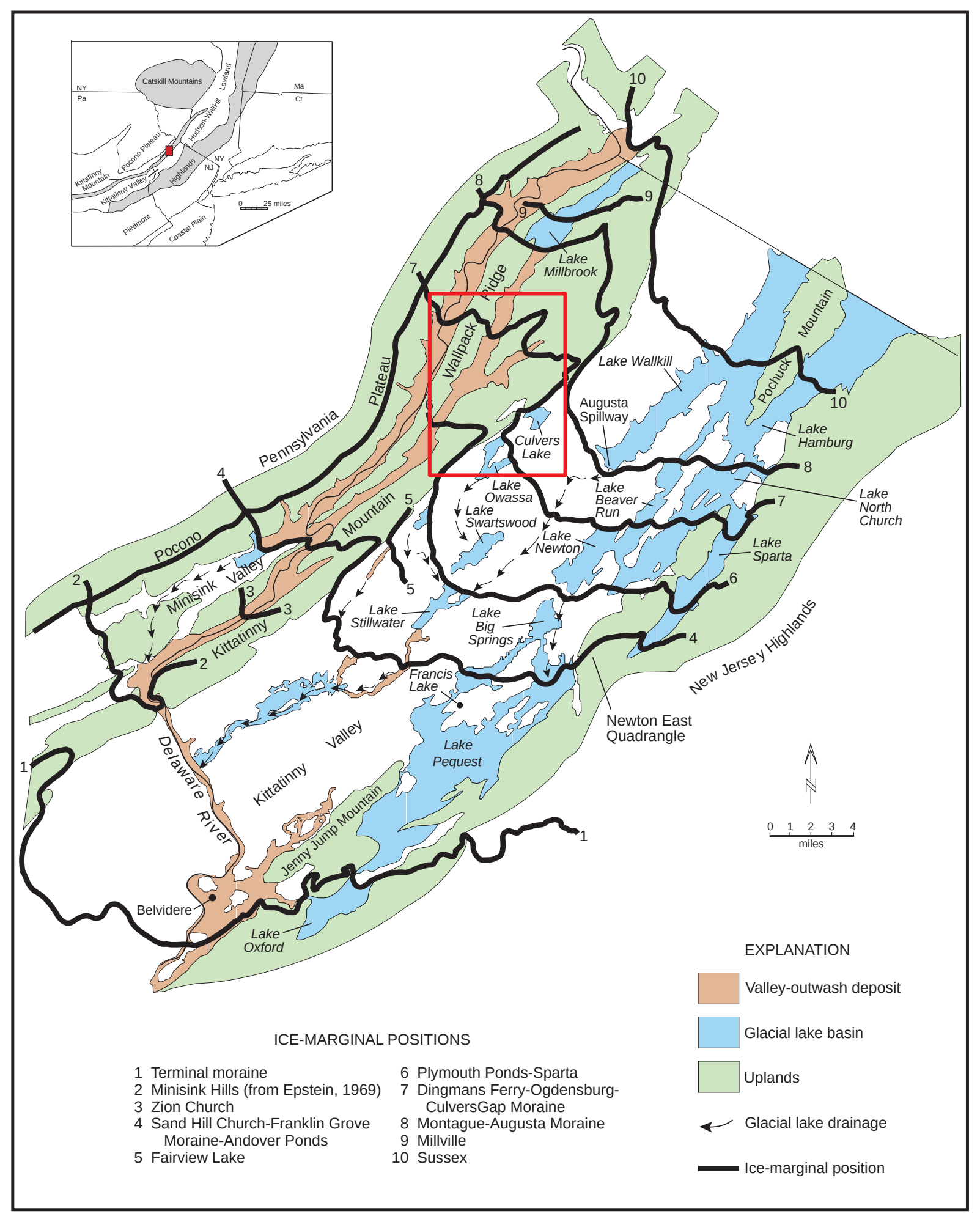
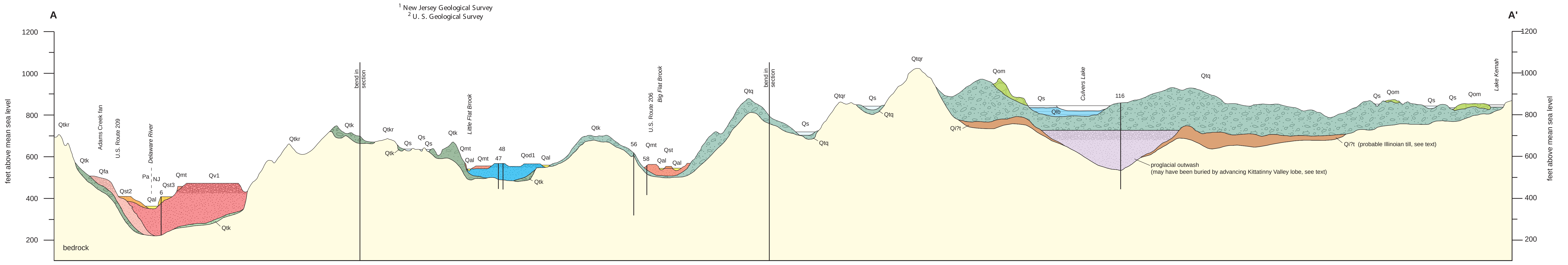


Figure 1. Physiography of Kittatinny Valley and surrounding area. Location of late Wisconsinan ice-margin positions of the Kittatinny and Minisink Valley ice lobes, large glacial lakes, extensive valley-outwash deposits, and Culvers Gap topographic quadrangle. Modified from Crowl (1971), Epstein (1969), Minard (1961), Ridge (1983), and Witte (1997a).

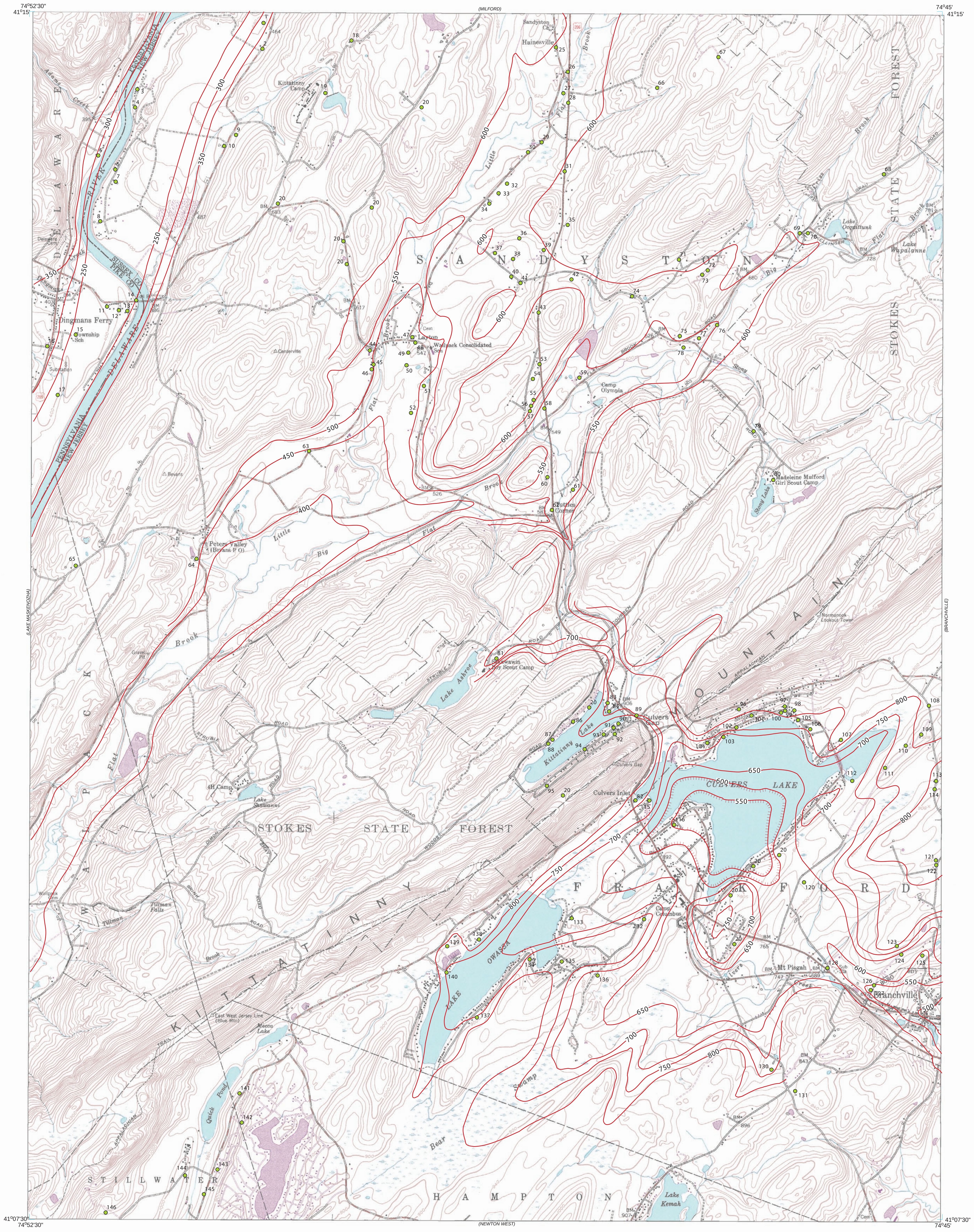


Vertical exaggeration = 8x. Thin till (Qtkr, Qtqr), inferred to be less than 10 feet thick and rock outcrop are not differentiated on the section. Records of wells used on section are listed in Table 1 (Plate 2).

Prepared in cooperation with the
U.S. Geological Survey
National Geologic Mapping Program

DEPARTMENT OF ENVIRONMENTAL PROTECTION
LAND USE MANAGEMENT
NEW JERSEY GEOLOGICAL SURVEY

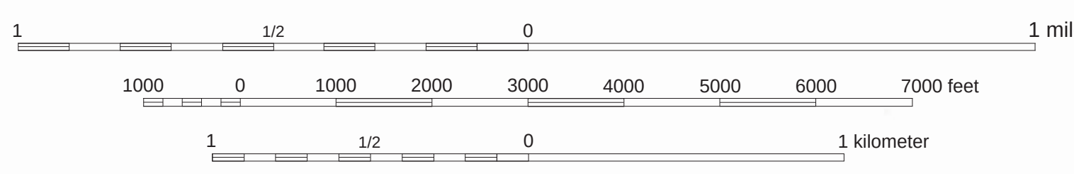
SURFICIAL GEOLOGIC MAP OF THE CULVERS GAP QUADRANGLE, SUSSEX COUNTY, NEW JERSEY
GEOLOGIC MAP SERIES GMS 04-1, Plate 2 of 2



Base from U.S. Geological Survey, 1954
Photorevised, 1971
GIS application and digital cartography by Ron W. Witte

Reviewed by John Peper, U.S. Geological Survey
John Inners, Pennsylvania Geological Survey
Karl Muessig, Richard Dalton, Dave Pasicznyk,
New Jersey Geological Survey

SCALE 1:24000



CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

LOCATION AND GEOLOGIC RECORDS OF SELECTED WELLS AND BORINGS, AND ELEVATION OF THE BURIED-BEDROCK SURFACE BENEATH THICK GLACIAL DRIFT IN CULVERS GAP QUADRANGLE, NEW JERSEY - PENNSYLVANIA

BY

RON W. WITTE [1] AND JACK B. EPSTEIN [2]

2005

[1] New Jersey Geological Survey
[2] U. S. Geological Survey

Table 1. Records of selected wells in the Culvers Gap quadrangle, Sussex County, New Jersey, and Pike County, Pennsylvania. The d wells were drilled for private and public water supply, and exploration. Wells 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 records from Davis (1989) are noted in the table as "Pike" followed by an identification number that was used in that report. The location of wells listed with NJDEP are based on property maps, and they are generally accurate to 500 feet of their actual location. A few geologic records were compiled from New Jersey Geological Survey Permanent Notes, which are on file at the New Jersey Geological Survey, PO Box 427, Trenton, New Jersey. "?" indicates incomplete geologic log.

well number	NJDEP permit number	Discharge in gallons per minute	Depth in feet below land surface	Driller's log
1	21-915	15	0-241	sand and siltstone
			241-285	bluestone
2	21-90	20	0-80	depth of casing
3	21-155	20	0-60	depth of casing
4	21-611	30	0-179	depth of casing
5	Pike 163	--	0-40	depth of casing
6	21-1016	30	0-180	depth of casing
7	21-2071	30	0-171	depth of casing
8	21-6539	100	0-185	sand, clay, and gravel
			185-205	sand and gravel
9	21-627	8	0-22	depth of casing
			22-80	rock
10	21-1292	20	0-37	depth of casing
			37-141	rock
11	Pike 165	--	0-130	depth of casing
12	Pike 170	--	0-170	depth of casing
13	Pike 167	15	0-95	depth of casing
14	Pike 234	15	0-40	depth of casing
15	Pike 235	50	0-180	depth of casing
16	Pike 419	20	0-80	depth of casing
17	Pike 236	20	0-165	depth of casing
18	21-1203	13	0-131	depth of casing
			131-258	rock
19	21-586	40	0-60	depth of casing
			60-420	rock
20	21-3343	21	0-25	hardpan and boulders
			25-35	sand, gravel, and water
			35-47	broken rock, limestone
			47-124	lime rock
			124-137	sandstone
21	21-6071	6	0-18	gravel
			18-145	limestone
22	21-5176	1	0-60	clay, gravel, and boulders
			60-105	clay
			105-120	clay and gravel
			120-395	shale
			395-415	hard red sandstone
			415-450	blue shale
23	21-65	9	0-45	glacial drift
			45-70	limestone
			70-110	limestone and limey shale
			110-155	limestone
24	21-5283	60	0-30	bouldery overburden
			30-105	limestone
25	21-5152	20	0-58	overburden with big boulders
			58-123	red rock
26	21-5113	20	0-50	overburden with clay, gravel, and boulders
			50-123	red, blue, and yellow shale
27	22-5569	5	0-20	overburden
			20-175	red rock
28	21-5282	35	0-15	overburden
			15-250	red rock
29	21-52	15	0-23	hardpan
			23-131	pink rock
30	21-5653	20	0-30	boulders and gravel
			30-105	red rock
31	21-2486	5	0-45	overburden
			45-106	red shale
32	21-5976	20	0-40	overburden
			40-125	red rock
33	21-4932	25	0-35	clay and gravel
			35-180	slate rock
34	21-6323	20	0-50	sand and gravel
			50-188	limestone
35	21-6510	3	0-8	large gravel
			8- 301	red rock
36	21-503	20	0-25	hardpan and boulders
			25-50	sand, gravel, and water
			50-60	quicksand
			60-94	red rock
37	21-5569	5	0-20	overburden
			20-175	red rock
38	21-4637	10	0-30	large gravel and loam
			30-208	red rock
39	21-249	25	0-16	depth of casing
			16-211	rock
40	21-600	45	0-35	hardpan, boulders, and gravel
			35-100	red sandstone
			100-120	blue rock
			120-125	red sandstone
41	21-1934	12	0-123	clay and sand
			123-132	clay
			132-238	slate
42	21-6330	50	0-10	gravel and sand
			10-270	red rock
43	21-2380	4	0-25	hardpan and boulders
			25-50	hardpan
			50-75	large boulders and hardpan
			75-100	clay, sand, gravel, and water
			100-110	sand and water
			110-225	red shale
			225-233	green shale
44	21-3364	18	0-20	hardpan and boulders
			20-30	boulders, clay, and gravel
			30-40	gravel and water
			40-50	sand, water, and clay
			50-60	blue clay
			60-70	blue shale
			70-80	shale with clay pockets
			80-129	hard gray rock
			129-162	blue shale
			162-175	soft black shale
45	21-6142	8	0-78	overburden
			78-208	shale
46	21-6491	20	0-18	sand and gravel
			18-145	red rock
47	21-5628	--	0-74	sand and gravel
			74-?	red shale
48	21-6154	30	0-75	gravel and sand
			75-125	limestone
49	21-6298	15	0-52	sand, clay, and gravel overburden
			52-150	shale
50	21-4625	30	0-57	sand, clay, and gravel overburden
			57-75	shale
51	21-5975	20	0-40	overburden
			40-125	red rock
52	21-6643	10	0-60	gravel and sand
		(artesian)	60-75	shale and limestone
53	22-18407	2	0-20	gravel, hardpan, and boulders
			20-349	red slate
54	21-4233	4	0-53	sand, clay, and gravel overburden
			53-280	red slate
55	21-6999	9	0-20	sand, clay, and gravel overburden
			20-125	red shale
56	21-5471	3	0-11	clay overburden
			11-300	red slate
57	21-5314	4	0-14	clay overburden
			14-225	red slate
58	21-6262	15	0-40	sand, clay, and gravel overburden
			40-150	red slate
59	21-927	35	0-50	hardpan and boulders
			50-89	red sandstone
60	21-814	20	0-25	red hardpan
			25-75	red sand, gravel, and boulders
			75-96	quicksand
			96-200	red sandstone
61	21-822	20	0-25	hardpan
			25-52	hardpan, gravel, and sand
			52-130	red sandstone
62	21-1314	16	0-25	boulders and hardpan
			25-50	boulders, hardpan, and gravel
			50-63	gravel, sand, and water
			63-120	red shale
63	21-545	25	0-60	depth of casing
			60-144	rock
64	21-3444	20	0-30	gravel and gray clay
			30-50	sand and gravel
			50-85	gray clay and gravel
			85-95	layer of limestone
			95-102	gray clay
			102-110	sand, clay, and gravel
			110-115	gravel and water
65	21-1371	--	0-25	hardpan and boulders
			25-32	gravel and sand
			32-45	blue clay
			45-?	rock
66	21-7170	2	0-15	sand, clay, and gravel overburden
			15-500	slate
67	21-6982	80	0-65	red loam, boulders, and gravel
			65-535	red rock
68	21-478	--	0-10	gravel and sand
			10-20	sand and pea gravel
			20-60	sand
			60-?	rock
69	21-1592	42	0-25	boulders and hardpan
			25-40	boulder
			40-60	large boulders and sand
			60-75	boulders, gravel, and sand
			75-83	red clay
			83-90	gravel with water
70	21-5037	30	0-120	boulders and gravel
			120-205	shale
71	21-7082	11	0-212	sand, clay, and gravel overburden
			212-600	red slate
72	21-4927	25	0-2	overburden
			2-125	clay, heavy gravel, and boulders
			125-135	rotten red rock
			135-173	soft red rock
73	21-5886	20	0-127	sand, gravel, and boulders
			127-175	shale
74	21-760	25	0-25	hardpan and boulders
			25-50	sand, red gravel, and water
			50-82	red quicksand
			82-115	red sandstone
75	21-6686	20	0-52	sand, clay, and gravel overburden
			52-174	red slate
76	21-5429	15	0-121	clay overburden
			121-233	slate
77	21-274	20	0-50	boulders, gravel, and sand
			50-75	hardpan and gravel
			75-100	hardpan and clay
			100-125	gravel and boulders
			125-155	quicksand
			155-175	red sandstone
78	21-2335	6	0-108	sand and gravel (depth of casing)
			108-122	red rock
79	21-4887	32	0-2	overburden
			2-10	heavy gravel and boulders
			10-100	heavy gravel, sand, and some clay
			100-180	clay and gravel
			180-190	soft red rock
			190-295	hard red rock
			295-300	soft red rock
80	21-3201	32	0-42	sand and gravel (depth of casing)
			42-299	quartzite
81	21-2379	25	0-160	gravel and boulders
			160-179	gravel, boulders, and water
82	permanent notes	--	0-82	glacial drift
83	21-4711	30	0-160	sand, gravel, clay, and hardpan on red shale
84	21-4328	15	0-180	clay, gravel, and hardpan
			180-200	red slate
85	21-3798	15	0-70	sand and gravel (depth of casing)
			70-185	red slate
86	21-4570	10	0-25	clay and gravel overburden
			25-80	soft red slate
			80-125	red slate
87	21-4931	10	0-55	clay and gravel overburden
			55-130	red slate
88	21-5368	20	0-14	overburden
			14-58	boulders and rock
			58-126	granite (quartzite)
89	permanent notes		0-163	sand, gravel, and hardpan on red shale
90	21-4537	20	0-20	muck and boulders
			20-45	gravel, sand, and small boulders
			45-50	clay and gravel
			50-222	red shale
91	21-4588	3	0-8	overburden with boulders
			8-23	clay and gravel
			23-43	sand and gravel
			43-51	clay, and gravel
			51-298	granite (quartzite)
92	21-5315	4	0-51	clay and gravel
			51-?	red slate
93	21-4345	7	0-65	gravel and hardpan
			65-174	red slate
94	21-5680	3	0-27	clay and gravel
			27-275	red slate
95	21-3554	2	0-32	sand and gravel (depth of casing)
			32-272	red slate
96	21-4763	50	0-100	sand, gravel, and hardpan
			100-199	slate
97	21-5049	3	0-54	clay and gravel
			54-250	slate
98	21-5141	2	0-46	clay, gravel, and boulders
			46-273	blue shale
99	21-5038	20	0-25	gravel and sand
			25-?	shale
100	21-5039	8	0-43	sand and gravel
			43-198	shale
101	21-799	25	0-50	hardpan and boulders
			50-75	boulders
			75-100	blue clay and boulders
			100-140	blue clay, boulders, and gravel
			140-163	gravel, sand, and water
			163-220	blue shale
102	21-4618	25	0-85	sand and gravel
			85-175	slate
103	21-4807	30	0-180	sand, gravel, and hardpan
			180-300	slate
104	21-431	15	0-140	yellowish-gray silt and minor clay
			140-180	medium-gray clay, angular shale fragments
105	21-5454	30	0-61	clay and gravel
			61-250	slate
106	21-2964	38	0-25	hardpan and boulders
			25-50	hardpan, boulders, and gravel
			50-75	gravel, clay, and water
			75-100	clay and water
			100-111	blue clay and broken rock
			111-175	blue shale
			175-253	hard gray rock
			253-275	brown sandstone
107	21-6861	3	0-25	hardpan and boulders
			25-50	gravel, sand, and water
			50-100	black shale
			100-112	hard gray rock
			112-135	soft brown sandstone
108	22-19221	6	0-32	sand and boulders
			32-152	shale
109	22-18217	10	0-105	sand and gravel
			105-199	slate
110	22-22617	10	0-118	clay and gravel
111	22-21462	1	0-25	clay
		(artesian)	25-75	hardpan and gravel
			75-125	hardpan, boulders, and gravel
			125-144	brown silt
			144-477	shale
112	22-8491	1	0-166	boulders and gravel
			166-446	gray shale
113	22-21248	5	0-42	clay and boulders
			42-120	shale
114	22-20195	45	0-2	overburden
			2-30	clay and gravel
			30-35	boulder
			35-70	clay and gravel
			70-76	brown shale
			76-231	blue shale
115	21-5032	11	0-118	clay and gravel
			118-225	slate
116	21-1027	32	0-50	hardpan and boulders
			50-75	gravel, sand, and cobbles
			75-100	boulder
			100-125	large boulders and clay
			125-150	gravel, sand , and clay
			150-175	gravel, sand, and water
			175-200	sand and water
			200-225	sand and clay
			225-300	quicksand
			300-325	quicksand, red clay, and blue shale
			325-412	blue shale
117	22-18925	10	0-180	clay, gravel, boulders, and sand
			180-273	shale
118	22-18652	20	0-26	hardpan and boulders
			26-116	sand, gravel, and clay
			116-210	quicksand
			210-238	gravel
			238-262	sand
			262-294	clay
			294-333	gravel (tight)
119	21-5122	--	0-2	overburden
			2-30	clay and gravel
			30-35	boulder
			35-115	clay and gravel
			115-118	boulder
			118-220	clay and gravel
			220-235	red sand
			235-242	red gravel
120	21-4912	10	0-2	overburden
			2-20	sand, clay, and gravel
			20-23	boulder
			23-50	sand, clay, and gravel
			50-52	boulder
			52-60	sand, clay, and gravel
			60-63	boulder
			63-100	sand, clay, and gravel
			100-120	sand and water
			120-138	sand and clay
			138-150	sand and gravel
121	22-8909	2	0-25	hardpan and boulders
			25-50	hardpan, gravel, and water
			50-61	blue clay
			61-148	blue shale
			148-193	hard gray rock
			193-267	blue shale
			267-299	hard gray rock
			299-328	blue shale
122	22-21777	3	0-46	clay and gravel
			46-225	slate
123	22-20886	8	0-40	clay and hardpan
			40-75	clay and sand
			75-150	clay and gravel
			150-235	slate
124	22-6026	6	0-50	hardpan and boulders
			50-75	hardpan
			75-125	hardpan and boulders
			125-140	blue clay
			140-150	blue clay, sand, and water
			150-155	blue clay
			155-200	blue shale
			200-237	hard gray rock
			237-248	brown sandstone
			248-279	blue shale
			279-300	brown sandstone
125	22-22350	3	0-140	clay and gravel
			140-650	slate
126	22-18051	15	0-100	clay and gravel
			100-160	gravel
			160-197	red clay and gravel
127	22-18451	1	0-20	gravel
			20-50	sand
			50-155	clay and gravel
			155-180	red clay
			180-400	gray slate
128	22-22578	2	0-60	clay and gravel
			60-450	slate
129	21-2102	10	0-25	hardpan and boulders
			25-50	boulders, gravel, and sand
			50-75	gravel, sand, and water
			75-103	blue shale
130	21-5207	30	0-30	clay and hardpan
			30-45	gravel and clay
			45-100	slate
131	22-17861	5	0-14	clay and gravel
			14-224	slate
132	21-3263	10	0-20	overburden
			20-25	boulder
			25-95	clay and gravel
			95-115	sand and gravel
			115-150	clay and gravel
			150-175	sand and gravel
			175-182	gravel
			182-183	boulder
			183-206	sand and gravel
			206-225	blue shale
133	21-2973	25	0-160	gravel and boulders
			160-179	gravel, boulders, and water
134	21-1434	45	0-25	hardpan and boulders
			25-50	boulders, gravel, and water
			50-75	blue clay and gravel
			75-100	blue clay
			100-125	blue clay, sand, and water
			125-130	blue clay and shale
			130-176	shale
135	21-1260	22	0-50	hardpan and boulders
			50-75	hardpan, gravel, sand, and water
			75-100	gravel, sand, and water
			100-115	blue clay
			115-120	broken shale
			120-195	shale
136	21-5011	5	0-2	overburden
			2-15	sand, gravel, and boulders
			15-52	sand, gravel, clay and boulders
			52-53	boulder
			53-80	clay, sand, and gravel
			80-81	boulder
			81-88	clay, sand, and gravel
			88-190	clay, sand, and big gravel
			190-208	clay and sand
			208-280	clay, sand, and gravel
			280-423	blue shale
137	21-2133	3	0-25	sand
			25-75	sand, gravel, and clay
			75-100	sand and gravel
			100-140	clay seams
			140-275	shale
138	21-4673	10	0-25	sand and gravel
			25-248	blue shale
139	21-1966	3	0-45	clay and hardpan
			45-80	clay
			80-146	shale
140	21-1131	12	0-25	hardpan, gravel, and boulders
			25-50	hardpan and sandy loam
			50-75	blue clay and gravel
			75-100	blue clay, gravel, and water
			100-125	gravel
			125-220	blue shale
141	21-925	10	0-20	clay and hardpan
			20-45	hardpan
			45-65	clay and sand
			65-81	clay
			81-148	slate
142	21-599	10	0-100	hardpan and gravel
			100-150	hardpan and red clay
			150-200	red clay and sand
			200-215	very fine sand and water
			215-230	blue shale
143	21-1821	9	0-50	clay and gravel
			50-90	clay and hardpan
			90-116	clay
			116-160	slate
144	21-5521	--	0-61	overburden
			61-400	shale
145	21-5220	2	0-100	overburden
			100-175	black shale
			175-350	blue shale
146	21-5466	50	0-20	gravel and boulders
			20-125	shale

Explanation of Map Symbols

—550—	Bedrock surface contour - Shown where rock surface is buried beneath thick glacial sediment. Approximately located, shows altitude of rock surface in feet above sea level. Contour interval is 50 feet. Hachures indicate closed depression. Contours terminate where bedrock is less than 20 feet from surface.
● 12	Location of well or boring listed in Table 1.

Prepared in cooperation with the
U.S. Geological Survey
National Geologic Mapping Program

NEW JERSEY GEOLOGICAL SURVEY
GEOLOGIC MAP SERIES GMS 04-1

Nephelene syenite erratics along the glacial geology trail in Stokes State Forest, Sussex County, New Jersey. Photograph by Ron Witte, 2001.

Surficial Geology of the Culvers Gap Quadrangle, Sussex County, New Jersey

Ron W. Witte - *New Jersey Geological Survey*
Jack B. Epstein - *U.S. Geological Survey*

New Jersey Geological Survey
2005

Contents

Figures

Plates (in pocket)

SURFICIAL GEOLOGY OF THE CULVERS GAP QUADRANGLE, SUSSEX COUNTY, NEW JERSEY

Ron W. Witte, *New Jersey Geological Survey*
Jack B. Epstein, *U.S. Geological Survey*

Introduction

The Culvers Gap quadrangle (fig. 1) lies in a glaciated part of the Appalachian Valley and Ridge physiographic province in Sussex County, New Jersey, and Pike County, Pennsylvania. The land is rugged, dominated by the rocky summit of Kittatinny Mountain that rises as much as 1200 feet above the floors of Minisink, Wallpack, and Kittatinny Valleys. Culvers Gap, a wind gap cut by the Culvers Gap River, forms a prominent pass through the mountain. The rural countryside is covered by large tracts of forested land in the Delaware Water Gap National Recreation Area and Stokes State Forest, and by patchwork woodlands and cultivated land in the valleys. The Delaware River, which separates New Jersey and Pennsylvania, flows southwestward through Minisink Valley in the Delaware Water Gap National Recreation Area.

Surficial materials include glacial deposits of till and outwash, and postglacial deposits of alluvium, colluvium, talus, organic-rich soil, and wind-blown sand. Collectively, these materials may be as much as 340 feet (104 m) thick. They lie on bedrock, and form the parent material on which soils form. The glacial deposits are of late Wisconsinan age and are correlative with the Olean Drift (Crowl and Sevon, 1980) in northeastern Pennsylvania. Till is generally less than 20 feet (6 m) thick and covers the bedrock surface in most places. However, in places bedrock exposures are abundant. Thicker till subdues bedrock topography, and in places masks the uneven bedrock surface. Very thick till forms ground moraine, drumlins, and aprons on some north-facing hillslopes. Where the margin of the ice sheet remained in a constant position, end moraines were deposited. Outwash, laid down at and beyond the glacier margin, lies in river valleys through which Paulins Kill, Flat Brook, and the Delaware River now flow. The ice-contact heads of these deposits mark ice-recessional positions.

Previous Investigations

The geology of surficial deposits in Sussex County, New Jersey was discussed by Cook (1877, 1878, and 1880) in a series of Annual Reports. He included detailed observations on recessional moraines, ages of drift, distribution and types of drift, and evidence of glacial lakes. Shortly thereafter, White (1882) described the glacial geology of Pike County, Pennsylvania. A voluminous report by Salisbury (1902) detailed the glacial geology of New Jersey, region by region. The Terminal Moraine (fig. 2) and glacial deposits north of it were interpreted to be products of a single glaciation of Wisconsinan age. Salisbury also commented 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.” In Pennsylvania, Leverett (1934) also assigned a Wisconsinan age to the Terminal Moraine and the glacial drift north of it, and Crowl and Sevon (1980), and Cotter and others (1986) showed the youngest glacial deposits in Pennsylvania and New Jersey to be late Wisconsinan. Crowl (1971), and Sevon and others (1989) produced surficial geologic maps of part of the quadrangle, and included detailed observations on the character of glacial drift, and the late Wisconsinan history of Minisink Valley, and Witte (1997a) described the glacial history of the upper Part of Kittatinny Valley.

Recessional moraines in Kittatinny Valley (fig. 2) were first identified by Salisbury (1902), and later remapped by Herpers (1961), Ridge (1983), and Witte (1988). Both the Ogdensburg-Culvers Gap and Augusta moraines (fig. 2) were traced on Kittatinny Mountain by Herpers (1961), Minard (1961), Stone and others (2002), and Witte (1991 and 1997a).

Physiography and Bedrock Geology

The Culvers Gap quadrangle (base map, Plate1) lies entirely within the Delaware River drainage basin, except for a very small area northeast of Culvers Lake that lies in the Wallkill River drainage basin. The Delaware River is the master stream in this area, flowing southwestward through Minisink Valley. Flat Brook flows southwestward through Wallpack Valley (informal name for the Flat Brook valley that lies between the village of Hainesville and Wallpack Bend) and joins the Delaware at Wallpack Bend. In Kittatinny Valley, the Paulins Kill flows southwestward to the Delaware River following a course that largely overlies dolomite. The southwest course of these streams appears to be chiefly controlled by the location of less resistant

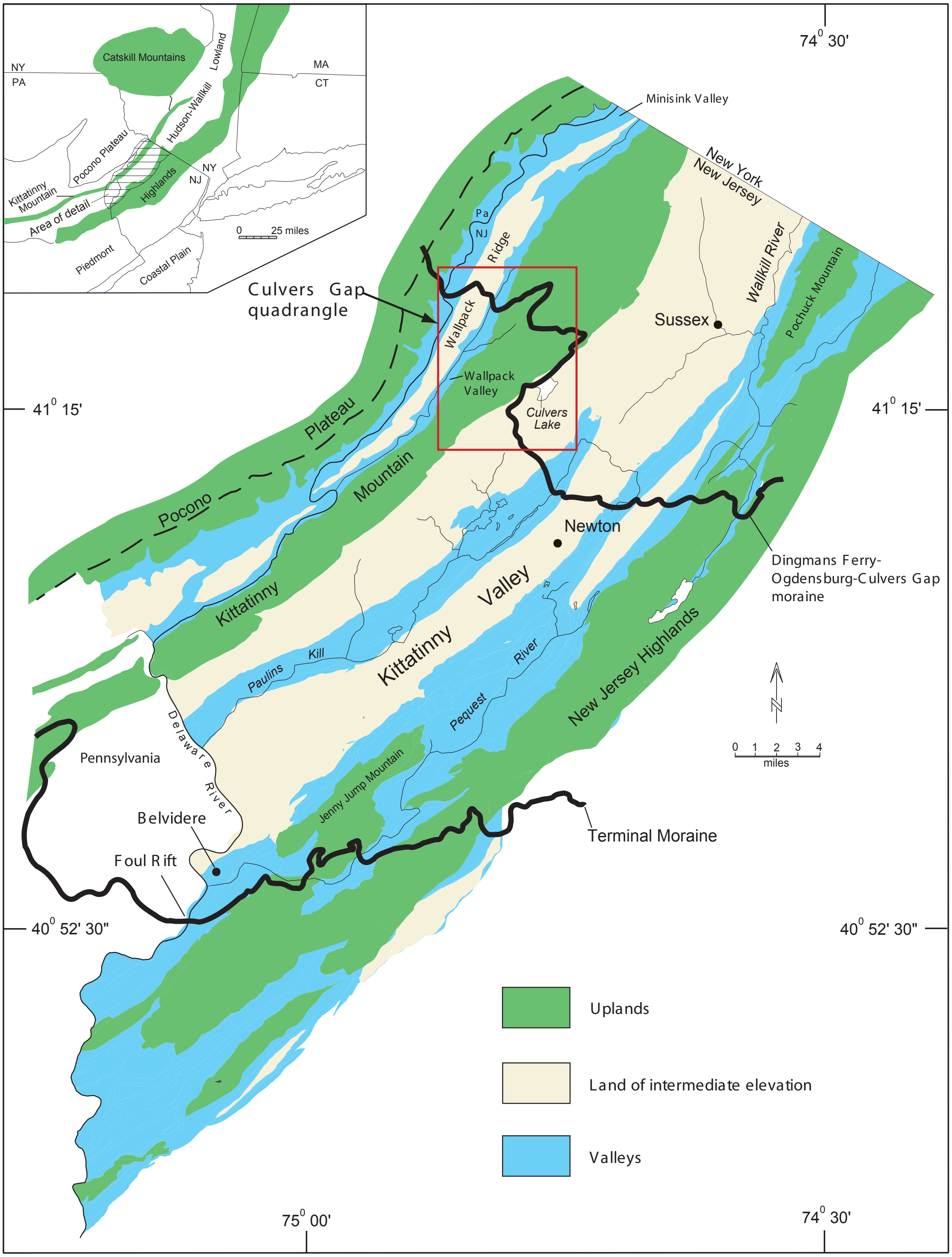


Figure 1. Physiography of northwestern New Jersey, and part of northeastern Pennsylvania and location of the Culvers Gap quadrangle. Kittatinny Valley is a local name for the southwest continuation of the Hudson-Wallkill lowland.

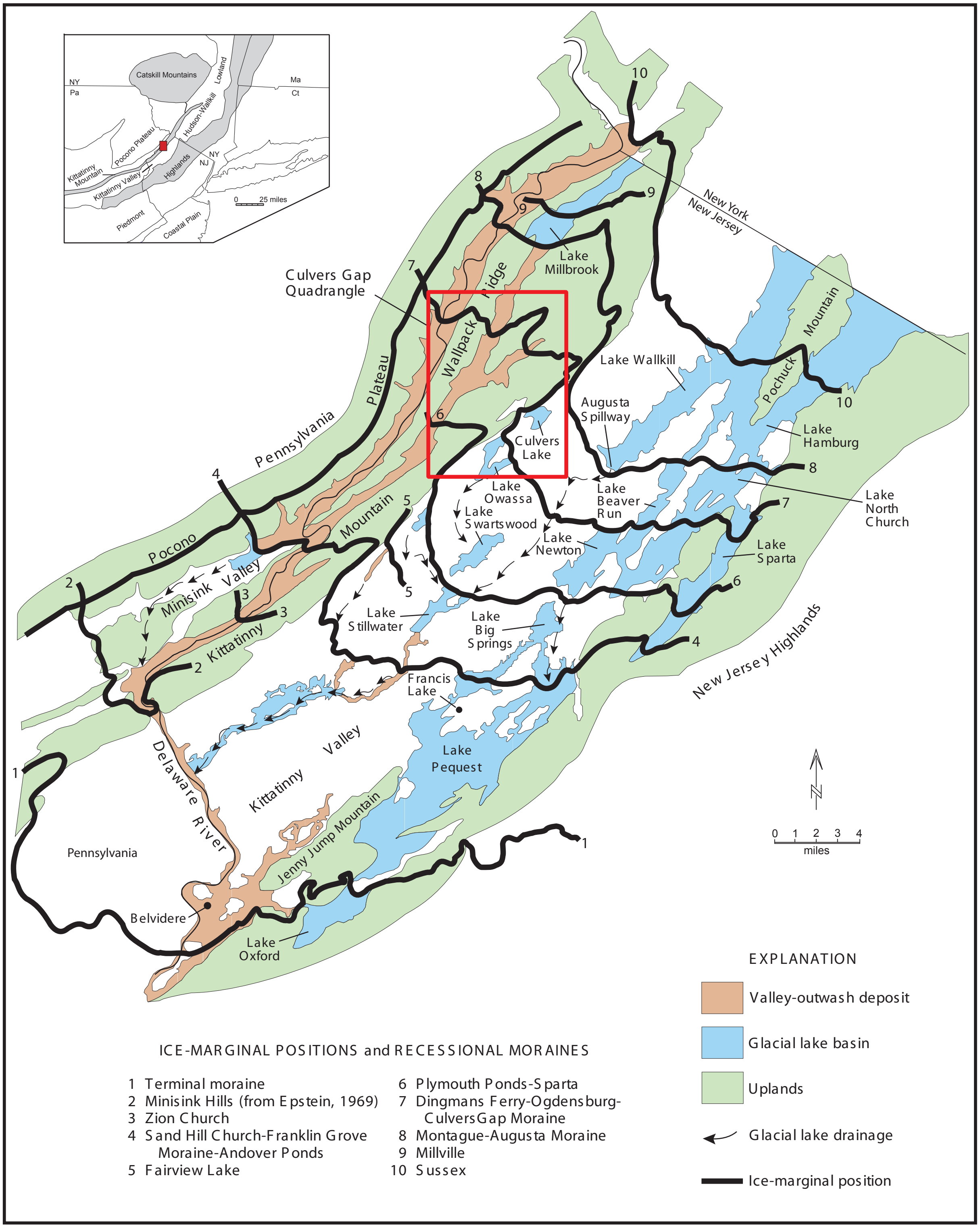


Figure 2. Late Wisconsinan ice margins of the Kittatinny and Minisink Valley ice lobes, location of large glacial lakes, and extensive valley-outwash deposits. Modified from Crowl (1971), Epstein (1969), Minard (1961), Ridge (1983), and Witte (1997).

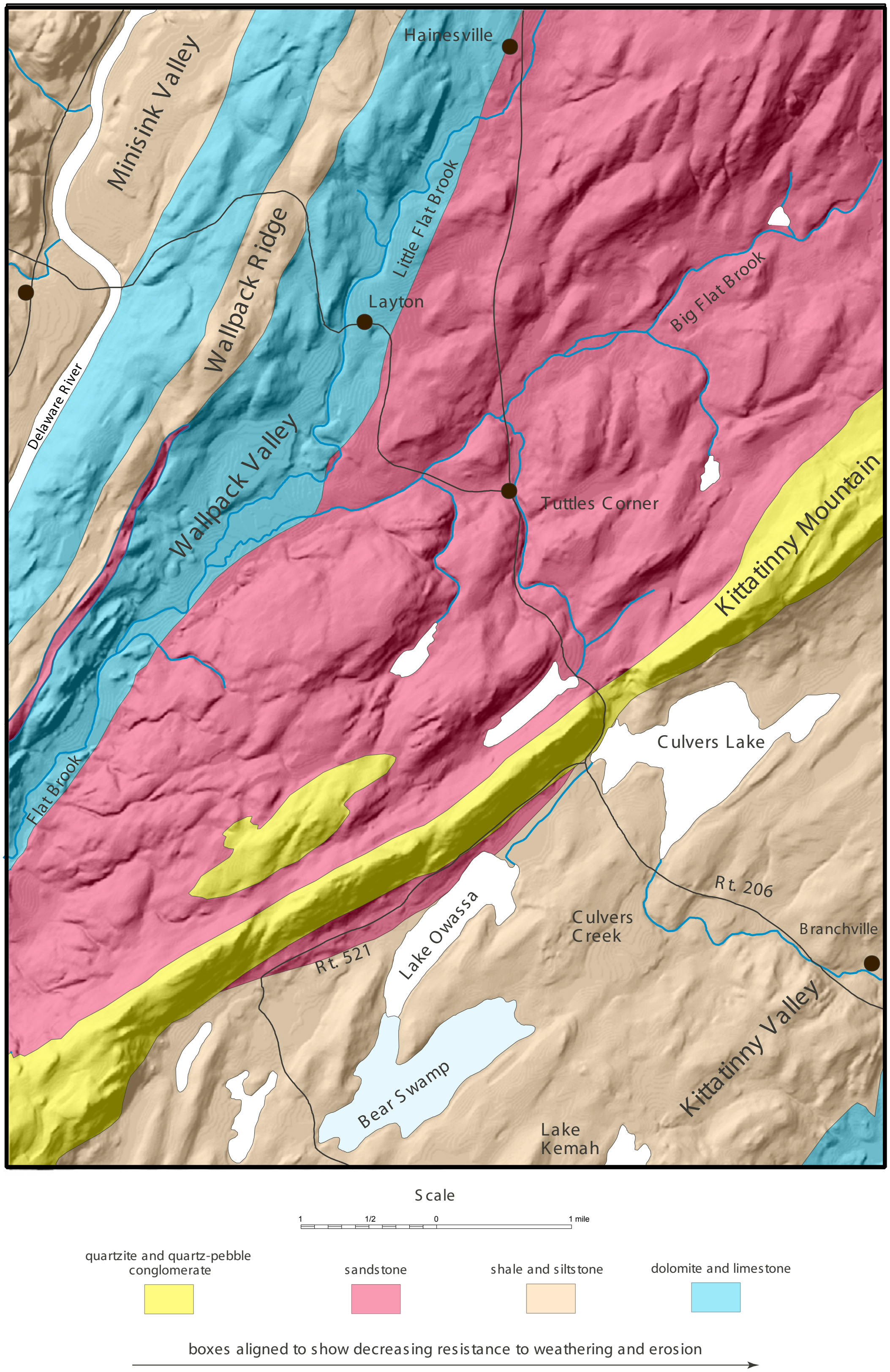


Figure 3. Shaded-relief map and lithotypes of the Culvers Gap quadrangle. Base map constructed from USGS 10-meter DEM, and Culvers Gap quadrangle. Lithotypes more resistant to weathering and erosion typically form higher areas.

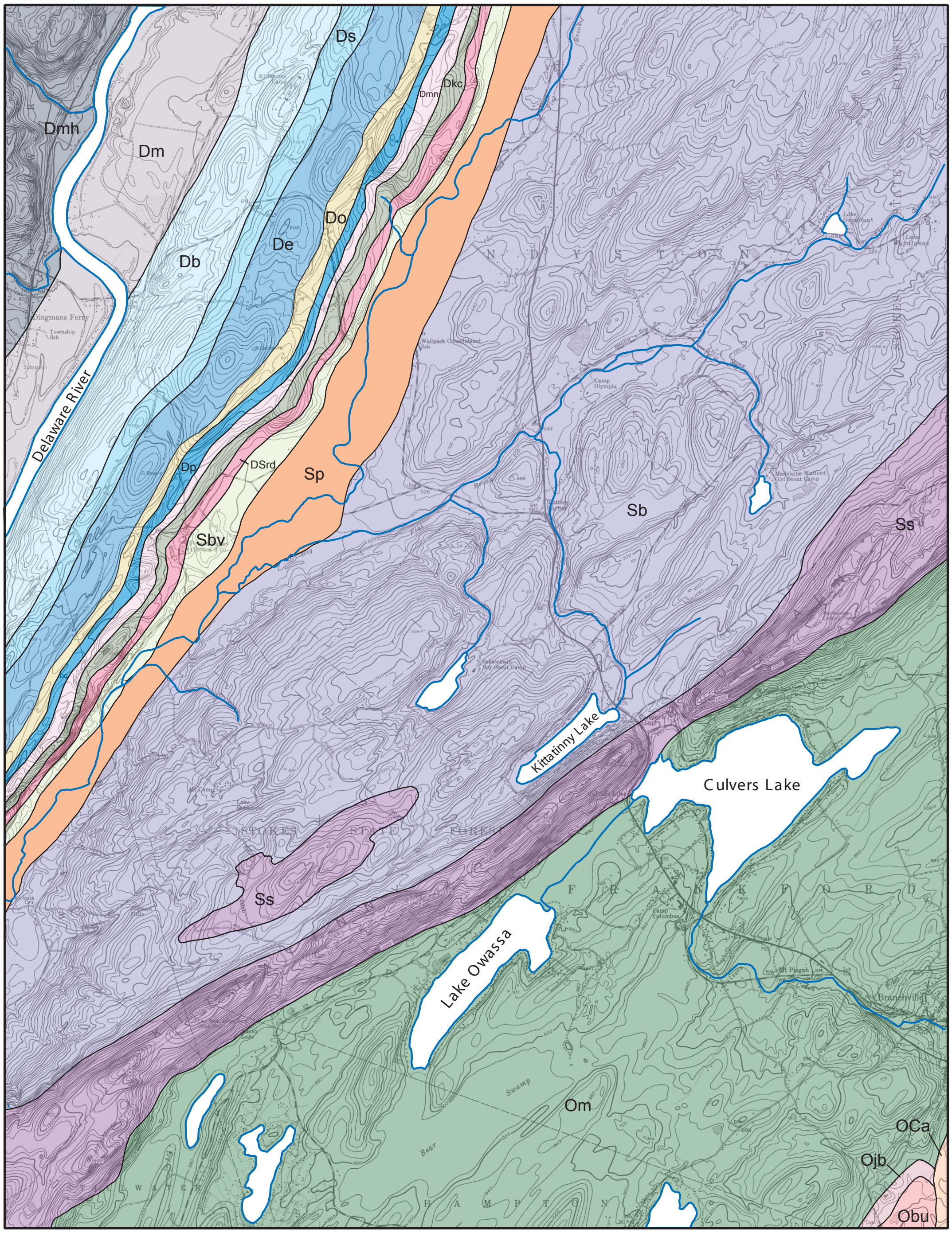


Figure 4. Bedrock geologic map of Culvers Gap Quadrangle. Modified from Monteverde (1992). Age of units: D - Devonian, S - Silurian, O - Ordovician, and C - Cambrian

1 1/2 0 1 mile

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Dmh	Mahantango Formation	Do	Oriskany Group	Sbv	Bossardville Limestone	Ojb	Jacksonburg Limestone
Dm	Marcellus Shale	Dp	Port Ewen Shale	Sp	Poxono Island Formation	Obu	Beekmantown Group (upper part)
Db	Buttermilk Falls Limestone	Dmn	Minisink Limestone - New Scotland Formation	Sb	Bloomsburg Red Beds	OCa	Allentown Dolomite
Ds	Schoharie Formation	Dkc	Kalkberg Limestone - Coeymans Formation	Ss	Shawangunk Conglomerate		
De	Esopus Formation	DSrd	Decker-Rondout Formations	Om	Martinsburg Formation		

bedrock (fig. 3) along monoclinal and synclinal fold axes. In places, smaller tributaries follow the trend of oblique joints and form a modified trellis drainage pattern. Where there is thick till, a dendritic drainage pattern has formed.

Kittatinny Mountain forms a prominent ridge (inset map, fig. 1) from the Shawangunk Mountains in New York southwestward through New Jersey into Pennsylvania. In places, its continuity is broken by gaps, such as Culvers Gap, and Delaware Water Gap. The mountain is divided into two distinctive physiographic areas. The first is the “high ridge” area that forms the eastern part of the mountain. It is held up by the Shawangunk Formation, a quartz-pebble conglomerate, and quartzite of Silurian age that is very resistant to erosion (fig. 4). Outcrops, most of them smoothed by glacial erosion, are abundant. Topography is rugged, consisting of steep-sided, parallel, narrow to broad-crested ridges that trend southwestward following the main trend of the mountain. The mountain’s steep southeast face also forms a nearly continuous escarpment in New Jersey. The second area, which lies on the western part of the mountain, is underlain by the Bloomsburg Red Beds (fig. 4), an interlayered red shale and red sandstone. Bedrock outcrops are scarce because the rock surface is covered in many places by thick till. Topography is moderate, chiefly formed by drumlins, ground moraine, and a few rock ridges held up by anticlinal folds.

Kittatinny Valley is a broad northeast-to-southwest-trending lowland underlain by the Allentown Formation (dolomite), Beekmantown Formation (dolomite), Jacksonburg Formation (limestone), and the Martinsburg Formation (slate, siltstone, and sandstone) (fig. 4). Dolomite underlies Paulins Kill valley and relief there is as much as 200 feet (61 m). Rock outcrops are very abundant and karst topography is common. Slate, siltstone, and sandstone underlie the area between Paulins Kill valley and Kittatinny Mountain. Overall, the average elevation here is about 300 feet (91 m) higher than in the carbonate-floored valleys, and relief may be as much as 400 feet (122 m). Topography consists of rolling hills of moderate to steep slopes, and many strike-parallel ridges streamlined by glacial erosion. In most places, bedrock is deeply buried beneath drumlins and thick ground moraine.

Wallpack Valley, Minisink Valley, and Wallpack Ridge lie northwest of Kittatinny Mountain (fig. 1). Bedrock in this area (figs. 3 and 4) consists of Silurian and Devonian strata that dip northwest and form a southwest-trending homocline (Drake and others, 1996; Sevon and others, 1989). Minisink and Wallpack Valleys are narrow, deep, and trend southwest, following belts of weaker rock. The western side of Minisink Valley is bordered by high cliffs formed on the Mahantango Shale. The valleys were the sites of a planned hydroelectric and water-storage project by the Army Corps of Engineers. A dam constructed at Tocks Island would have flooded Minisink Valley upstream to Port Jervis, New York, and Wallpack Valley upstream to Layton. The reservoir would have provided a storage capacity of 130 billion gallons. This project has since been de authorized by the U.S. Congress. Wallpack Ridge separates Minisink and Wallpack Valleys. It is largely held up by sandstone (Esopus Formation) and rises as much as 300 feet (91 m) above the adjacent valley floors.

Preglacial Drainage

Culvers Gap (fig. 5) is a relict feature of a much earlier drainage system that had its beginnings in early Tertiary time. The Culvers Gap River was part of the ancient Raritan River drainage basin during the late stages of its history (fig. 6). Before its abandonment of Culvers Gap, the river followed a course through Kittatinny Valley and crossed the New Jersey Highlands into the Raritan lowland (Witte, 1997b). The demise of the Culvers Gap River appears to have resulted from a series of stream captures by tributaries of the Delaware River. At some point during the Late Miocene or Early Pliocene, and possibly driven by base-level lowering and incision during the growth of the Antarctic ice sheet, a tributary of the Delaware River captured the Culvers Gap River in Minisink Valley. Apparently, the narrow width and structural weakness of resistant rocks along the Delaware River where it crossed the New Jersey Highlands, gave it an advantage over the Culvers Gap River and its course through similar terrane (Witte, 1997b). The previous capture of Wind Gap River by the Delaware (Mackin, 1933) may have also hastened the end of the Culvers Gap River.

Glacial Deposits

Till

Till is typically a compact silty sand containing volumetrically as much as 20 percent pebbles, cobbles, and boulders. Clasts are subangular to subrounded, faceted, and striated, and clast fabrics show a preferred long axis orientation that generally parallels the regional direction of glacier flow. Presumably, this material is lodgement

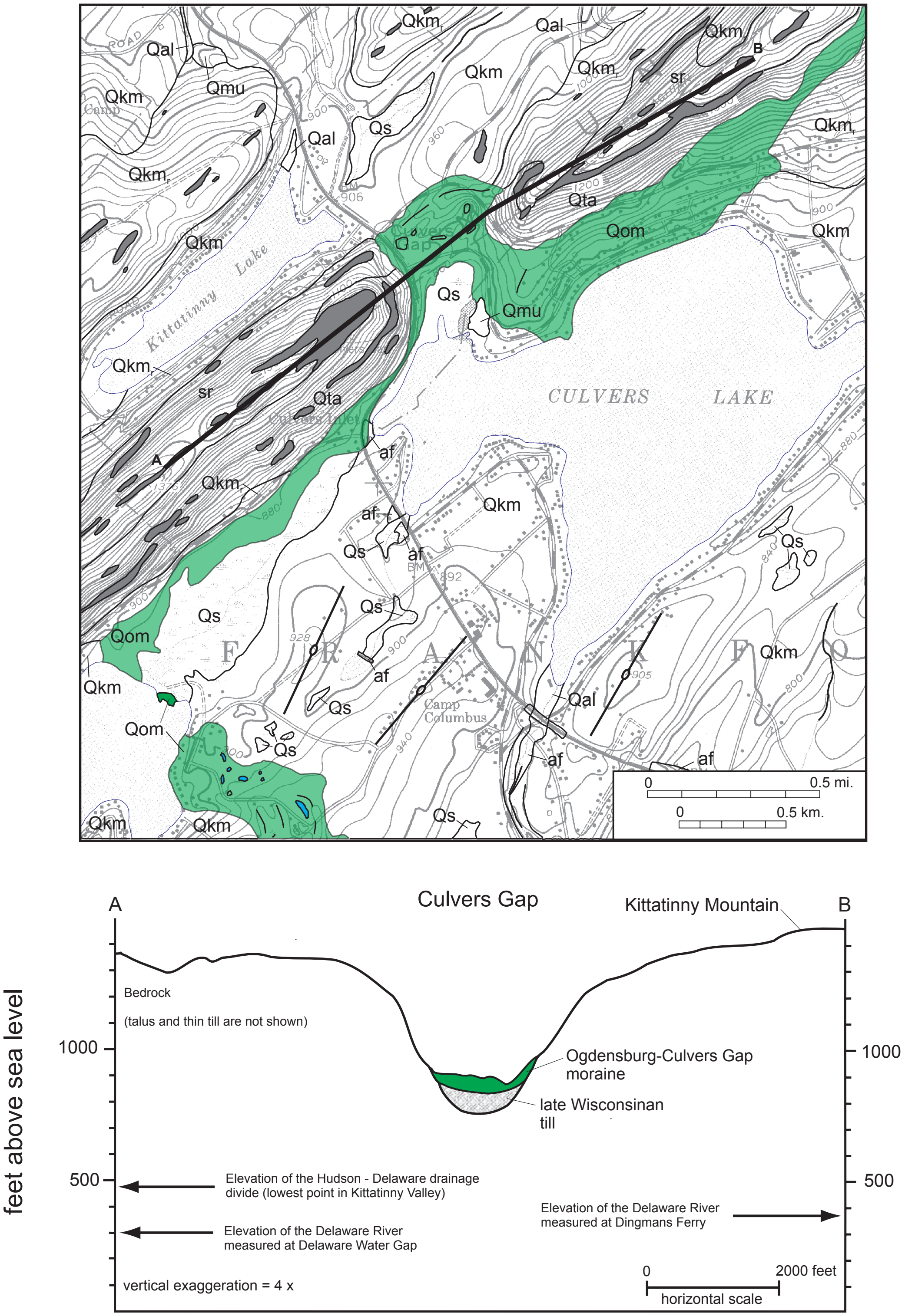


Figure 5. Surficial geology and longitudinal profile of Culvers Gap, Sussex County, New Jersey. Map units: af - artificial fill, Qs - swamp and bog deposits, Qal - alluvium, Qta - talus, Qkm - thick till, Qkmr - thin till, Qom - Ogdensburg-Culvers Gap moraine, Qmu - small undifferentiated meltwater deposits, Qft - meltwater-terrace deposits, sr - regolith, chiefly rock waste on steep hillslopes and ridge crests with minor talus, scattered erratics, and a few rock outcrops. Shaded areas represent extensive rock outcrop. On Qom, lines show the crest of large morainal ridges, and small polygons represent kettles. Modified from Witte 1997b.

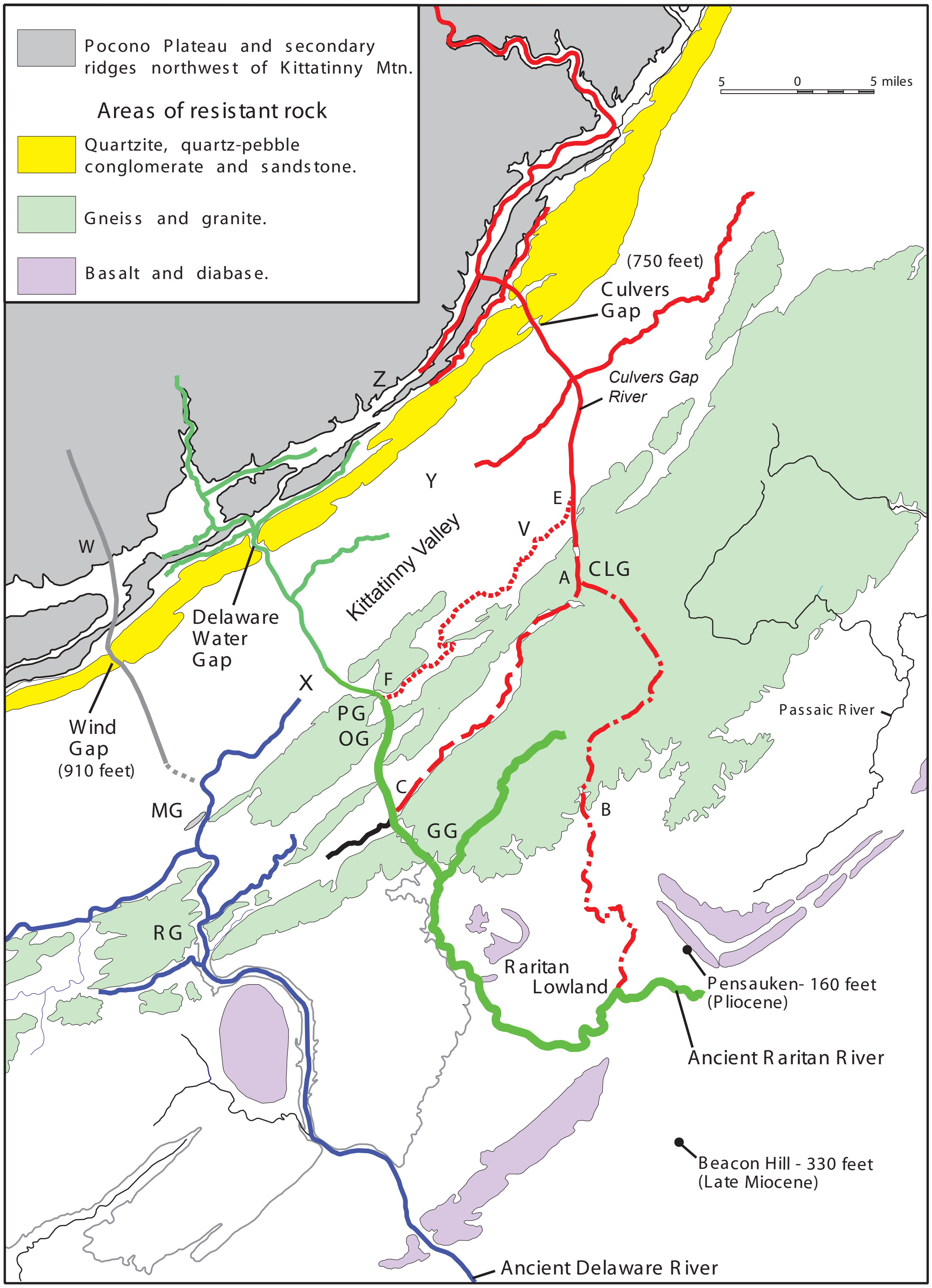


Figure 6. Reconstruction of the late course of the Culvers Gap River, and several scenarios for its capture by the ancient Delaware River. Key to gap names abbreviated in figure: PG - Pequest Gap, OG - Oxford Gap, GG - Glen Gardner Gap, MG - Marble Mountain Gap, RG - Riegelsville Gaps, CLG - Cranberry Lake Gap. Pre-capture course of the Culvers Gap River: A-B Andover-Ledgewood course, A-C Andover-Musconetcong Valley Course, E-F Pequest Valley course. Location of capture: V - Pequest Valley capture, W - Wind Gap capture, X - Pequest Gap capture, Y - Paulins Kill valley capture, Z - Minisink Valley capture. Modified from Witte (1997b).

till. Overlying this lower compact till is a thin, discontinuous, noncompact, poorly sorted silty sand or sand containing as much as 35 percent pebbles, cobbles, boulders; interlayered with lenses of sorted sand, gravel, and silt. Overall, clasts are more angular, and they lack a preferred orientation, or have a weak orientation that is oblique to the regional direction of glacier flow. This material may be ablation till and flowtill, but it has not been mapped separately owing to its scant distribution and poor exposure. Also, cryoturbation and bioturbation have altered the upper few feet of till, masking its original character by making it less compact, reorienting stone fabrics, and sorting clasts.

Till composition was dependent on the south-to-southwest direction of ice flow over narrow, southwest-trending belts of local sedimentary source rocks. Till in Kittatinny Valley near the Paulins Kill was chiefly derived from slate, graywacke, dolostone, and limestone. In Minisink Valley and atop Wallpack Ridge, till consists of limestone, shale, limey shale, and sandstone clasts and their weathering products. On Kittatinny Mountain till was chiefly derived from quartzite, quartz-pebble conglomerate, and red sandstone and shale that underlie Kittatinny Mountain. Owing to the southward movement of the ice sheet across the mountain, this material also lies in a narrow belt in Kittatinny Valley along the eastern base of Kittatinny Mountain.

Drumlins

Drumlins are found throughout the quadrangle in two different settings. The first consists of multiple drumlins in areas of very thick and widespread till. This includes a 1-to-2 mile wide belt in Kittatinny Valley that extends southwestward along the base of Kittatinny Mountain from Culvers Lake, and an area on Kittatinny Mountain north of Culvers Gap. Well records (Plate 2, table 1) and seismic refraction data (unpublished data on file at the New Jersey Geological Survey, Trenton New Jersey) show the overburden in this setting is typically greater than 100 feet (30m) thick, and most of the drumlins lack a bedrock core. The second setting consists of solitary to few drumlins found among areas of thin till. These drumlins are scattered throughout the quadrangle, and well records and rock outcrops near them suggest that many of these have a bedrock core. Pre-Wisconsinan glacial deposits have not been observed in the study area. However, Stanford and Harper (1985) have shown that some drumlins in Kittatinny Valley have cores that consist of weathered, older till. Based on their observation, some of the Culvers Gap drumlins may also have a core of pre-Wisconsinan till.

Moraines

Morainal deposits include the Ogdensburg-Culvers Gap (Qom) and Dingmans Ferry (Qdfm) moraines, and a few small, uncorrelated patches. Both the larger moraines delineate a major recessional position of the Kittatinny Valley and Minisink Valley lobes called the Culvers Gap margin (fig. 2). In the quadrangle, the Ogdensburg-Culvers Gap moraine forms a nearly continuous, cross-valley ridge that extends northwestward from Lake Kemah to the base of Kittatinny Mountain. From there it swings into Culvers Gap and then continues along the eastern side of Kittatinny Mountain to where it crosses the mountain's crest, approximately 4 miles northeast of Culvers Gap. After crossing the main ridge of the mountain, the moraine follows a looping course through the Big Flat Brook valley and joins the Dingmans Ferry moraine. From there the Dingmans Ferry moraine traces a lobate and segmented course across Wallpack Valley and Wallpack Ridge into Minisink Valley where it ends.

The recessional moraines are as much as 65 feet thick and 2500 feet wide, although most are less than 1000 feet wide. Their surfaces are bouldery, and they are made of poorly compacted, stony till with minor beds of stratified sand, gravel, and silt. Cross-sectional profiles are typically asymmetrical with the distal (southern) slopes the steepest. Their distal limits are also topographically distinct, whereas their innermost limits 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. However, most are less than 500 feet (152 m) long. Many ridges appear to have been continuous, but may have been disconnected by collapse during melting of buried ice. 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. These depressions parallel the ridges. Irregularly shaped depressions also occur. They are as much as 40 feet (12 m) deep, 500 feet (152 m) wide, and they represent the former location of buried or partly buried ice blocks. Both types of depressions may contain bogs. The innermost parts of the moraines have fewer ridges, fewer elongated depressions, and are marked by knob-and-kettle rather than ridge-and-kettle topography. In places where moraines lie amongst or south of thick and widespread till, they are generally larger, more continuous, and have more fully developed moraine-parallel ridges than those abutting thin patchy drift.

The trend of the recessional moraines shows the extent of both regional and local lobation of the Kittatinny and Minisink Valley ice lobes (fig. 2). Nearby striations are perpendicular to their courses and this suggests ice was active at the glacier's margin. Also, well logs show the Ogdensburg-Culvers Gap moraine overlies late Wisconsinan ice-contact deltaic outwash, where it crosses the Paulins Kill and Wallkill River valleys (Witte, 1991). This shows the moraine was laid down following a readvance.

The lobate course of the end moraines, their morphology, and evidence of readvance shows they were formed by 1) the pushing and glacial transport of debris and debris-rich ice at the glacier margin, and 2) penecontemporaneous and postdepositional 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 are 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 was carrying the sediment to the margin by some kind of "conveyor-belt" process. Inwash is not a viable mechanism because the larger morainal deposits lie on mountains and ridges.

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 (Qd, 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 ice tunnels to the glacier margin, and by meltwater streams draining deglaciated upland areas beside the valley (Witte, 1988; Witte and Evenson, 1989). Sources of sediment were till beneath the glacier, debris in the glacier's basal dirty-ice zone, and till and reworked outwash in deglaciated uplands. Based on the provenance of glacial outwash (Witte, 1988), debris carried to the margin of the ice sheet by direct glacial action is only a minor component.

Glaciofluvial sediments were laid down by meltwater streams in valley-train (Qv), outwash-fan (Qf), meltwater-terrace deposits (Qmt), and delta topset beds (Qd, Qod). These sediments include cobbles, pebbles, sand, and some boulders laid down in channel bars, and sand, silt, and pebbly sand in minor overbank and channel-fill deposits. Sediments 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 tributaries where they enter trunk valleys. These deposits were laid down beyond the glacier margin, and are graded to the surface of the valley-train deposits that lie in the trunk valley.

Glaciolacustrine sediments were laid down by meltwater streams in glacial lake deltas (Qd, Qod), lake-bottom deposits (Qlb), and in ice-hole fillings mapped as kames (Qk). 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 and parallel-laminated sand 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.

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 proglacial lake basins in the Minisink, Wallpack, and Paulins Kill Valleys were very narrow, they were filled with glaciolacustrine sediment and covered by a thick wedge of glaciofluvial sand and gravel from valley wall to valley wall. In a few places, outwash was laid down over and around stagnant ice.

Lake-bottom deposits include 1) glacial varves and 2) subaqueous-flow deposits. Glacial varves consist of stacked annual layers that consist of a lower "summer" layer, chiefly silt, that grades upward into a thinner "winter" layer of very fine silt and clay. Most of these materials were deposited from suspension. However, the summer layer may contain sand and silt carried by density currents. Each summer and winter couplet represents one year. Subaqueous-flow deposits consist of graded beds of sand and silt that originated from higher areas in the lake basin; such as the prodelta front, and were carried down slope into deeper parts of the lake basin by gravity flows. Lake-bottom deposits grade laterally into bottomset beds of deltas.

Kames (Qk) consist of a varied mixture of stratified sand, gravel, and silt interlayered with flowtill. In many places they lie above local glacial lake, base-level controls. However, exposures reveal collapsed deltaic foreset bedding. Presumably, the kame was laid down in a meltwater pond that formerly occupied an ice-crevasse, ice-walled sink, or moulin near the edge of the glacier.

Postglacial Deposits

Wind-blown sediment

In Minisink Valley, thin deposits of well sorted, very fine sand and fine sand lie along its eastern side, extending up the valley slope as much as 180 feet (55 m). An extensive sheet of eolian sand also covers the valley-train terrace north of Dingmans Ferry. This material is generally less than three feet thick. However, in a few places, a five-foot-long hand auger did not penetrate the base of the sand sheet. Low ridges and knolls are found across the sand's surface. These are presumably dunes. No other areas of wind-blown materials have been recognized in the quadrangle.

Hillslope-sediment

Thin deposits of shale-chip colluvium (Qsc) lie at the base of cliffs formed by the Mahantango Formation in Minisink Valley. The rubble, well described in Sevon and others (1989), consists of angular, elongated, platy, prismatic and bladed clasts of the Mahantango Formation. Clast length typically ranges from one to six inches. Larger clasts, up to boulder size, may be interspersed throughout the deposit. Typically, the rubble has very little matrix, although many of the clasts exhibit a thin coating of clay. The few beds that did have a substantial matrix component displayed a coarsening upwards of shale clasts, suggesting they were deposited as a slurry flow. Bedding is slope parallel, and averages between one to four inches thick. However, in many places the homogeneity of the rubble makes it difficult to discern bedding. Most of the elongated fragments are oriented downslope. Bedding, sorting, and clast orientation of the rubble suggest that most of this material, after it has fallen off the outcrop and accumulated at the top of the apron, moves downslope as a massive sheetflow. Bedding and grading show that this downslope transport is episodic and in some cases may have involved water.

Glacial erosion and the lithology and structural elements of the Mahantango Formation have created a geologic setting that is conducive to the formation of very large volumes of shale-chip rubble over a short time. Glacial erosion during at least three glaciations has cut back the west side of Minisink Valley and formed a very steep rock face that is as much as 500 feet high. Mechanical weathering of the rock by frost shattering has formed an extensive apron of shale-chip rubble that has accumulated since Minisink Valley was deglaciated about 18,000 years ago. The steep southeast-dipping cleavage of the Mahantango Formation, its thin, northwest-dipping beds of shale and siltstone, and its vertical joints form weak zones with extensive surface area subject to rapid fragmentation. The size of the rubble clasts is directly related to cleavage spacing, bedding thickness, and joint depth.

Other hillslope deposits include thick talus (Qta), which is chiefly made up of blocks of conglomerate and quartzite. This material forms 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

Many swamp and bog deposits (Qs) are in the quadrangle. They formed in kettles and glacially scoured bedrock basins, in glacial lakes that persisted into the Holocene, in abandoned stream channels on alluvial plains, and in poorly-drained areas on ground moraine. These deposits principally consist of peat, muck, marl, and minor detritus. Peat in Kittatinny Valley is largely of the reed-and-sedge type. Where limestone and dolomite crop out, peat is commonly underlain by calcareous marl (Waksman and others, 1943). Peat deposits on Kittatinny Mountain, in Minisink Valley, and those northwest of the Paulins Kill 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. It forms narrow, sheet-like deposits on the floors of modern valleys. Channels, channel scarps and levees are preserved on flood plains along the larger rivers. In Minisink Valley, the modern flood plain 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 a narrow strip of land that flanks the river's channel.

Stream-terrace deposits (Qst) include both channel and flood-plain sediment, and they lie 5 to 35 feet (2 to 11 m) above the modern flood plain and below meltwater-terrace deposits. In Minisink Valley they may be grouped into two distinct sets (fig. 7). The youngest (Qst2) lies between 20 and 35 feet (6 to 11 m) above 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 the terrace lie next to the Delaware River on a levee. In places the levee is well developed and forms a prominent ridge that is as much as 8 feet (2 m) high. However, the levee is commonly 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 cut by a shallow channel that typically contains organic deposits. In many places, multiple levees, and channel scrolls are preserved, especially where the terrace lies on the inside of a large river bend. The 15-foot (5 m) range in elevation of the terrace throughout Minisink valley is due to: 1) as much as 8 feet (2 m) of constructional relief on the terrace, and 2) lowering of parts of the terrace by erosion as the river cut down to its modern level. It is also possible that the Qst2 terrace consists of several levels, as shown by Wagner (1994). However, without better elevation control, these terrace subsets are difficult to correlate on a valley-wide scale. The differing levels may also be related to local riparian conditions and channel morphometry of the postglacial Delaware River. Archaeological investigations in the Delaware River valley above Delaware Water Gap (Stewart, 1991) showed that the base of the Qst2 terrace may be as old as 11,000 yrs B.P., with its surface dated to historic times. This suggests that the Qst2 terrace is Holocene age and that it has been largely built up by vertical accretion. However, in a few places, channel scrolls preserved on some terraces, and the course of the Delaware River show that stream-terrace deposits have also been built by lateral accretion.

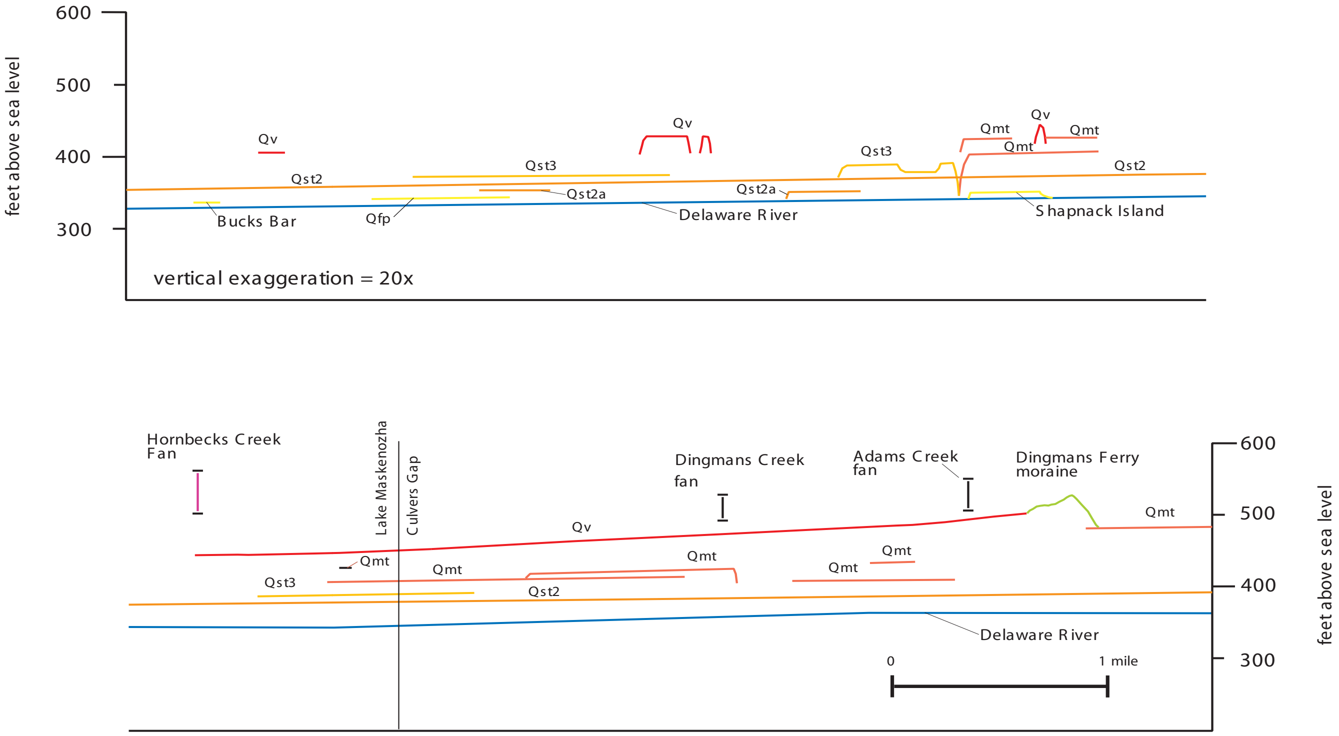


Figure 7. Longitudinal profiles of glacial outwash and postglacial alluvial terraces in Minisink Valley, Lake Maskenozha and Culvers Gap, Pa. - N.J., 7 1/2 minute quadrangles. Profiles constructed by projecting elevation and contacts to a center line drawn up Minisink Valley. Additional elevation data 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, Qst3 - abandoned Pleistocene flood plain, Qst2 and Qst2a - abandoned Holocene flood plains, Qfp - 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 from Witte (1997a).

The oldest stream-terrace deposits in Minisink Valley (Qst3) lie 40 to 48 feet (12 to 15 m) above the modern river and typically consist of as much as 10 feet (3 m) of overbank fine sand and medium sand overlying glacial outwash. In places, this material has been eroded, revealing the underlying outwash. The Qst3 terraces are typically small and flank the younger Qst2 deposits. In some places they lie 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 fan-shaped deposits that lie at the base of hillslopes at the mouths of gullies, ravines, and tributary valleys. Their sediment is highly variable and is derived chiefly from local surficial materials eroded and laid down by streams draining adjacent uplands. Most alluvial fans are entrenched by modern streams, which suggests that they are 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 Erosion

The distribution and differences in weathering characteristics of glacial drift in northwestern, New Jersey (Salisbury, 1902; Witte and Stanford, 1995) show that continental ice sheets covered the study area at least three times during the Pleistocene epoch. The action of each ice sheet modified the landscape by deeply scouring valleys, and also wearing down and streamlining bedrock ridges, hills, and slopes. Both the floor of the Minisink and Wallpack Valleys, and part of Kittatinny Valley beneath Culvers Lake were deeply scoured by glacial erosion (Plate 2). Only erosional features of the late Wisconsinan glaciation have been preserved because older features have been eroded. These include polished and plucked bedrock, striations, and streamlined bedrock forms called whale backs. The many unweathered and lightly weathered bedrock outcrops also show that preglacial saprolite and soil were removed by glacial erosion. However, an outcrop of saprolite observed by the authors on the Poxono Island Formation downvalley in the Bushkill quadrangle shows that at least some preglacial materials were not completely eroded.

Glacial Advance and Changes in the Direction of Regional Ice Flow

The late Wisconsinan advance of ice into the upper part of Kittatinny Valley is obscure because glacial drift and striae that record this history were eroded or buried. If the ice sheet advanced in lobes, as suggested by the lobate course of the Terminal Moraine (fig. 8), then its initial advance was marked by lobes of ice moving southwestward down the

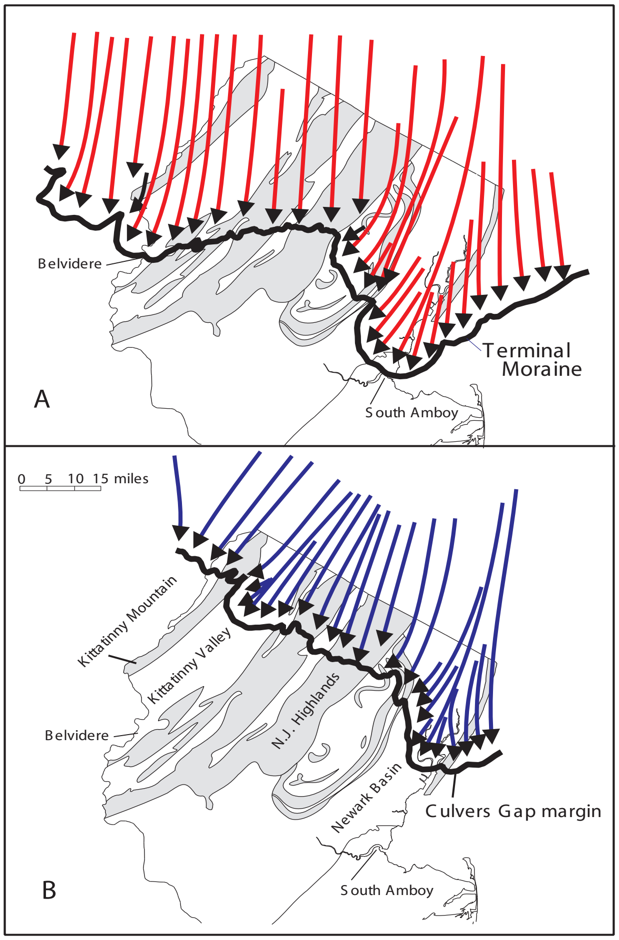


Figure 8. Generalized direction of ice movement in northern New Jersey during the late Wisconsinan. Lines represent regional ice-flow movement at the base of the ice sheet. Flow directions are based on striae, drumlins, dispersal of erratics, and till provenance. Shaded areas represent major uplands. Figure 8a shows direction of ice flow when the glacier margin was at the Terminal Moraine. Field data in the Kittatinny Valley area indicate ice flowed southward across the valley's southwest-trending regional topographic grain. Figure 8b shows direction of ice flow during deglaciation. Flow lines in Kittatinny and Minisink Valleys and surrounding uplands are oriented in a southwest direction with well developed lobate ice flow at the glacier's margin. The change in regional ice flow to a southwest direction appears to be related to thinning of the ice sheet at its margin, and reorganization of ice flow around the Catskill Mountains, and in the Hudson-Wallkill Valley. Data from Ridge (1983), Stanford and Harper (1985), Witte (1988), Sevon and others (1989), Stone and others (2002), and unpublished field maps on file at the New Jersey Geological Survey, Trenton, New Jersey.

Kittatinny and Minisink Valleys. Sevon and others (1975) speculated 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) near 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. Analysis of striae, drumlins, and the distribution of erratics in the upper part of Kittatinny Valley and adjacent Kittatinny Mountain support Ridge's view. These data further show that by the time the Ogdensburg-Culvers Gap moraine was formed, ice flow in Kittatinny Valley had turned to the southwest with extensive lobation at the margin (fig. 8).

History of Deglaciation

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, and 1997a) showed that the margin of the Kittatinny and Minisink Valley lobes retreated systematically with minimal stagnation. However, the age of the Terminal Moraine, timing of the late Wisconsinan maximum, and precise chronology of deglaciation are very uncertain. This is due to scant radiocarbon dates because of a lack of organic material that can be used to date deglaciation, inadequacies of dating bog-bottom organic material and concretions, and use of sedimentation rates to extrapolate bog-bottom radiocarbon dates. Also, varved lake-bottom exposures that can be used for chronology are scarce.

The few radiocarbon dates available bracket the age of the Terminal Moraine and retreat of ice from New Jersey. Radiocarbon dating of basal organic material cored from Budd Lake by Harmon (1960) yielded a date of 22,890 ± 720 yr B.P. (I-2845), and a concretion sampled from sediments of Lake Passaic by Reimer (1984) that yielded a date of 20,180 ± 500 yr B.P. (QC-1304) suggest that the age of the Terminal Moraine is about 22,000 to 20,000 yr B.P. Basal organic materials cored from a bog on the side of Jenny Jump Mountain approximately 3 miles (4.8 km) north of the Terminal Moraine by D. H. Cadwell (written commun., 1997) indicates a minimum age of deglaciation at 19,340 ± 695 yr B.P. (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 18,570 ± 250 yr B.P. (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 B.P. (I-4935) from sediments of Lake Hudson (cited in Stone and Borns, 1986) and an estimated age of 17,210 yr B.P. for the Wallkill moraine by Connally and Sirkin (1973) suggest ice had retreated from New Jersey by 18,000 yr B.P.

Based on the morphosequence concept of Koteff and Pessl (1981), many ice-recessional positions have been delineated in Kittatinny Valley (Ridge 1983: Witte 1988; 1997a). 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. Regionally however, the Minisink lobe retreated more rapidly (Witte, 1991).

Kittatinny Valley

The Ogdensburg-Culvers Gap moraine (Plate 1, geologic map) follows a lobate course from the north shore of Lake Kemah into Culvers Gap, where it forms a plug of thick till. From there it ascends the southeast face of Kittatinny Mountain at 200 feet per mile, crossing the Mountain's crest about two miles northeast of Culvers Gap. Based on the moraine's size, continuity, lobate course, and correlation to the Dingmans Ferry moraine further west, it marks a major recessional position of the Kittatinny Valley ice lobe (fig. 2).

South of the moraine (Plate 1, geologic map) a few kame deposits are found in small valleys near

Quick Pond. Most of these appear to have been laid down in ice crevasses or ice-walled ponds in the stagnant glacier margin. Because of their small size and unclear history, they are not used to delineate ice-retreatal positions.

Ice retreat from the Quick Pond area resulted in the formation of glacial Lake Owassa (fig. 2) in the north-draining Culvers Creek drainage basin. The lake initially drained out over a spillway at the south end of Bear Swamp, elevation 890 feet (271 m). The small sand and gravel deposit just south of Lake Owassa (Qd1) has been mapped as an ice-contact delta on the basis of its similar elevation. During ice retreat, a lower spillway, elevation 875 feet (267 m), was uncovered on the west side of the lake basin. The ice-contact delta at the north end of Bear Swamp (Qd2) was laid down in this lower lake stage. At the same time the delta was built, or shortly afterwards the Ogdensburg-Culvers Gap moraine was deposited. Farther retreat of the margin northward resulted in the glacial lake draining out to the Paulins Kill valley along a course now drained by Culvers Creek. The large meltwater channel west of Mt. Pisgah suggests that drainage may have been catastrophic. However, the lake did not drain completely, persisting into modern time as Culvers Lake and Lake Owassa (Plate 1, geologic map).

Outwash in Paulins Kill valley (Qod) are remnants of an ice-contact delta that had filled a small unnamed glacial lake (Witte, 1988). These deposits reach an elevation of 530 feet (162 m) and they show that the Ogdensburg-Culvers Gap moraine and older outwash had dammed the valley downstream. A decrease in the elevation of younger outwash sequences up valley (northeast of the Culvers Gap quadrangle) and the presence of meltwater-terrace deposits cut in the delta plain are evidence of an eroding sediment dam downstream.

Kittatinny Mountain

Except for a few small kame deposits near Lake Ashroe, Kittatinny Lake and Tuttles Corners, outwash deposits are absent in this area. This is largely because the floors of most valleys have steep gradients that prohibit the deposition of sediment by meltwater streams. Valley floors are typically covered by a lag of boulders and cobbles chiefly derived from meltwater-washed till. In many places meltwater channels are deeply cut in thick till, and a few, such as part of Tillmans Ravine, may mark the former lobate edge of the glacier margin. Others are found in front of the Ogdensburg-Culvers Gap and Dingmans Ferry moraines.

The Ogdensburg-Culvers Gap moraine follows a nearly continuous course westward from Kittatinny Mountain toward Wallpack Valley. The moraine's reentrant north of Lake Ocquitunk marks the boundary with the Dingmans Ferry moraine. Although, the two moraines are the same age, they have different names because they were laid down at the margins of different ice lobes.

Wallpack Valley and Big Flat Brook valley

Meltwater deposits in Wallpack Valley (Plate 1, geologic map, and fig. 9) consist of kames, valley-train deposits, ice-contact deltas, and meltwater-terrace deposits. Kames are small collapsed deposits of coarse gravel and sand that lie higher than valley-train deposits and ice-contact deltas. Their collapsed form and higher position show they were laid down on and against stagnant ice and the nearby hillslope. Topographically below the kames and covering large parts of the valley floor lie kettled, noncontinuous terraces of sand and gravel (Qod1). Exposures in the lower part of Wallpack Valley revealed deltaic foreset bedding, showing that these deposits were laid down in a small proglacial lake dammed by older outwash down valley. In places, outwash was laid down against stagnant ice, whereas in other areas it filled the narrow lake basin from valley wall to valley wall. This material was later eroded by meltwater and postglacial streams. In the lower part of Wallpack Valley the noncollapsed part of the delta plain is at an elevation of 465 feet (142 m) near the quadrangle boundary and it rises to 625 feet (191 m) upstream at its head near the Dingmans Ferry moraine north of Layton. In Big Flat Brook valley outwash also extends downstream from the moraine. Both the moraine and extensive outwash built off its distal slope mark a major ice recessional position of the Minisink Valley ice lobe. Taken together with the OgdensburgCulvers Gap moraine they delineate the Culvers Gap ice margin (fig. 2).

In Wallpack Valley meltwater deposits north of the moraine near Hainesville consist of collapsed ice-contact deltaic outwash (Qod2). They are at an elevation of 645 feet (197 m) and their reconstructed profile (fig. 7) suggests they were laid down in a short-lived proglacial lake dammed in the valley by the Dingmans Ferry moraine. In Big Flat Brook valley, retreat from the Dingmans Ferry moraine may have also resulted in the formation of a proglacial lake. However, there are no deltaic deposits in the valley that record the lake's existence. Immediately upstream from the moraine is an outwash terrace that reaches an elevation of 700 feet (213 m), about 25 feet (8 m) above the modern valley floor. Its low position

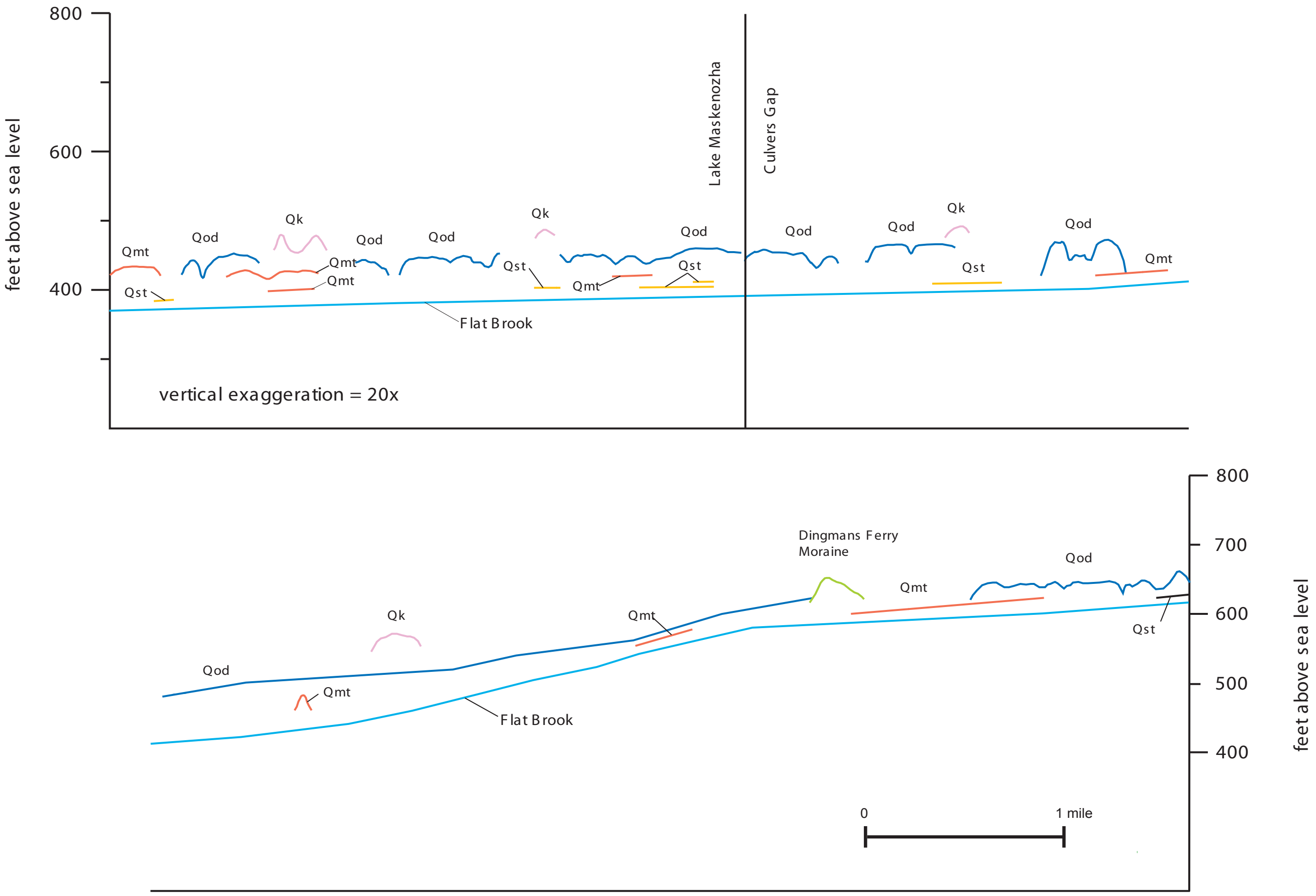


Figure 9. Longitudinal profiles of glacial outwash, recessional moraine, and postglacial alluvial terraces in Wallpack Valley, Lake Maskenozha and Culvers Gap, Pa - NJ, 1 1/2 minute quadrangles. Profiles constructed by projecting elevation and geologic contacts to a center line drawn up Wallpack Valley. Geologic units; Qod - glacial lake delta, Qft - meltwater terrace, Qk - Kame, and Qst - postglacial stream terrace. From Witte (1997a).

in the valley suggests that it was deposited after the moraine dam had been breached. Meltwater drainage off Kittatinny Mountain may have hastened erosion of the moraine. The few meltwater-terrace deposits in the valleys record a period of incision and a decline in local base level as meltwater streams adjusted to their longer courses. Meltwater continued to flow down the Wallpack Valley until the time the Minisink Valley lobe had retreated from the Augusta margin (fig. 2).

Minisink Valley

Meltwater deposits in Minisink Valley consist of a few kames, valley-train deposits, outwash-fan deposits, and meltwater-terrace deposits (Plate 1, geologic map, and fig. 7). The valley-train deposit (Qv1) south of the Dingmans Ferry moraine is a remnant of an extensive outwash plain that ranges in elevation from approximately 420 feet (128 m) downstream near the quadrangle boundary to 490 feet (149 m) upstream near the moraine. Based on the reconstructed longitudinal profiles of the valley train (fig. 7), and an increase in grain size upstream, the outwash appears to have been laid down from an ice-recessional position located at the position of the Dingmans Ferry moraine (fig. 2). The valley train (Qv2) north of the moraine is about 20 feet (6 m) lower and appears to have been laid down from a position marked by the Montague moraine (fig. 2).

On the Pennsylvania side of Minisink Valley are large fan-shaped deposits of sand and gravel (Qfd, Qfa, and Qfdb) that lie at the mouths of Dingmans Creek, Adams Creek, and Dry Brook. These deposits reach an elevation of as much as 520 feet (158 m). They are non-ice-contact deposits laid down by meltwater streams draining the upper reaches of these tributaries, and they are graded to the surface of the valley-outwash deposits.

Meltwater-terraces in Minisink Valley (Fig. 7) are chiefly strath terraces that were cut down in valley-train deposits by meltwater streams emanating from the glacier margin up valley from the Dingmans Ferry moraine. These deposits are as much as 15 feet (5 m) thick and largely consist of material eroded from nearby valley-outwash deposits, and from till that covers the lower part of valley slopes. They generally have flat surfaces, which in places are cut by later meltwater channels, and they range in elevation from 450 feet (137 m) near the moraine to 400 feet (122 m) down valley.

Summary of deglaciation

The ice-retreatal positions marked by recessional moraines and the heads-of-outwash of ice-contact deltas and valley-train deposits show that the margins of the Kittatinny Valley and Minisink Valley ice lobes retreated in a systematic manner, chiefly by stagnation-zone retreat, to the northeast. In places proglacial lakes, dammed by till, moraine, and outwash downvalley, formed at the glacier's margin. A major ice-retreatal position, the Culvers Gap margin, is marked by the Ogdensburg-Culvers Gap and Dingmans Ferry moraines. These cross-valley till ridges were laid down at an active glacier margin.

Postglacial History

The Culvers Gap quadrangle is estimated to have been deglaciated by 18,000 yr B.P. based on the oldest Francis Lake 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 B.P. (estimated from Ozvath and Coates, 1986). Meltwater from Augusta stage of Lake Wallkill (fig. 2) continued to flow down Paulins Kill valley until a lower spillway, located on a divide between Moodna Creek and presently at about 400 feet (122 m) above sea level, was uncovered in the mid-Wallkill Valley and the lake's drainage flowed to the Hudson Valley. This occurred around 17,000 yr B.P., based on the estimated age of the Pellets Island moraine in Wallkill Valley by Connally and Sirkin (1986).

The postglacial landscape immediately after the late Wisconsinan glacier retreated from Kittatinny and Minisink Valleys was a cold, wet, and windswept wilderness. This 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, small to large, frost-rived blocks of conglomerate and quartzite form aprons of thick talus at the foot of cliffs. In Minisink Valley, deposits of shale-chip colluvium mantle the foot of cliffs and the lower part of steep slopes near Dingmans Creek. 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 stones, and a few others may have been concentrated and deposited by the glacier.

The many swamps and poorly drained areas in the Culvers Gap 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. Swamps and bogs contain sedimentary and organic records that record past climatic conditions. Because these materials were laid down layer upon layer, they may preserve a climatic record from the time of deglaciation to the present. The identification of pollen and radiocarbon dating of plant material retrieved from swamps has provided information on regional and local changes in vegetation, which have been used to interpret past climates. Several studies on bogs and swamps in northwestern New Jersey and northeastern Pennsylvania have established a dated pollen stratigraphy that nearly goes back to the onset of deglaciation (Cotter, 1983). Paleoenvironments, interpreted from pollen analysis, show a transition from tundra with sparse vegetal cover, to an open parkland of sedge and grass with scattered arboreal stands that largely consisted of spruce. From about 14,000 to 11,000 yrs. B.P. the regional pollen sequence records the transition to a dense closed boreal forest that largely consisted of spruce and fir blanketing the uplands. This was followed by a period (11, 000 to 9,700 yrs. B.P.) in which pine became the dominant forest component. These changes in pollen spectra and percentages, record the continued warming during the latter part of the Pleistocene and transition from the ice age to a temperate climate. About 9,400 yrs. B.P., oak and other hardwoods began to populate the landscape, eventually displacing the conifers and marking the transition from a boreal forest 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 eventually forming bogs and swamps. These organic-rich deposits principally consist of peat, muck, and minor rock and mineral fragments. Calcareous ponds also filled with marl, which is calcium carbonate precipitated by aquatic plants, chiefly chara (Waksman and others, 1943). In most ponds marl underlies peat. However, along the pond edges and where sedimentary peat has slumped into the deeper parts of the pond, they are interlayered.

Mastodon remains, excavated from Shotwell Pond in Stokes State Forest (Jepsen, 1959) show that large mammals roamed Kittatinny Mountain during the close of ice age.

A thin sheet of wind-blown sand in Minisink Valley records a period of intense eolian activity. The precise age of these deposits is unclear. However, their location on the east side of the valley and on valley-train deposits, and presumption of sparse floral cover suggests these materials were laid down in late glacial to early postglacial time (18,000 to 14,000 yrs. B.P.).

The glacial and postglacial fluvial history of the study area is well preserved in the Minisink Valley where events can be divided into 4 phases. Phase 1 is a period of valley filling when glacial stream deposits were laid down at the margin of the Minisink Valley lobe during deglaciation. Based on a few bog-bottom dates by Cotter and others (1986), and Connally and Sirkin (1973) it is estimated here that this phase lasted to about 17,500 to 18,000 years ago. At times, the margin of the glacier remained stationary and outwash built up in front of the glacier and extended many miles downstream. One such retreatal position is marked by the Dingmans Ferry moraine (fig. 7) where the outwash deposits now lie as much as 130 feet (40 m) above the modern river. Down valley, meltwater-terrace deposits were cut by meltwater in slightly older valley outwash deposits, as the proglacial river adjusted to its longer course.

Phase 2 marks a period of erosion in the valley and further development of meltwater-terrace deposits as the meltwater stream cut into the valley fill. Initially, meltwater from a distant ice margin may have cut a deep narrow channel in the glacial valley fill. In a few places, this straight channel is preserved. However, meltwater-terrace deposits in most parts of the valley show that meltwater streams also shifted laterally across the valley floor. These terraces are erosional and meltwater sediment, at least its gravel fraction, was derived from eroded local valley fill, rather than outwash laid down from a distant ice margin up valley. This phase lasted to about 14,000 years ago, based on an estimated age of deglaciation for the Delaware River drainage basin determined from Ozvath and Coates (1986).

Phase 3 marks the onset of stream-terrace deposition and presumably starts when the ice sheet retreated from the Delaware River drainage basin, and stream discharge diminished substantially. This faciliteted an interval of extensive lateral erosion and deposition on the valley floor as the main channel of the river began to meander. The Qst3 terrace (fig. 4) is a relict deposit of this phase and represents the oldest flood-plain deposits preserved in the valley. It lies as much as 48 feet above the modern river.

Phase 4 marks renewed downcutting and extensive vertical accretion of overbank deposits. During the Holocene these flood-plain materials built up to heights as much as 35 feet (11 m) (fig. 4) 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 B.P. (Koteff and Larsen, 1989), and 2) the onset of a warmer climate and the growth of deeper rooted and more extensive vegetation, which 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 lies in valley-train deposits (Qv), and ice-contact deltas (Qod). Sediment is used as aggregate, subgrade fill, select fill, surface coverings, and decorative stone. Shale-chip colluvium (Qsc) and weathered slate make excellent subgrade material. The locations of sand and gravel pits and quarries are shown on Plate 1. All are currently inactive except for occasional use by the landowner. 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.

References

Connally, G. G., and Sirkin, L. A., 1973, Wisconsinan history of the Hudson-Champlain lobe, in Black, R. F., Goldthwait, R. P. and William, H. B. (eds.), The Wisconsinan stage: Geol. Soc. Amer. Memoir 136, p. 47-69.

_____, 1986, Woodfordian ice margins, recessional events, and pollen stratigraphy of the mid-Hudson Valley, in Cadwell, D.H., (ed.), The Wisconsinan Stage of the First Geological District, Eastern New York: New York State Museum, Bull. no. 455, p. 50-69.

Cook, G.H., 1877, Exploration of the portion of New Jersey which is covered by the glacial drift: N.J. Geological Survey Ann. Rept. of 1877, p. 9-22.

____, 1878, On the glacial and modified drift: N.J, Geological Survey Ann. Rept. of 1878, p. 8-23.

____, 1880, Glacial drift: N.J. Geological Survey Ann. Rept. of 1880, p. 16-97.

Cotter, J. F. P., 1983, The timing of the deglaciation of northeastern Pennsylvania and northwestern New Jersey: Doctoral Dissertation, Lehigh University, Bethlehem, Pa., 159 p.

Cotter, J. F. P., Ridge, J. C., Evenson, E. B., Sevon, W. D., Sirkin, Les,and Stuckenrath, Robert, 1986, The Wisconsinan history of the Great Valley, Pennsylvania and New Jersey, and the age of the "Terminal Moraine": in Cadwell, D. H.(ed.), The Wisconsinan stage of the First Geological District, eastern New York: N.Y. State Museum Bulletin 455, p. 22-50.

Crowl, G.H., 1971, Pleistocene geology and unconsolidated deposits of the Delaware Valley, Matamoras to Shawnee on Delaware, Pennsylvania, Pennsylvania Geological Survey, 4th., ser., General Geology Report 71, 68 p.

Crowl, G.H., and Sevon, W.D., 1980, Glacial border deposits of late Wisconsinan age in northeastern Pennsylvania, Pennsylvania Geological Survey, 4th ser., General Geology Report 71, 68 p.

Drake, A. A., Jr., Volkert. R. A., Monteverde, D. H., Herman, G. C., Houghton, H. H., Parker, R. A., and Dalton, R. F., 1996, Bedrock geologic map of northern New Jersey: U.S. Geological Survey Misc. Geol. Inv. Map I-2540-A.

Epstein, J. B., 1969, Surficial Geology of the Stroudsburg Quadrangle, Pennsylvania-New Jersey: Pennsylvania Geological Survey, 4th series, Bulletin G57, 67p., scale 1:24,000

Gustavson, T.C., Ashley, G. M., and Boothroyd, J. C., 1975, Depositional sequences in glaciolacustrine deltas: in Jopling, A.V., and McDonald, B.C., eds., Glaciofluvial and Glaciolacustrine Sedimentation, Society of Economic Paleontologists and Mineralogists, Special Publication no. 23, p. 264-280.

Harmon, K. P., 1968, Late Pleistocene forest succession in northern New Jersey: unpublished M.S. thesis, Rutgers Univ., 164 p.

Herpers, Henry, 1961, The Ogdensburg-Culvers Gap recessional moraine and glacial stagnation in New Jersey: New Jersey Geological Survey Report Series no. 6, 15 p.

Jepsen, Glenn, 1959, A New Jersey Mastodon: New Jersey State Museum Bulletin, no. 6, 20 p.

Koteff, Carl, and Larsen, F. D., 1989, Postglacial uplift in western New England: Geologic evidence for delayed rebound in Gregersen, S., and Basham, P. W., (eds.), Earthquakes at North Atlantic passive margins: Neotectonics and Postglacial Rebound, p. 105-123.

Koteff, Carl, and Pessl, Fred, Jr., 1981, Systematic ice retreat in New England: U.S. Geological Survey Professional Paper 1179, 20 p.

Leverett, Frank, 1934, Glacial deposits outside the Wisconsin terminal moraine in Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bulletin G 7.

Mackin, J. H., 1933, The evolution of the Hudson-Delaware-Susquehanna Drainage: Amer. Jour. Sci., v. 26, pp. 319-331.

McNett, C. W. Jr., and McMillian, B. W., 1977, The Shawnee-Minisink site in Newman, W. S., and Salwen, Bert (eds.) Amerinds and Their Paleoenvironments in Northeastern North America, Annals of the New York Academy of Sciences, v. 288, p. 282-298.

Minard, J. P., 1961, End moraines on Kittatinny Mountain, Sussex County, New Jersey: U.S. Geological Survey Prof. Paper 424-C, p. C61-C64.

Monteverde, D. H., 1992, Bedrock Geologic Map of the Sussex County, New Jersey Portions of the Culvers Gap and Lake Maskenozha Quadrangles, New Jersey Geological Survey, GMS 92-1.

Munsell Color Company, 1975, Munsell soil color charts: a division of Kollmorgan Corp., (unnumbered text and illustrations).

Ozvath, D.L., and Coates, D.R., 1986, Woodfordian stratigraphy in the western Catskill Mountains, in Cadwell, D.H., (ed.), The Wisconsinan Stage of the First Geological District, Eastern New York: New York State Museum, Bull. no. 455, p. 109-120.

Reimer, G. E., 1984, The sedimentology and stratigraphy of the southern basin of glacial Lake Passaic, New Jersey: unpublished M.S. thesis, Rutgers University, New Brunswick, New Jersey, 205 p.

Ridge, J.C., 1983, The surficial geology of the Great Valley section of the Valley and Ridge province in eastern Northampton County, Pennsylvania, and Warren County., New Jersey: Unpublished M.S. thesis, Lehigh University, Bethlehem, Pa., 234 p.

Salisbury, R. D., 1902, The glacial geology of New Jersey: N.J. Geological Survey Final Report, v. 5, 802 p.

Sevon, W.D., Berg, T.M., Schultz, L.D., and Crowl, G.H., 1989, Geology and mineral resources of Pike County, Pennsylvania: Pennsylvania Geological Survey, County Report 52, 141 p., 2 pls., scale, 1:50,000.

Sevon, W.D. Crowl, G.H., and Berg, T.M., 1975, The Late Wisconsinan drift border in northeastern Pennsylvania: Guidebook for the 40th Annual Field Conference of Pennsylvania Geologists, 108 p.

Stanford, S. D., and Harper, D. P., 1985, Reconnaissance map of the glacial geology of the Hamburg quadrangle, New Jersey: New Jersey Geological Survey, Geol. Map Series 85-1, scale 1:24,000.

Stewart, Michael, 1991, Archaeology and environment in the upper Delaware: in Orr, D. G., and Campana, D. V. (Eds.) The People of Minisink, Papers from the 1989 Delaware Water Gap Symposium: National Park Service, U.S. Department of the Interior, p. 79-115.

Stone, B. D., and Borns, H. W., 1986, Pleistocene glacial and interglacial stratigraphy of New England, Long Island, and adjacent Georges Bank and Gulf of Maine: in Sibrava, V., Bowen, D. Q., and Richmond, G. M. (eds.), Quaternary glaciations in the northern hemisphere: Quaternary Science Reviews, v. 5, p. 39-53.

Stone, B. D., Stanford, S. D., and Witte, R. W., 2002, Surficial geologic map of northern New Jersey: U.S. Geological Survey Misc. Geol. Inv. Map I-2540-C, scale 1:100,000.

Wagner, D. P., 1994, Pedology and geomorphology of the Depew Recreation Area, in Inashima, P. Y.,Gemorphology, Remote Sensing, and Archealogical Monitoring at Depew Recreation Area, Dept of the Interior, National Park Service, p. 1-36.

Waksman, S. A., Schulhoff, H., Hickman, C. A., Cordon, T. C., and Stevens, S. C., 1943, The peats of New Jersey and their utilization: N.J. Department of Conservation and Development Geologic Series Bulletin 55, Part B, 278 p.

White, I.C., 1882, The geology of Pike and Monroe Counties: Pennsylvania Geological Survey, 2d, Report G-6, 333 p.

Witte, R.W., 1988, The surficial geology and Woodfordian glaciation of a portion of the Kittatinny Valley and the New Jersey Highlands in Sussex County, New Jersey: Unpublished M.S. thesis, Lehigh University, Bethlehem, Pa., 276 p.

______, 1991, Deglaciation of the Kittatinny and Minisink Valley area of northwestern New Jersey: Stagnant and active ice at the margin of the Kittatinny and Minisink Valley lobes: in Geological Society of America Abstracts with Programs, v. 23, p. 151.

______, 1997a, Late Wisconsinan glacial history of the upper part of Kittatinny Valley, Sussex and Warren Counties, New Jersey: Northeastern Geology and Environmental Sciences, v. 19, no. 3, p. 155-169.

______, 1997b, Late history of the Culvers Gap River: A study of stream capture in the Valley and Ridge, Great Valley, and Highland Physiographic Provinces, northern New Jersey: in Pliocene-Quaternary Geology of Northern New Jersey, 60th Annual Reunion of the Northeastern Friends of the Pleistocene, May 30th to June 1st , 1997, Ledgewood,New Jersey, chap. 3, p. 3.1-3.16.

Witte, R. W., and Evenson, E.B., 1989, Debris sources of morphosequences deposited at the margin of the Kittatinny Valley lobe during the Woodfordian deglaciation of Sussex County, New Jersey, in Geological Society of America Abstracts with Programs, v. 21, p. 76.

Witte, R. W., and Stanford, S. D., 1995, Surficial geology and earth-material resources of Warren County, New Jersey: N.J. Geological Survey Open-file Map no. 15c, scale 1:48,000, 3 pl.