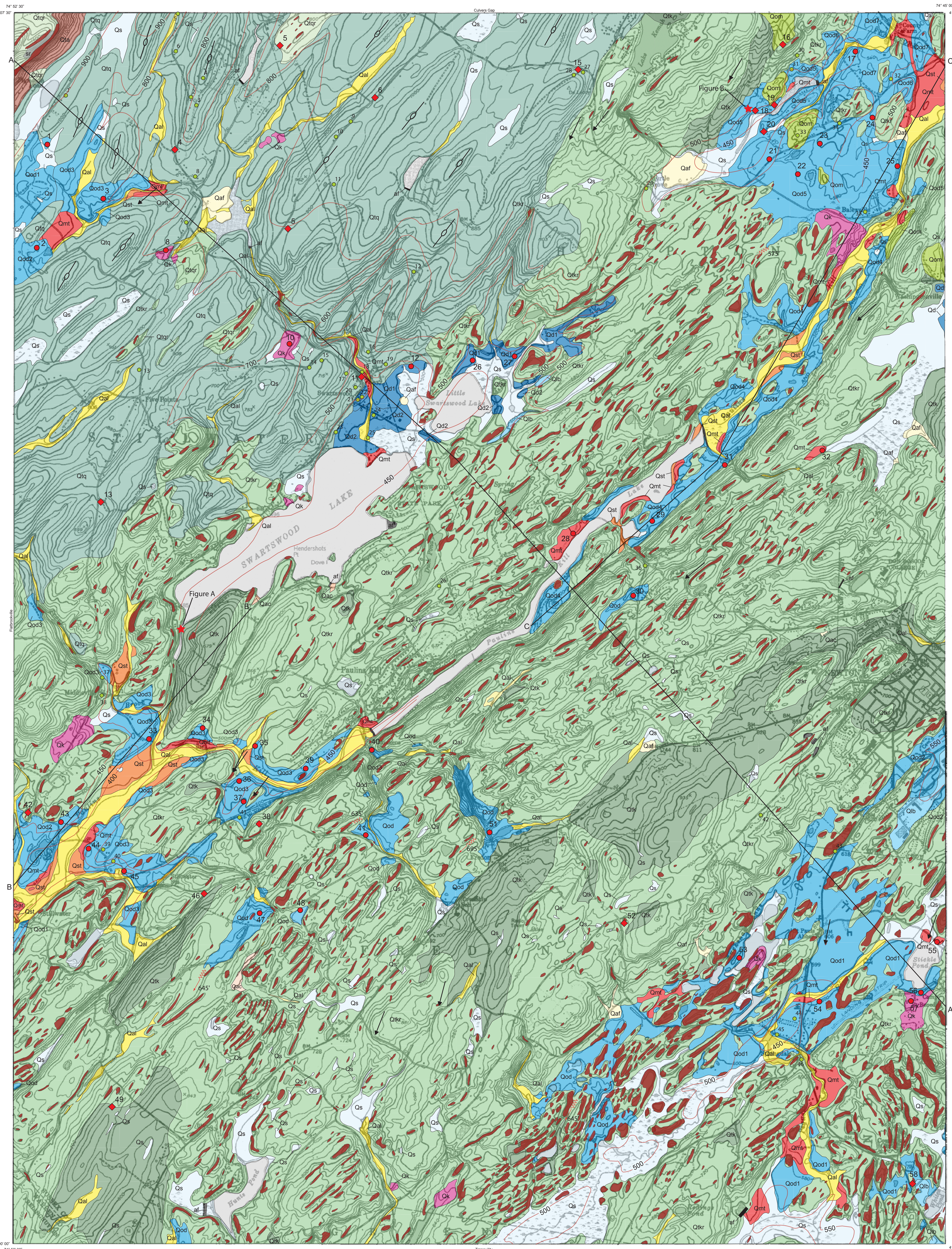


Base from U.S. Geological Survey
Newton West, 1971
The data presented in here is provisional pending external peer review. There may be changes made prior to publication as a New Jersey Geological and Water Survey Geologic Map Series.

MN GN 13° 231 MILS 0° 07´ 2 MILS

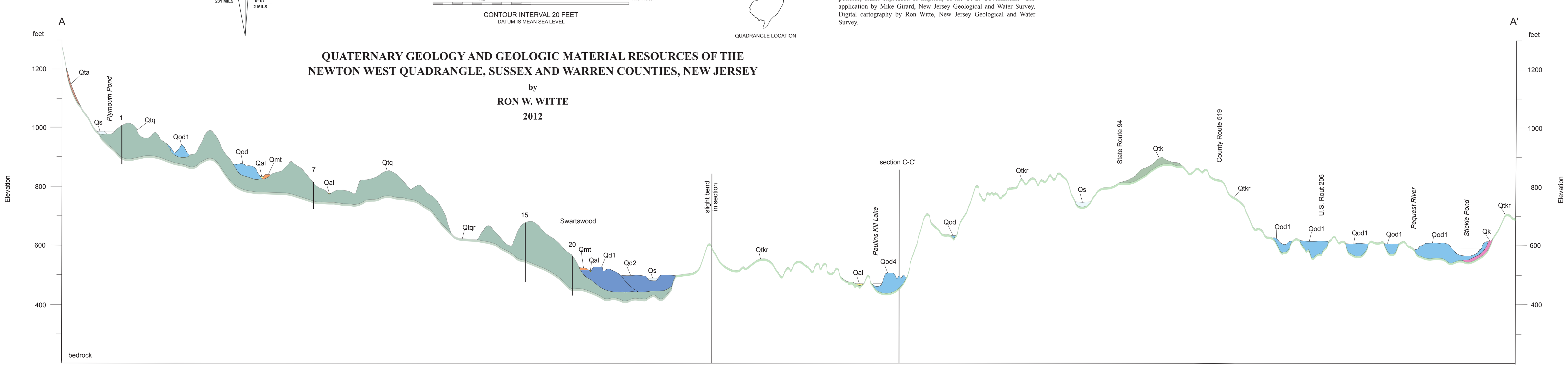
SCALE 1:24000
1 ½ 0 1 mile
1000 0 1000 2000 3000 4000 5000 6000 7000 feet
1 ½ 0 1 kilometer
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

NEW JERSEY
QUADRANGLE LOCATION

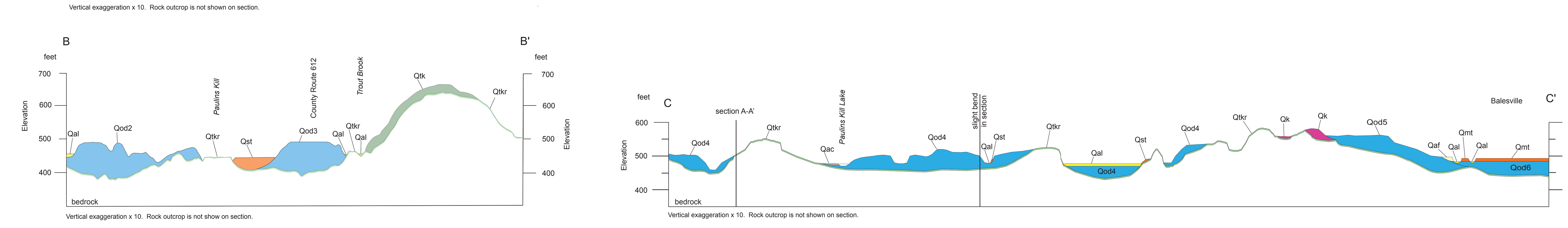
Geology mapped by Ron W. Witte, 1985 - 1991. Research supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 99HQAG0141. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Government. GIS application by Mike Girard, New Jersey Geological and Water Survey. Digital cartography by Ron Witte, New Jersey Geological and Water Survey.

QUATERNARY GEOLOGY AND GEOLOGIC MATERIAL RESOURCES OF THE NEWTON WEST QUADRANGLE, SUSSEX AND WARREN COUNTIES, NEW JERSEY

by
RON W. WITTE
2012



Vertical exaggeration x 10. Rock outcrop is not shown on section.



Vertical exaggeration x 10. Rock outcrop is not shown on section.

Vertical exaggeration x 10. Rock outcrop is not shown on section.

INTRODUCTION

Industrial, commercial, and residential expansion in New Jersey has promoted the increased use of surficial geologic data for 1) land-use planning, 2) identification, management and protection of ground water resources, 3) locating and developing sources of geologic aggregate, and 4) delineation of geologic hazards. Surficial deposits in Newton West quadrangle are lithologically diverse, cover much 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 250 feet (87 m) thick and they form the parent material on which soils form. They are defined by their lithic characteristics, stratigraphic position, and location on the landscape, and further delineated by genetic and morphologic criteria. Geologic history, detailed observations on surficial materials, and list of references are found in the accompanying booklet.

DESCRIPTION OF MAP UNITS

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

Postglacial Deposits

af

Artificial fill (Holocene) -- Rock waste, solid waste, soil, gravel, sand, silt, and manufactured materials put in place by man. As much as 25 feet (8 m) thick. Not shown beneath roads, and railroads where it is less than 10 feet (3 m) thick. Primarily used to raise the land surface, construct earthen dams and sanitary landfills, 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 Paulins Kill, and Pequest River and their tributaries. As much as 25 feet (8 m) thick. Includes planar- to cross-bedded gravel and sand, and cross-bedded and rippled sand in channel deposits, and massive and parallel-laminated fine sand, and silt in flood-plain deposits.

Qaf

Alluvial-fan deposits (Holocene and late Wisconsinan) -- Stratified, moderately to poorly sorted sand, gravel, and silt in fan-shaped deposits. As much as 35 feet (11 m) thick. Includes massive to planar-bedded sand and gravel and minor cross-bedded channel-fill sand. Beds dip as much as 30° toward the trunk valley. Stratified sediment is locally interlayered with poorly sorted, sandy-silty to sandy gravel. Most fans dissected by modern streams.

Qst

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.

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, and in places marl. Accumulated in kettles, shallow postglacial lakes, poorly-drained areas in uplands, hollows in ground and end moraine, and in abandoned channels on flood plains. As much as 25 feet (8 m) thick. Locally interbedded with alluvium and thin colluvium.

Qac

Colluvium and alluvium undifferentiated (Holocene and late Wisconsinan) -- Stratified, thinly 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.

Qta

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

Glacial Deposits

Deposits of Glacial Meltwater Streams

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 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 in glaciofluvial topset beds that are as much as 25 feet (8 m) thick. Overlies and grades into foreset beds that dip 20° to 35° basinward and consist of well- to moderately-sorted, rhythmically-bedded cobble-pebble and pebble gravel and sand. These beds grade downward and outward into ripple cross-laminated and parallel-laminated, sand, silt and pebble gravel that dip less than 20°. Lower foreset beds grade into gently inclined prodelta bottomset beds of rhythmically-bedded, ripple cross-laminated to graded fine sand and silt with minor clay drapes. Qod similar to Qd except deposit laid down in a very narrow lake basin. Fluvial topset beds may have been extensively aggraded and deposit may have once filled the valley from wall to wall. Thickness may be as much as 100 feet (30 m). In places deposits are extensively collapsed indicating their deposition over and against stagnant ice. Sequentially numbered units in the Paulins Kill and Pequest Valleys define successively-younger ice-contact deltas that delineate local ice-retreat positions (see text for a detailed description of the lake's history).

Qlb

Glacial lake-bottom deposits (late Wisconsinan) -- Parallel-laminated, rhythmically-bedded, alternating layers of thin clay and very fine silt, and silt and very fine sand deposited from suspension; and minor cross-laminated silt, and fine sand deposited on the floor of glacial lakes chiefly by subaqueous flows. As much as 100 feet (30 m) thick. Thick deposits lie beneath Qs deposits in Newton Meadows.

Qmt

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

Qk

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

Non-stratified Materials

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

Qtk Qtkr

1) Compact, unstratified, poorly sorted yellowish-brown (10YR 5/4), light yellowish-brown (2.5Y 6/4), light olive-brown (2.5Y 5/4) to grayish-brown (2.5Y 5/2), gray (5Y 5/1) to olive-gray (5Y 5/2) noncalcareous to calcareous silt and sandy silt that typically contains 5 to 15 percent gravel. As much as 100 feet (30 m) thick. Locally overlain by thin, discontinuous, non-compact to slightly compact, poorly sorted, indistinctly layered yellow-brown (10YR 5/6-8), light yellowish-brown (10YR 6/4) sandy silt that contains as much as 30 percent gravel, and minor thin beds of well- to moderately sorted sand, gravel, and silt. Clasts chiefly consist of unweathered slate, siltstone and sandstone, dolomite, limestone, chert, minor quartzite, and quartz-pebble conglomerate. Matrix is a varied mixture of unweathered quartz, rock fragments, and silt; minor constituents include feldspar and clay. Till derived chiefly from slate, graywacke, dolomite, and minor limestone bedrock in Kittatinny Valley. Subscript "r" denotes areas of till generally less than 10 feet thick (3 m) with few to some bedrock outcrops.

Qtq Qtqr

2) Slightly compact to compact, unstratified, poorly sorted yellowish-brown (10YR 5/4), brown (10YR 5/3, 7.5 YR 5/4) to light olive-brown (2.5Y 5/4) and reddish-brown (5YR 4/3) silty sand and sand containing 10 to 20 percent gravel. As much as 50 feet (15 m) thick. Locally overlain by thin, discontinuous, non-compact, poorly sorted and layered, sand and minor silty sand, similar in color to lower till, that contains as much as 35 percent gravel, and minor thin beds of well- to moderately-sorted sand and pebbly sand. Clasts chiefly consist of unweathered quartz-pebble conglomerate, quartzite, red sandstone, and red shale. Matrix is a varied mixture of quartz, rock fragments, silt, minor feldspar, and clay. Till derived chiefly from quartzite, quartz-pebble conglomerate, and red sandstone bedrock on Kittatinny Mountain. Subscript "r" denotes areas of till generally less than 10 feet thick (3 m) with few to some bedrock outcrops.

Qom

Ogdensburg-Culvers Gap moraine (late Wisconsinan) -- Unstratified to poorly stratified sand, gravel, and silt deposited at the active margin of the Kittatinny Valley ice lobe. As much as 80 feet (24 m) thick. Consists of poorly compact stony till, silty-sandy compact till, and minor lenses and layers of water laid sand, gravel, and silt in discontinuous, bouldery, chiefly cross-valley segmented ridges that mark the former glacier margin. Overlies till (Qtk and Qtq) in uplands and locally outwash in valleys.

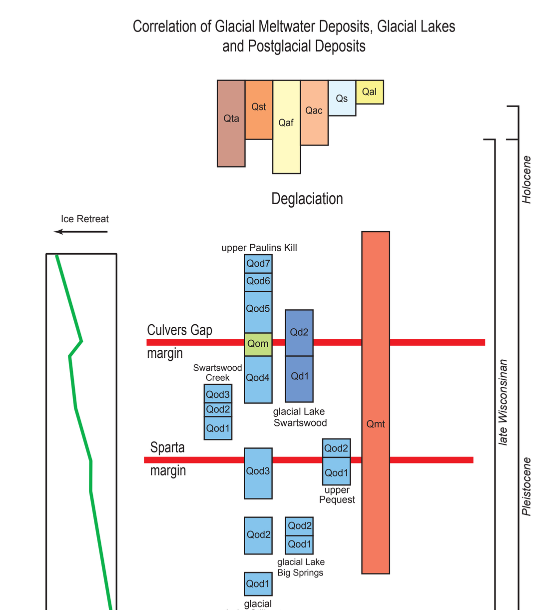
Bedrock

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

rr

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

Correlation of Glacial Meltwater Deposits, Glacial Lakes and Postglacial Deposits



ENVIRONMENTAL CHARACTERISTICS OF GEOLOGIC MATERIALS

Surficial Deposits

Qal, Qac - *Alluvium, Colluvium and Alluvium undifferentiated* - Permeable but too thin to store large quantities of water; drainage is generally poor because of high water table, and accumulation of fines and organic material on flood plains. Easy to excavate. Unsuitable for foundations and septic systems. Very limited use for fill because of high water table. Areas susceptible to frequent flooding.

Qst - *Stream-terrace deposits* - Permeable but generally too thin to store large quantities of water; drainage is good. Easy to excavate. Suitable for foundations; generally unsuitable for septic systems. Maintain shallow- to moderately-cut slopes. Limited use for aggregate and fill. Areas susceptible to infrequent flooding.

Qaf - *Alluvial-fan deposits* - Permeable but too thin to store large quantities of water; drainage may be poor because of seasonally high or perched water table. Easy to excavate. Generally unsuitable for foundations and septic systems. Maintain shallow- to moderately-cut slopes. Limited use for coarse aggregate and fill. May be susceptible to infrequent flooding.

Qs - *Swamp and bog deposits* - Low permeability and very poor drainage; generally underlain by lake-bottom deposits. Easy to excavate, but generally requires artificial drainage at and near the land surface. Not suitable for foundations or septic systems. Peat is mined for use as humus.

Qmt - *Meltwater-terrace deposits* - Highly permeable but too thin to store large quantities of water. Drainage is good and material is easy to excavate except for bouldery lags. Suitable for foundations but generally not for septic systems. Maintain shallow- to moderately-cut slopes. Limited use as aggregate and fill.

Qd, Qod - *Glacial-lake delta deposits* - Highly permeable, may store large volumes of water. Drainage is good and material is easy to excavate. Suitable for foundations but generally not for septic systems. Maintain shallow- to moderately-cut slopes. Excavated extensively for aggregate, road base and fill.

Qlb - *Glacial lake-bottom deposits* - Very low permeability; typically underlie swamp deposits. Drainage is very poor and material is easy to excavate. Not suitable for foundations and septic systems. Maintains moderately- to deeply-cut slopes, although susceptible to slope failure due to liquifaction. Used to make impermeable liners and covers in landfills, and has been used to make bricks.

Qtk, Qtq - *Till* - Generally low permeability. Drainage is poor to fair and material is moderately to highly difficult to excavate. Suitable for foundations; suitability for septic systems is highly variable. Maintains moderate- to deep-cut slopes. Used for fill, and fines may be screened for use as impermeable cover or liner material.

Qom - *Ogdensburg-Culvers Gap moraine* - Low to moderate permeability. Drainage is poor to fair and material is easy to excavate except where bouldery. Suitable for foundations; suitability for septic systems is highly variable. Maintains shallow- to moderately-cut slopes. Minor use for fill.

Qk - *Kame deposits* - Highly permeable, generally too small to store large volumes of water. Drainage is good and material is easy to excavate, although it may contain unsorted, compact to bouldery till. Suitable for foundations, but generally not suited for septic systems. Maintain shallow- to moderately-cut slopes. Minor use as aggregate and fill.

EXPLANATION OF MAP SYMBOLS

Contact, dashed where inferred.

Striation, measurement at tip of arrow.

Drumlin.

Large excavation in sand and gravel pit. Tics point downslope.

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

550 Bedrock surface contour - Shown where rock surface is buried beneath thick glacial sediment. Approximately located, indicates altitude of rock surface in feet above sea level. Contour interval is 50 feet.

Active sand and gravel pit.

Inactive sand and gravel pit.

Quarry.

Inactive quarry.

12 Well or boring, log listed in table 1 (on this plate).

58 Till pebble sample, lithology listed in table 2 (in booklet, p. 12-13).

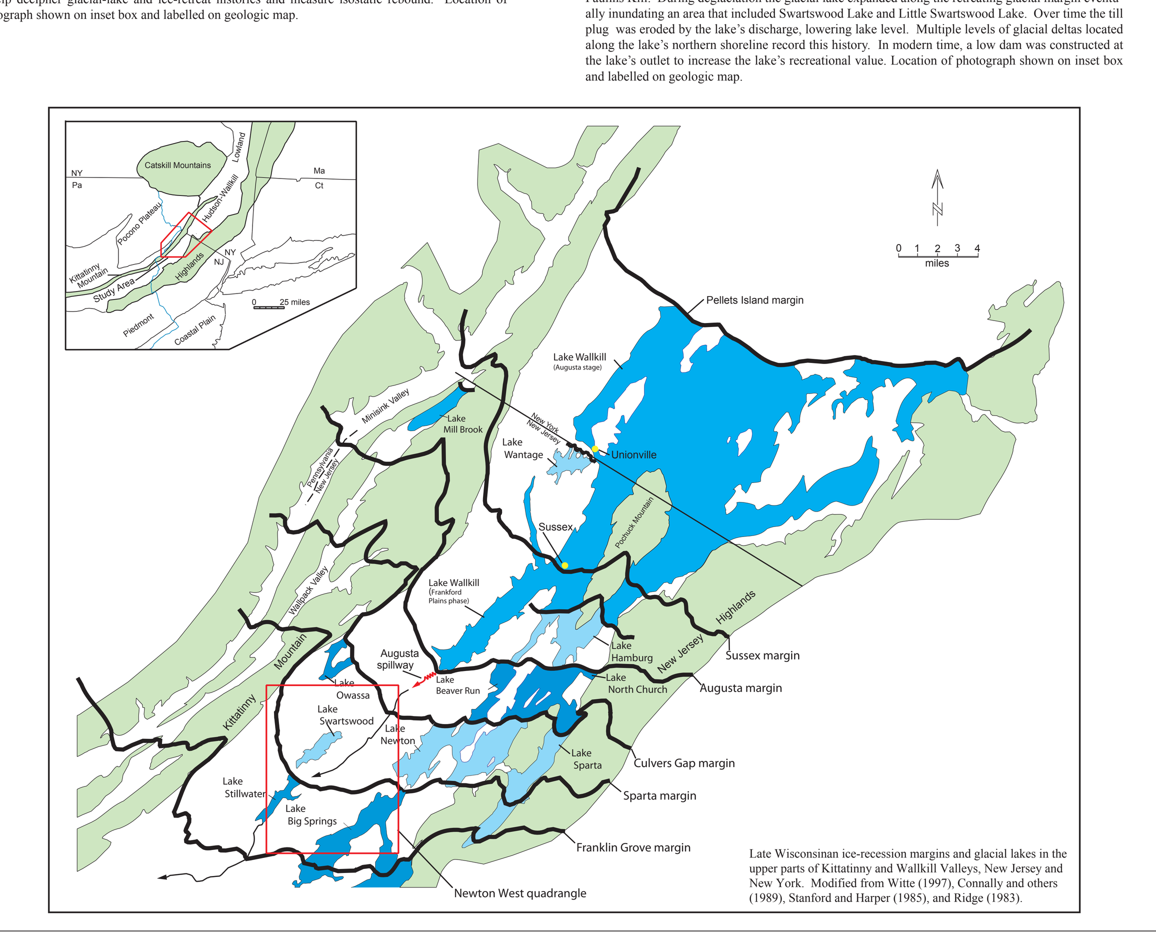
44 Outwash pebble sample, lithology listed in table 2 (in booklet, p. 12-13).

Table 1. Records of water wells and exploration wells in the Newton West quadrangle. NJDEP permit numbers are from the files of the Bureau of Water Allocation and Well Permitting, New Jersey Department of Environmental Protection. Well locations are based on property tax maps or site maps supplied with the NJDEP well record. The letters "S" and "F" indicate that the well location shown on geologic map is accurate to 200 or 500 feet of actual location, respectively.

Well no.	NJDEP Permit	Location	Discharge in gallons per minute	Depth in feet	Driller's log
1	21-670	F	9	0-30 30-50 50-88 88-103 103-130	Clay and hardpan Hardpan Sand and gravel Clay Slate
2	21-2252	F	5	0-40 40-200 200-225	Sandy clay Clay and gravel slate
3	21-837	F	5	0-100 100-208 208-262	Clay and gravel Clay Slate
4	21-166	F	7	0-2 2-22 22-51 51-180 180-190	Clay Hardpan Gravel Clay Slate
5	21-703	F	7	0-15 15-53 53-120 120-147	Clay Clay and gravel Sand and gravel Slate
6	21-990	F	20	0-75 75-109 109-127 127-157 157-180	Clay and hardpan Clay and gravel Clay and sand Clay Slate
7	21-746	F	10	0-30 30-60 60-66 66-85	Clay and hardpan Sand and gravel Clay Slate
8	21-1209	F	5	0-30 30-96 96-155	Clay and gravel Clay and sand Slate
9	21-2859	F	3	0-108 108-260	Sand and gravel slate
10	21-568	F	na	0-20 20-93 93-101 101-106 106-116	Clay and gravel Sand and gravel Gravel Clay Slate
11	21-5055	S	50	0-60 60-90	Clay and boulders Some gravel
12	21-4084	F	3	0-50 50-131 131-166	Clay and gravel Sand and gravel Slate
13	21-4989	F	10	0-30 30-136 136-137 137-148	Overburden Blue shale Soft white and blue shale Blue shale
14	21-5060	F	5	0-140 140-250	Clay and gravel Lime rock
15	21-5622	F	10	0-180 180-200	Clay, gravel, and boulders Limestone
16	21-445	F	10	0-20 20-50 50-120 120-123	Clay Sand and clay Clay Gravel
17	21-5279	F	15	0-98 98-250	Clay and gravel Lime rock
18	21-704	F	10	0-35 35-72 72-82	Clay and hardpan Clay and gravel Limestone
19	21-1077	F	20	0-75 75-96 96-123	Clay and sand Clay Limestone
20	21-1297	F	15	0-105 105-130	Clay and gravel Limestone
21	21-929	F	12	0-80 80-108	Clay, sand, and hardpan Limestone
22	21-1386	F	na	0-52 52-70 70-100	Clay and gravel Clay Limestone
23	21-497	F	2	0-40 40-112	Sand Sand and gravel
24	21-637	F	5	0-53 53-68 68-75	Gravel Sand Gravel
25	21-924	F	20	0-22 22-46 46-61 61-73	Overburden Sand and clay Gravel and clay Limestone
26	21-5319	F	5	0-14 14-800	Overburden Limestone
27	21-4054	S	10	0-76 76-150	Clay and gravel Slate
28	21-4275	F	3	0-140 140-274	Sand, clay, and gravel Slate
29	21-994	S	8	0-51	Gravel
30	22-22596	S	15	0-35 35-175	Clay and gravel Limestone
31	22-21891	S	25	0-8 8-60 60-100	Gravel Sand Limestone
32	22-22313	F	10	0-10 10-355	Sand Limestone
33	22-3984	S	10	0-25 25-150 150-182	Hardpan and broken limestone Limestone Brown sandstone
34	22-21896	S	50	0-17 17-19 19-175	Overburden Boulder Limestone
35	22-18960	F	20	0-25 25-149	Overburden Limestone
36	21-5351	S	20	0-21 21-175	Clay overburden Slate
37	21-564	F	15	0-42	Gravel
38	21-2976	F	30	0-30 30-50 50-100	Clay and gravel Sand and gravel Slate
39	21-1171	F	15	0-34 34-60	Gravel and sand Limestone
40	21-284	F	10	0-11 11-89 89-94	Gravel Sandy loam Gravel
41	21-507	F	2	0-25 25-53 53-160	Gravel Clay Slate
42	21-1804	F	3	0-32 32-215	Clay Slate
43	21-4674	S	10	0-13 13-148	Clay and gravel Limestone
44	21-523	F	20	0-6 6-120 120-126	Gravel Clay Gravel
45	21-855	F	30	0-8 8-48 48-98 98-163 163-170	Gravel Sand and clay Clay and sand Clay Gravel
46	21-2882	F	na	0-10 10-50 50-65 65-75 75-130	Dirt and rock fill Soft silt Fine broken clean gravel Broken shale mixed with some silt Shale

Figure A. Delta topset beds (planar-bedded cobble-pebble gravel) over foreset beds (inclined beds of sand and pebbly sand) in an ice-contact delta, near Myrtle Grove. The horizontal contact between the units represents the former surface of a glacial lake. Reconstructed lake levels are used by geologists to help decipher glacial-lake and ice-retreat histories and measure isostatic rebound. Location of photograph shown on inset box and labelled on geologic map.

Figure B. Swartswood Lake looking northeast from its outlet. It is estimated that glacial lake Swartswood was as much as 30 feet higher than the modern lake. During the Late Wisconsinan glaciation, a thick plug of till at the lake's outlet blocked drainage in this south-draining tributary of the Paulins Kill. During deglaciation the glacial lake expanded along the retreating glacial margin eventually inundating an area that included Swartswood Lake and Little Swartswood Lake. Over time the till plug was eroded by the lake's discharge, lowering lake level. Multiple levels of glacial deltas located along the lake's northern shoreline record this history. In modern time, a low dam was constructed at the lake's outlet to increase the lake's recreational value. Location of photograph shown on inset box and labelled on geologic map.



Late Wisconsinan ice-recession margins and glacial lakes in the upper parts of Kittatinny and Wallkill Valleys, New Jersey and New York. Modified from Witte (1997), Connally and others (1989), Stanford and Harper (1985), and Ridge (1983)

NEW JERSEY GEOLOGICAL AND WATER SURVEY

OPEN-FILE MAP OFM 90

Duck Pond, Swartswood State Park, Sussex County, New Jersey.

QUATERNARY GEOLOGY AND GEOLOGIC MATERIAL RESOURCES OF THE NEWTON WEST QUADRANGLE, SUSSEX AND WARREN COUNTIES, NEW JERSEY

by

Ron W. Witte
New Jersey Geological and Water Survey
OPEN FILE MAP
OFM 90
2012

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

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Ron W. Witte

New Jersey Geological and Water Survey

Introduction

Industrial, commercial, and residential expansion in New Jersey has promoted the increased use of geologic data for land-use planning, identification of aquifers, management and protection of groundwater resources, siting for solid waste disposal, development of aggregate and construction materials, contaminant remediation, and delineation of natural geologic hazards. The Newton West surficial geologic map depicts a diverse assemblage of earth materials on the basis of their physical characteristics, readily distinguishable boundaries, and position on the landscape. Surficial geologic materials in the quadrangle include glacial drift (till and meltwater sediment) deposited during the late Wisconsinan glaciation about 22,000 to 18,000 radiocarbon years ago (yrs. BP), and nonglacial stream sediment, hillslope sediment, and swamp deposits laid down in late glacial and postglacial time. These surficial materials exhibit a wide range of physical characteristics, may be as much as 250 feet thick, and are the parent material on which soils form.

The purpose of this report is to describe these geologic materials, show their distribution, summarize their geologic history, and discuss geologic processes in a way that informs and educates the increasing number of people using geologic maps. Surficial materials were examined in sand and gravel pits, excavations, and banks along streams and roads. Where there were no exposures, a shovel and hand auger were used. Surficial deposits, geologic contacts, and areas of extensive bedrock outcrops were marked on the Newton West 7 1/2-minute topographic map by direct observation in the field, and completed by viewing colored stereographic air photos, scale 1:12,000, on file at the New Jersey Geological and Water Survey, Trenton, New Jersey. Subsurface data were obtained from well records and geologic borings.

Physiographic and Geologic Setting

The Newton West quadrangle is located in the glaciated section of the Appalachian Valley and Ridge physiographic province in Sussex County and Warren County, New Jersey. Most of it lies in Kittatinny Valley except for the northwest corner, which includes Kittatinny Mountain. Kittatinny Valley (fig. 1) is a broad northeast-southwest trending lowland chiefly underlain by limestone, dolomite, slate, shale, siltstone, and sandstone; all range from Cambrian to Ordovician age (fig. 2). It is bordered on the northwest by Kittatinny Mountain, a narrow upland of moderate relief that forms a nearly continuous ridge from the Shawangunk Mountains in New York southwestward through New Jersey into Pennsylvania. Kittatinny Mountain consists of quartz-pebble conglomerate, quartzite, and red sandstone and shale; all of Silurian age. The New Jersey Highlands, part of the Highlands Physiographic Province, borders the valley on the southeast. It is an upland area of moderate to rugged relief underlain by gneiss, granite, and marble of Proterozoic age, except for a few intermontane valleys underlain by sedimentary rock of Lower and Middle Paleozoic age.

Elevations in the quadrangle range from 500-800 feet above sea level in Kittatinny Valley to as much as 1480 feet above sea level on Kittatinny Mountain. Paulins Kill and Pequest River, the principal streams in the quadrangle, flow southwestward toward the Delaware River.

The physiography of the Newton West quadrangle reflects a composite landscape shaped by 1) differential resistance of bedrock to erosion largely during a temperate climate, 2) superposition of streams on northeast trending fold- and thrust-belt structures, 3) dissolution of carbonate rock, and 4) modification by glaciation and periglacial weathering. Rocks more resistant to weathering form areas of higher elevation (fig. 2). Quartzite and quartz-pebble conglomerate make up the mountains, slate, shale, siltstone, and sandstone underlie areas of intermediate elevation, and carbonate rock underlies the lower areas.

Glaciation

The distribution of glacial drift in New Jersey, and its differing degrees of weathering show that continental ice sheets covered the northern part of the state at least three times (fig. 3). Each ice sheet modified the landscape; valleys underlain by weathered rock were deeply scoured, bedrock ridges, hills, and slopes were worn down to more streamlined topographic forms, and preglacial surficial materials were mostly eroded. Material entrained by the ice sheet was either deposited as till or stratified sediment laid down by meltwater streams.

The youngest glacial deposits, laid down during the late Wisconsinan substage, provide the clearest record of glaciation. This most recent ice sheet reached New Jersey about 25,000 yrs. BP. Its farthest advance in most places is marked by a terminal moraine (fig. 3). During deglaciation, the outer part of the ice sheet thinned and its flow, which was largely independent of topography, became much more constrained by the northeast-to-southeast orientation of the large valleys. This changed the geometry of the ice sheet's margin and regional ice flow was directed to the southwest more in line with the topographic trend of Kittatinny Valley. Detailed mapping in Kittatinny Valley by Ridge (1983) and Witte (1988, 1992) showed that deglaciation varied from stagnation-zone retreat (Koteff and Pessl, 1981) to oscillatory retreat of an active ice margin. Accordingly, deglaciation of the Newton West quadrangle was characterized by the systematic northeastward retreat of the Kittatinny Valley ice lobe (fig. 1). This interpretation is based on the distribution of morphosequences (suites of correlative meltwater deposits) and moraines, and correlative relationships between elevations of delta topset-foreset contacts, former glacial-lake-water plains, and lake spillways. During glacial retreat, meltwater sediment was chiefly laid down in glacial lakes (fig. 1) that occupied valleys now drained by the Pequest River, Paulins Kill, and Wallkill River, and to a lesser extent in small upland basins and valleys (Ridge, 1983; Witte, 1988, 1997). These former lake basins were dammed by stratified drift, moraine,

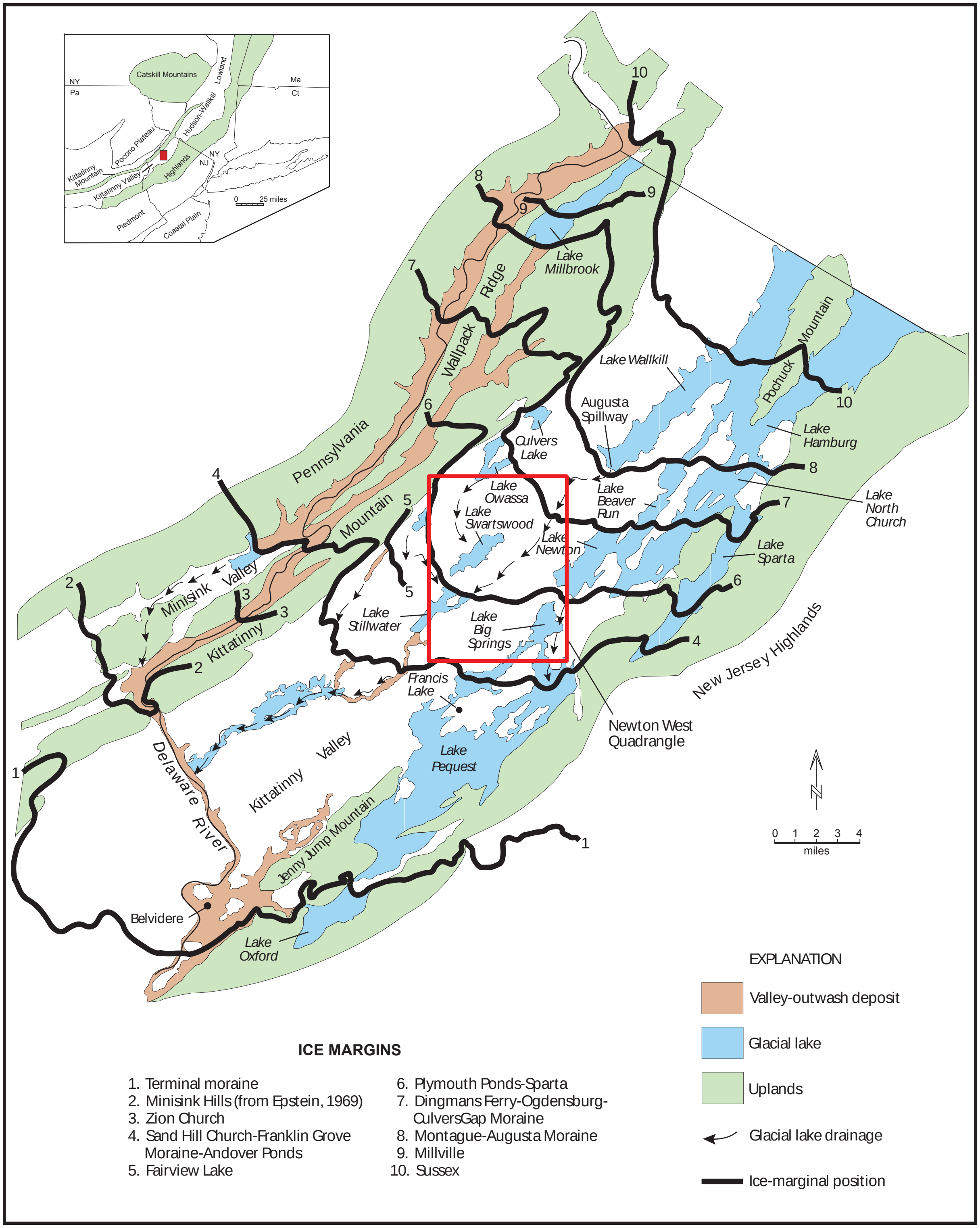

Figure 1. Physiography of Kittatinny Valley and surrounding area, location of the Newton West quadrangle, late Wisconsinan ice margins, large glacial lakes, and extensive valley outwash deposits in northwestern New Jersey and northeastern Pennsylvania. Modified from data by Crowl (1971), Epstein (1969), Minard (1961), Ridge (1983), and Witte (1997).

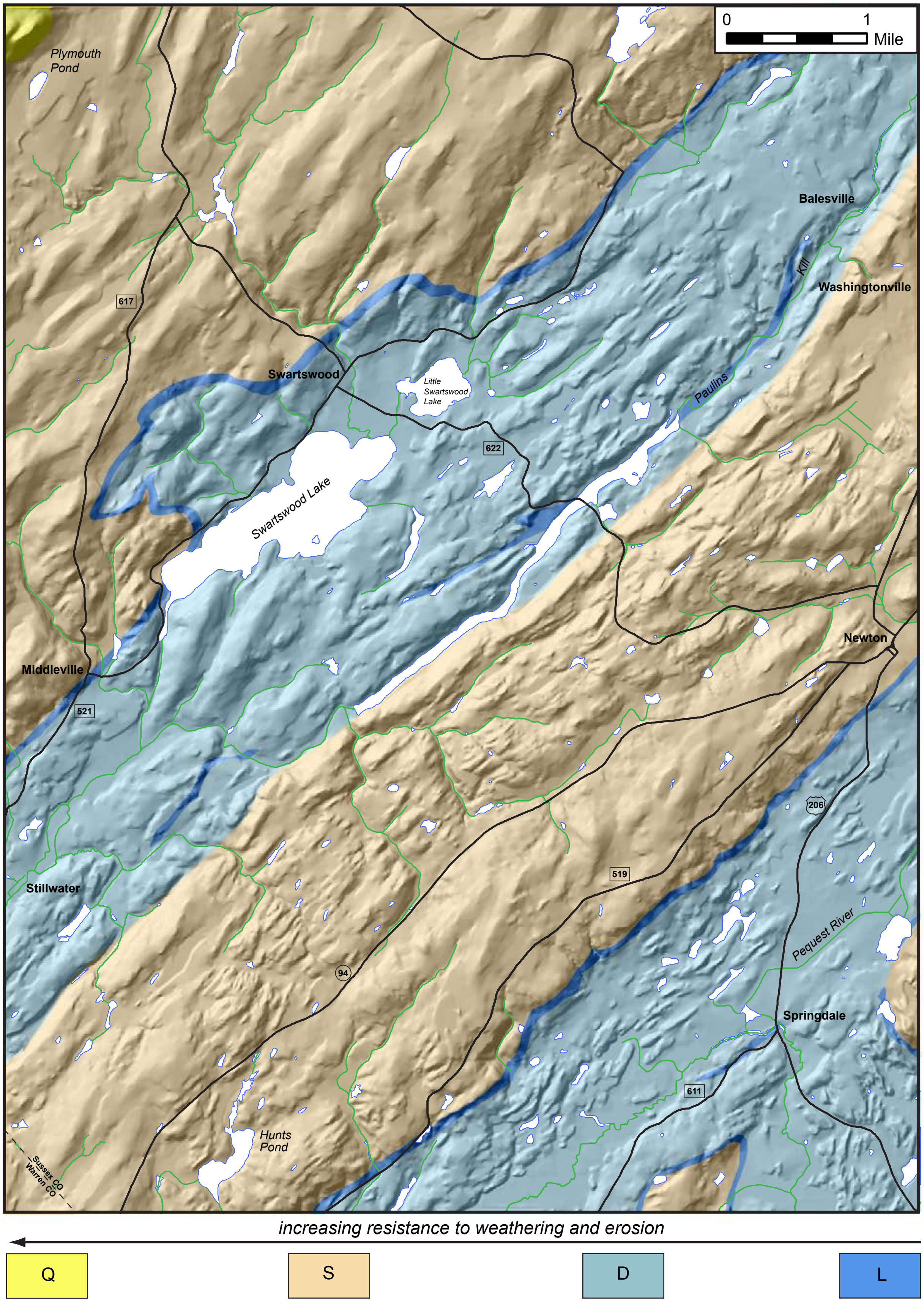

Figure 2. Composite bedrock and shaded-relief map of the Newton West quadrangle. Rocks that are more resistant to weathering and erosion hold up areas of higher elevation. Q, which consists of quartzite and quartz-pebble conglomerate is the most resistant lithotype and forms Kittatinny Mountain in the northwestern part of the quadangle. Key: Q - quartzite and quartz-pebble conglomerate (Shawangunk Formation), S - slate and siltstone (Martinsburg Formation), D - dolomite (Beekmantown Formation, Allentown Dolomite, and Leithsville Formation), and L - limestone (Jacksonburg Formation).
Geology modified from Drake and others (1996).

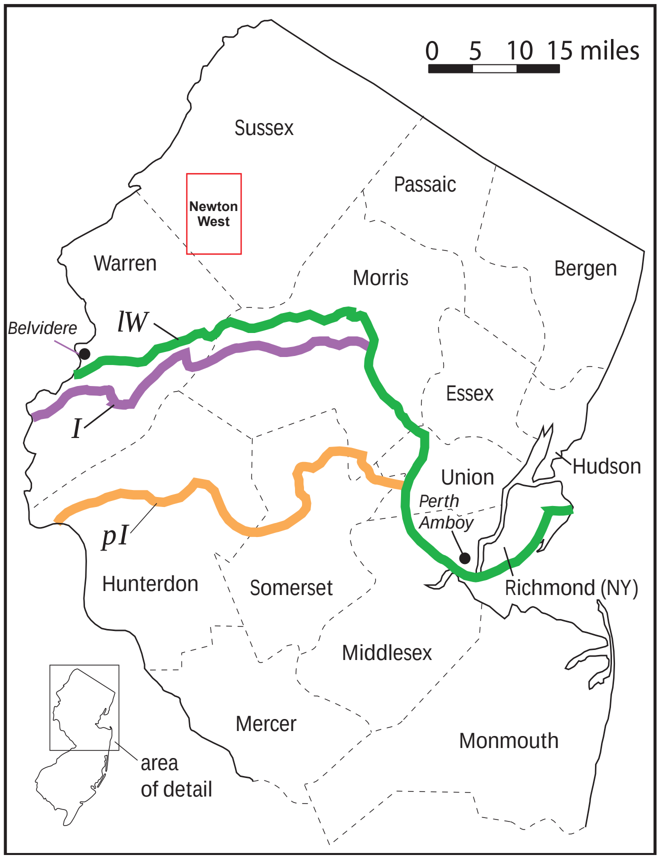

Figure 3. Limits of glaciation in New Jersey and nearby New York (modified from Stone and others, 2002). Key: lW - late Wisconsinan (21,000 years BP), trace generally marks the position of the Terminal Moraine, I - Illinoian (135,000 years BP), and pI - preIllinoian (> 788,000 years BP)

and stagnant blocks of ice, or by the glacier's margin.

In postglacial through modern time, shallow lakes and ponds were slowly filled with decayed vegetation and minor detritus, forming swamps and bogs. Initially, cold and wet conditions, and sparse vegetative cover enhanced erosion of hillslope material by solifluction, soil creep, and slope wash. Gradually, as climatic conditions warmed, vegetation spread, and was succeeded by types that further limited erosion. Rebound of the Earth's crust, delayed at first (Koteff and Larsen, 1989), tilted the land surface to the south.

Previous Investigations

Glacial deposits in Sussex County, New Jersey were discussed by Cook (1877, 1878, 1880) in a series of annual reports to the State Geologist. He included observations on recessional moraines, age of glacial drift, distribution and kinds of drift, and evidence of glacial lakes. A voluminous report by Salisbury (1902) detailed the entire glacial geology of New Jersey region by region. The terminal moraine and all drift north of it were interpreted to be products of a single glaciation of Wisconsinan age. Salisbury recognized kames, kame terraces, deltas and moraines in Wallkill Valley, and although he realized that some of these deposits defined ice-retreat positions, he did not document them within the context of regional deglaciation. Most stratified deposits were thought to have been laid down in crevasses, or in small, short-lived proglacial lakes. Based on the collapsed morphology of the meltwater deposits, their position on the sides of the valley, and exposed bedrock and till on the valley floor, it was thought that stagnant ice had covered large parts of the upper Wallkill Valley and its tributary Papakating Valley during deglaciation.

Fairchild (1912) alluded to probable glacial lakes in Wallkill Valley, and Adams (1934), Connally and Sirkin (1973), Connally and others, (1989), and Stanford and Harper (1985) suggested a single former glacial lake consisting of several stages. The highest and oldest stage, which Adams termed the 500-foot lake, was controlled by a spillway at the head of Papakating Valley near Augusta. The lake's outlet lies at an elevation of 495 feet (151 m) above sea level, and it straddles a drainage divide between Paulins Kill and Papakating Creek. Adams envisioned glacial meltwater in the upper Wallkill Valley, especially in Papakating Valley, flowing through a system of ice-contact lakes, crevasse passageways and supraglacial valleys to the Augusta divide. The open waters of the 500-foot lake only occupied the wide parts of the Wallkill Valley near the New Jersey-New York border. A later stage, which Adams called the 400-foot lake, was created when a drainage divide between Wallkill River and Moodna Creek east of Middletown, New York, was uncovered by melting stagnant ice. Connally and Sirkin (1973) further added that a series of local ice-contact lakes occupied the upper Wallkill Valley before the formation of the 500-foot lake, and that a lower and final stage, called the 230-foot lake, was created when a low divide near Wallkill, New York was uncovered.

Witte (1988, 1992, 1997, and 2000) detailed the late Wisconsinan history of Kittatinny Valley, which includes the upper Wallkill Valley. During retreat of the Kittatinny Valley lobe, proglacial lakes formed in the Paulins Kill, Pequest, and Wallkill River Valleys where drainage became blocked by meltwater sediment, moraine, and ice (fig. 1). The largest lakes are Lake Sparta, Lake Newton, and Lake Beaver Run (Witte, 1991). The history of these glacial lakes, and ice-recessional positions marked by end moraines, and heads-of-outwash of ice-contact deltas, show that the margin of the Kittatinny Valley lobe retreated in a systematic manner to the northeast, chiefly by a process of stagnation-zone retreat. In addition, minor readvances are indicated by the Ogdensburg-Culvers Gap and Augusta moraines where they overlie glacial lake deposits (Witte, 1997). Five ice margins, the Franklin Grove, Sparta, Culvers Gap, Augusta, and Sussex, delineate major recessional positions of the Kittatinny Valley lobe. The strong evidence of systematic deglaciation and the presence of at least two readvances, show that deglaciation by regional or valley-ice lobe stagnation did not occur in the upper part of Kittatinny Valley. Witte (1997, 2008) further refined the history of Lake Wallkill by naming the "500 foot level" the Augusta stage and added a higher pre-Augusta, Frankford Plains phase, based on the elevation of ice-contact deltas in the upper part of Papakating Creek valley.

Glacial Materials

Till

Till is a poorly sorted, nonstratified or very poorly stratified mixture of clay- to boulder-sized material deposited directly by a glacier (fig. 4). It typically covers the underlying preglacial surface. Where it is thin, topography reflects the underlying bedrock surface. Where it is thick, the topographic form of the bedrock surface is subdued, and in many places completely masked. Very thick till forms drumlins, aprons on some north-facing hillslopes, and ground moraine. It may also fill narrow preglacial valleys; especially those that are oriented transverse to glacier flow. Till consists of two types. The first is a compact, massive clayey silt to silty sand containing as much as 20 percent gravel laid down at the base of the glacier. Gravel clasts typically are subrounded, faceted, and striated; their long axes generally parallels the direction of glacial flow. This material was deposited at the glacier's base. The second is a poorly compacted, poorly sorted silty sand or sand containing as much as 35 percent gravel, and minor beds of sorted sand, gravel, and silt. This material was laid down on the substrate as the glacier melted or as it flowed off the glacier's surface. It forms a discontinuous surface cover overlying more compact till.

Each type of till consists of two varieties that reflect different source rocks. The till's lithology was dependent on the south-to-southwest direction of ice flow over narrow, southwest-trending belts of sedimentary source rocks. Because glacial flow at times was southward across varied bedrock, the resulting till in many places differs in lithology from the underlying bedrock. Till in Kittatinny Valley (Qtk) is chiefly derived from slate, graywacke, dolostone, and limestone. On Kittatinny Mountain till (Qtq) is chiefly derived from quartzite, quartz-pebble conglomerate, and red sandstone and shale underlying Kittatinny Mountain. The southward movement of the ice sheet across the mountain, deposited this material in a narrow belt in Kittatinny Valley along the eastern base of Kittatinny Mountain. Because lithologic changes in till sheets are generally gradational, the contacts on the map (pl. 1) represent approximations based on field observations, pebble counts (Witte, 1988), and reconstruction of glacier flow.

Meltwater deposits

Most stratified, glacial sediment was transported by meltwater through glacial tunnels to the glacier margin (Gustavson and Boothroyd, 1987), or by meltwater streams draining ice-free upland areas adjacent to the valley (Evenson and Clinch, 1987; Witte, 1988; Witte and Evenson, 1989). Sources of such sediment include till and debris from beneath the glacier, material entrained in the basal dirty-ice zone and till and reworked outwash in upland areas. Debris carried to the margin of the ice sheet by direct glacial action was minor, except in places where it was deposited in recessional moraines.

Glacial-stream sediments were laid down in topset beds of deltas, valley-outwash, and meltwater-terrace deposits (fig. 4). These sediments include cobbles, pebbles, sand, and minor boulders deposited in stream channels; and sand, silt, and minor pebbly sand in overbank deposits. Sediment laid down near the glacier margin typically includes massive, imbricated, and horizontally-bedded coarse gravel and minor channel-fill deposits of cross-stratified sand. Downstream sand is more abundant, with trough and planar-crossbedded beds more common.

Glacial-lake sediments were laid down in ice-marginal deltas, fluviodeltas, lacustrine-fan and lake-bottom deposits (fig. 4). They are as much as 250 feet thick and were chiefly laid down in glacial Lakes Big Springs, Stillwater, and Swartswood (fig. 1), and small unnamed glacial lakes in Paulins Kill valley and the area northwest of Swarstwood. Deltas typically consist of steeply dipping (25° to 35°), foreset beds of rhythmically-bedded sand and fine gravel. Farther out in the lake basin these sediments grade into less steeply dipping foreset beds of graded, ripple cross-laminated, parallel-laminated sand and fine gravel with minor silt drapes. These in turn grade into gently dipping bottomset beds of ripple cross-laminated, parallel-laminated sand and silt with clay drapes. Overlying the foreset beds are topset beds of coarse to fine gravel and sand. These sediments are horizontally bedded and form a nearly level plain. Typically, deltas consist of individual lobes extending out from the delta front over the lake floor, thinning and widening with distance (Gustavson, and others, 1975). In narrow lake basins and in lake basins subsequently filled with deltaic sediment topset beds may become extensively aggraded, forming a thick wedge that thins down valley.

Unlike deltas, lacustrine-fan deposits lack topset beds; they were deposited at the mouth of glacial tunnels that generally exited the glacier near the floor of the lake basin (fig. 4). Some of these deposits may have also been laid down in cavities beneath the ice sheet. Lacustrine fans also become progressively finer grained basinward. However, near the former tunnel mouth, sediments may be coarser grained and less sorted because of high sedimentation rates and little chance for sorting. If the tunnel remained open and the ice front remained stationary, the fan may have built up to lake level and formed a delta. Lacustrine fans were not identified in the Newton West quadrangle. They presumably exist, buried beneath deltaic deposits.

Lake bottom deposits include 1) glacial varves and rhythmites and 2) subaqueous-flow deposits. Glacial varves consist of stacked annual layers that consist of a lower "summer" layer of chiefly silt that grades upward into a thinner "winter" layer of very fine silt and clay. Most of these materials were deposited from suspension, although the summer layer may contain sand and silt carried by density currents. Each summer and winter couplet represents one year. Rhythmites have similar layering as varves, but the layer couplets are sub annual; their distribution and layering related to changes in sediment source along the delta front rather than seasonal changes that affect meltwater supply. 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,

Planar-bedded gravel and sand (deposit of a glacial meltwater stream).

Basal Till - poorly sorted, nonstratified mix of clay- to boulder-sized material.

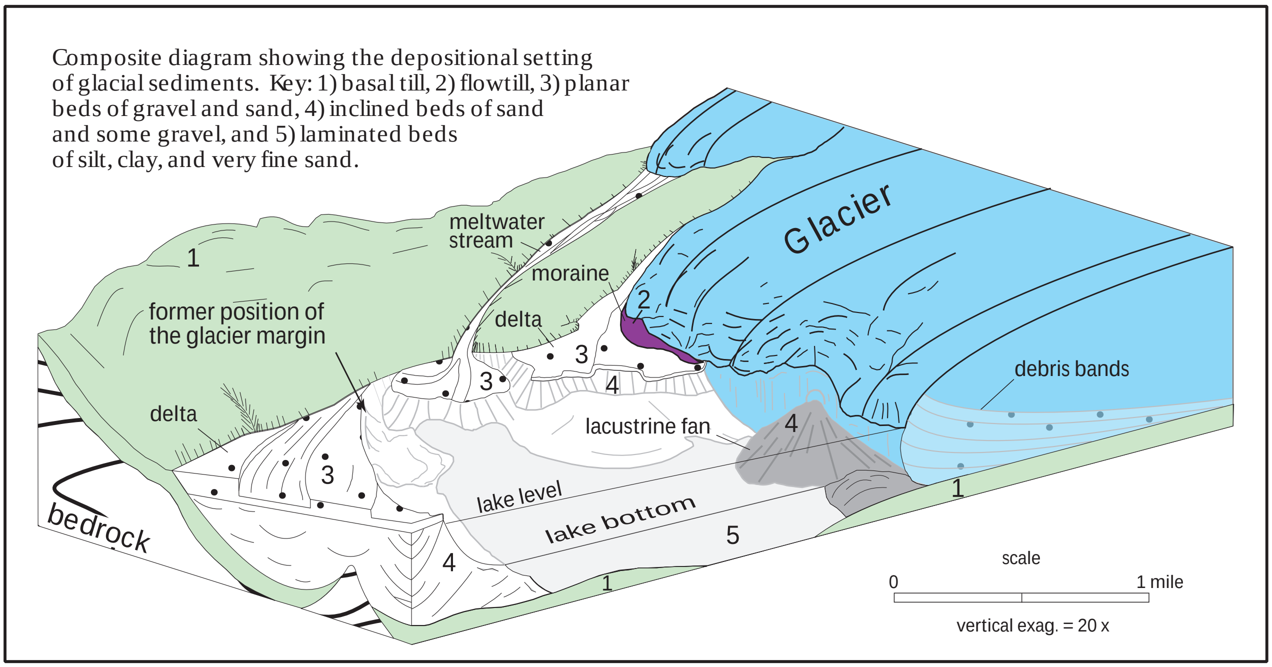

Figure 4. Composite diagram showing the depositional setting of glacial sediments and photographs of common glacial deposits found in the Newton West quadrangle.

and were carried down slope into deeper parts of the lake basin by turbulent gravity flows. Lake-bottom deposits grade laterally into bottomset beds of deltas.

Ice-contact materials

Materials and depositional settings at glacier margins are extremely diverse. Sediments may range from laminated silt and clay laid down in supraglacial meltwater ponds to bouldery flowtill. Most of this debris was released from ice by melting. Subsequent transport and resedimentation by meltwater or mass flows, chiefly caused by melting and collapse of the ice substrate, may have further sorted the sediment. Outwash laid down in contact with, and adjacent to glacier ice, is commonly interlayered with this material.

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 at the glacier's margin.

The Ogdensburg-Culvers Gap moraine (Qom) is the only recessional moraine in the quadrangle. It consists of several small segements that trace an arcuate course from Washingtonville to Lake Kemah. These segments, and correlative ones in Kittatinny Valley (Witte, 1997) define a lobate ice margin (fig. 1). Morainal segments have knob and kettle topography and chiefly consist of stony, poorly compacted till with minor stratified sand, gravel, and silt. In places, morainal deposits lie on top of outwash indicating a readvance of the glacier (Witte, 1997). Composition, morphology, and internal structures show that moraines are polygenetic deposits formed by pushing debris and debris-rich ice at the glacier margin (Witte, 2000). Penecomtemporaneous and postglacial resedimentation of morainal material following melting of buried ice further modified the moraine's morphology and composition (Witte, 2001).

Postglacial Materials

Postglacial deposits include alluvium, stream-terrace and alluvial fan deposits, swamp deposits, and talus. Alluvium is chiefly late Holocene in age and includes both channel and overbank deposits laid down by streams. It forms sheet-like deposits on the floors of modern valleys. The sediment is of highly variable composition, chiefly derived from local surficial materials. Channels, channel scarps and levees are commonly preserved on the flood plains bordering the larger streams. Alluvium lies on the floor of all modern stream valleys. In narrow valleys and drainage heads it may be interlayered with colluvium.

Stream-terrace deposits include both channel and flood-plain sediment. They lie five to ten feet above the modern (historic) flood plain and below the level of meltwater-terrace deposits. They are of highly varied composition, and are largely derived from reworked glacial outwash. Channels, channel scarps and minor levees are preserved on some terraces. Based on radiocarbon dates (McNett and others, 1977) and topographic position, these deposits are late Wisconsinan to late Holocene age.

Only a few alluvial-fan deposits are in the quadrangle. They form fan-shaped deposits near the base of hillslopes at the mouths of gullies, ravines, and tributary valleys. Their sediment is of highly varied composition, derived chiefly from local surficial sediment, and laid down by streams that emerge from adjacent uplands. The surface of most alluvial fans is entrenched by modern drainage. This suggests that their formation is cyclic, influenced chiefly by climate and its effects on weathering, sediment supply, and amount and type of hillslope vegetation.

Swamp and bog deposits are numerous. They formed in scoured bedrock basins, and in kettles that previously contained shallow lakes or ponds, in glacial lakes that persisted into the Holocene and in abandoned stream channels on alluvial plains. These deposits consist of peat, muck, marl, and minor detritus. Peat is largely the remains of plant material, which grew in shallow bodies of water and upon expiration accumulated on the floor of the watery basin. Cotter (1983) showed that climatic conditions were not favorable for subaquatic plants until the start of the Holocene. In Kittatinny Valley, peat is largely of the reed and sedge type and in many places where the local bedrock is limestone or dolostone, it is typically underlain by calcareous marl. Muck is a mass of finely-divided organic matter, having no resemblance to the original plant remains. In addition it contains silt and clay washed in from adjacent soils (Waksman, 1942).

Talus is an apron of rock rubble that collects at the base of bedrock cliffs, and below areas of extensive rock outcrop on very steep slopes. It consists chiefly of angular boulders of various sizes that have been loosened by the effects of frost heave and transported downslope by rock fall and later creep. Thick talus lies below the southeast-facing rock escarpment of Kittatinny Mountain where it forms a thick apron of quartzite and quartz-pebble conglomerate boulders.

Style and Timing of Deglaciation

The deglacial 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), Stone and others (2002), and Witte (1997, 2000) showed that the margin of the Kittatinny Valley and Minisink Valley lobes retreated in a systematic manner with minimal stagnation.

Five major ice-recessional positions have been recognized in the upper part of Kittatinny Valley. They are the Franklin Grove, Sparta, Culvers Gap, Augusta, and Sussex margins (fig. 1). Each position is traceable across the valley; their courses marked by end moraines and ice-contact deltas. Numerous minor recessional positions have been delineated in Kittatinny Valley by Ridge (1983), and Witte (1988, 1991, 2008). These positions are generally marked by ice-contact deltas and they provide additional evidence that deglaciation was systematic and chiefly characterized by stagnation-zone retreat. These minor ice-recessional margins are untraceable across Kittatinny Valley and are not discussed within the regional framework of deglaciation presented here.

The Franklin Grove margin delineates the first major ice-retreat position that is traceable across Kittatinny Valley. It is marked by an end moraine and promorainal outwash in Paulins Kill Valley. To the east, correlative ice-contact deltas were laid down in Lake Pequest and the initial phase of Lake Big Springs. Retreat of the ice margin from the Franklin Grove position was followed by the formation of several proglacial lakes that expanded northward with the retreat of the ice lobe. These are Lakes Stillwater, Big Springs, and the initial phase of Lake Sparta. Lake Stillwater was dammed downstream by slightly older outwash that had filled a narrow part of the Paulins Kill Valley. Similarly, Lake Big Springs was dammed by outwash previously laid down in narrow valleys in the northern part of the Lake Pequest basin, and Lake Sparta formed in the north-draining Wallkill Valley. The Sparta margin delineates a second major ice-recessional position and it is delineated by large ice-contact deltas laid down in the aforementioned lakes.

Retreat of the ice lobe to the Culvers Gap margin was marked by the northward expansion of Lake Sparta, and the formation of Lakes Newton, Swartswood, and Owassa. The level of Lake Newton was initially controlled by a sluiceway cut in deltas laid down in Lake Big Springs. Just prior to the time the Ogdensburg-Culvers Gap moraine was deposited, erosion had lowered the outlet to a position controlled by a bedrock floor (Witte 1988). Lakes Swartswood and Owassa were dammed by till at the south ends of their respective lake basins.

In Kittatinny Valley, the Culvers Gap margin is associated with ice-contact deltas that both predate and postdate the Ogdensburg-Culvers Gap moraine (Witte 1997). Initially, the deltas were laid down in proglacial lakes that occupied parts of the Wallkill River and Paulins Kill Valleys. Most of these deltas are large, presumably indicating that the stagnant glacier margin remained in the same place for a lengthy period. During a minor readvance of the Kittatinny Valley lobe, the glacier overran parts of these deltas and formed a moraine. Records of wells in Paulins Kill and Wallkill River Valleys (Witte 1997) show that morainal deposits (till) overlie outwash. This shows that the Kittatinny Valley lobe readvanced and overrode slightly older outwash. Ice-contact deltas and lacustrine fans laid down on the north side of the moraine mark local, slightly younger ice-retreat positions. These deltaic and morainal deposits had been mapped previously as kame moraine (Spencer and others, 1908; Herpers, 1961). In Minisink Valley, the Culvers Gap margin is also delineated by the Dingmans Ferry moraine (fig. 1), along with the heads-of-outwash of large valley-train deposits in both the Flat Brook and Delaware River valleys (Witte, 1997).

Glacial valley-fill stratigraphy

The areal extent and subsurface distribution of glacial meltwater deposits were constrained by lake-basin geometries, elevation of lake outlets, location of meltwater feeder streams, and rate of ice retreat. In the Newton West quadrangle, most meltwater deposits were laid down in proglacial lakes that formed in Pequest and Paulins Kill Valleys, in front of the receding glacier margin. These glacial lakes were small, narrow, and less than 150 feet deep. Their basin geometry was controlled by topography, elevation of the lake, and location of the glacier's margin. Most of the glacial lakes were held in carbonate floored valleys where glacially-scoured karst formed a very irregular basin floor and lake shorelines. Lake outlets were over glacial outwash and moraine in valleys or over rock-floored divides.

Meltwater exited the glacier through subglacial tunnels or flowed along channels along the glacier's margin. If the tunnel emptied directly in the lake, meltwater sediment eroded from till and ice-entrained debris at the glacier's base would form a lacustrine fan at the tunnel's mouth. Over time, the fan may build up to lake level forming a delta/fan. Where streams entered the lake along marginal channels a delta would form and grow quickly basinward, the delta plain becoming a platform to carry coarse sediment farther out in the lake basin.

Glacial lake deposits consist of a very diverse assemblage of sediments. These include glacial varves (laminated clay and silt), deltaic bottomsets (prodelta) of silt and sand, deltaic foresets of sand and gravel, and deltaic topsets of gravel and sand. Sorting of sediment is related to the carrying capacity of the meltwater stream. Meltwater streams entering a lake basin quickly drop their coarse clastic load. Finer material (fine sand, silt, and clay) is carried basinward largely by density currents (underflows). Sorting also occurs vertically as the delta builds outward into the lake covering finer materials previously deposited on the lake floor. Retreat of the glacier margin will also change the location of meltwater-feeder streams where they enter the lake basin, effectively shifting the deposition of coarser materials northward in the basin. If ice-retreat positions are close and the lake basin narrow, a sequence of overlapping deltas/lacustrine fans will be laid down in the lake forming a complex three-dimensional stratigraphy.

Meltwater deposits in the Newton West quadrangle occur largely in two valley-fill settings. The first includes deposits laid down in lake basins that were not filled completely with glaciolacustrine sediment (fig. 4). Typically, these basins were large and at least 100 feet deep. Deltas and lacustrine-fan deposits are generally separated by extensive areas of lake-bottom sediment, and a large part of the basin is covered by the lake-bottom plain. Glacial Lake Big Springs and the small lake basin near Washingtonville illustrate this setting. The second setting includes lake basins that were nearly or completely filled with glaciolacustrine sediment. These basins are small and/or narrow, and topset beds may have formed a thick clastic wedge as deposition in the basin became largely dominated by glaciofluvial sedimentation. Deltas and lacustrine-fan deposits commonly coalesce, and delta plains commonly form the floor of an entire lake basin. Lacustrine-fan deposits may also lie beneath younger deltaic and lake-bottom deposits. Typically these fans overlie till or bedrock at the bottom of the former lake basin and well records show that they do not form continuous sheets across the basin floor. In many places, the delta plain is collapsed and is pockmarked by kettles, indicating deposition over stagnant ice. Paulins Kill Valley and the upper part of the Pequest Valley illustrate this setting.

Postglacial History

The landscape immediately after deglaciation was a wet, cold, windswept wilderness. The harsh climate and sparse vegetative cover enhanced erosion of hillslope material by solifluction, soil creep, and slope wash. Mechanical disintegration of rock outcrops by frost shattering also provided additional sediment. This material forms extensive aprons of talus at the base of cliffs and some steep rocky slopes. A few small boulder fields were formed where boulders were transported downslope by creep, and accumulated at the base of hillslopes and in first-order drainage basins. These fields and other boulder concentrations formed by glacial transport and meltwater erosion, were further modified by freeze and thaw; their stones reoriented to form crudely-shaped stone circles. Gradually as the climate warmed, vegetation spread and was succeeded by types that further limited erosion.

The many swamps and poorly drained areas in Kittatinny Valley 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 poorly-drained areas that made up the glacial landscape. Throughout the Holocene the many shallow lakes and ponds left over from the ice age slowly filled with sediment and 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 became filled with marl, which is calcium carbonate precipitated by aquatic plants, chiefly chara (Waksman and others, 1943). In most ponds marl underlies peat. However, interlayering also occurs along pond edges and where sedimentary peat has collected in the deeper parts of the pond.

Swamps and bogs contain sedimentary and organic records that can be used to reconstruct past climates. Because these materials were laid down layer upon layer, they preserve a climatic record from the time of deglaciation to the present. The identification of pollen, and radiocarbon dating of plant and animal material retrieved from swamps by coring provides information on regional and local changes in vegetation, which can be used to determine the past climate. Several studies on bogs and swamps in northwestern New Jersey and northeastern Pennsylvania (Cotter, 1983) have established a dated pollen stratigraphy that goes back nearly to the onset of deglaciation. Paleoenvironments, interpreted from pollen analysis, show a transition from tundra with sparse vegetation, to a mix of open land populated by shrubs and grasses with scattered patches of spruce. From about 14,250 to 11,250 yrs. BP the regional pollen record shows the transition to a dense boreal forest of spruce and fir. This was followed by a period (11,250 and 9,700 yrs. BP) where pine became the dominant forest component. These changes in pollen taxa and percentages record the continued warming during the latter part of the Pleistocene and the transition from the ice age to a temperate climate. About 9,400 yrs. BP, oak started to displace the conifers, marking the transition from a boreal forest to a mixed-hardwood temperate forest.

Buried Bedrock Topography

Contours of the buried bedrock surface (geologic map, pl. 1) are based on well records (table 1, pl. 1), unpublished New Jersey Geological Survey information, and distribution of bedrock outcrops. Contours show that most buried valleys trend northeast to southwest, paralleling bedrock formations and their fold axes. In many places, the bedrock floor is deeply scoured, especially in places where the valley floor is underlain by dolomite.

Pebble Composition of Glacial Materials

The composition of aggregate material was determined because certain rocks are susceptible to deterioration by freeze-thaw, sorption, alkali-silica, and alkali-dolomite reactions (Dunn, 1983). Abrasion resistance and crushing strength are also chiefly related to composition.

Studies in Connecticut (Smith, 1989) indicate that 95 percent of the pebbles in late Wisconsinan till were transported less than 10 kilometers from their source. Heavy minerals in the sand-sized fraction had been transported 5 to 20 kilometers. Provenance studies by Ridge (1983) and Witte (1988) showed that regional ice flow in Kittatinny Valley during the glacial maximum was southward, obliquely across the southwest trend of the valley. During deglaciation, thinning near the margin of the ice sheet caused flow to become aligned with the southwestward topographic grain of Kittatinny Valley.

The composition of the pebble fraction of till (table 2) supports the above interpretation. Quartzite, quartz-pebble conglomerate, red sandstone and red shale, all derived from Kittatinny Mountain, are in most of the till samples. These rocks decrease in abundance with distance from Kittatinny Mountain. Most of these pebbles had been glacially transported southward over Kittatinny Mountain. The remaining till pebbles include limestone, dolomite, slate and graywacke, all from Kittatinny Valley. Their distribution indicates a more southwesterly ice flow down Kittatinny Valley, when during deglaciation, glacial flow became more constrained by this area's southwest topographic grain.

The pebbles in meltwater deposits (table 2) consist of a varied mix of debris from upland and valley sources. Gravel in Paulins Kill Valley chiefly consists of shale, siltstone, sandstone, limestone and dolomite, and lesser quartzite, quartz-pebble conglomerate, and red sandstone. Deposits in the upper reaches of Swartswood Brook consist of quartzite, and quartz-pebble conglomerate and lesser red sandstone, shale, and graywacke. Provenance studies in Kittatinny Valley show that meltwater sediment was chiefly derived from reworked till beneath the glacier or from debris in the basal dirty-ice zone, and material derived from adjacent ice- and non ice-covered uplands (Witte, 1988; Witte and Evenson, 1989).

Surficial Economic Resources

The most important natural resource in the quadrangle, other than groundwater, is sand and gravel. Most of this material lies in ice-contact deltas (Qod, Qd). This material is used as aggregate, subgrade fill, select fill, surface coverings, and decorative stone. All sand and gravel pits and quarries are shown on Plate 1. Till may be used for fill and subgrade material, and large cobbles and small boulders may supply building stone. Peat and marl from swamp deposits (Qs) may be used as a soil conditioner.

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Table 2. Pebble composition in percent of glacial sediment in Newton West quadrangle. Data based on 100 to 125 pebbles, one to three inches in diameter, collected at each sample site. List of abbreviations: pc - gneiss and granite, cb - dolomite and limestone, sh - shale and slate, qc - quartzite and quartz-pebble conlomerate, rs - red sandstone, and ss - gray sandstone. Total sum percentage of samples not equal to 100 is due to rounding errors.

sample	surficial material	pc	cb	sh	qc	rs	ss
1	fluvial gravel			18	65	17	
2	fluvial gravel			20	64	12	4
3	lacustrine gravel			23	66	7	3
4	till-lodgement		1	48	20	23	8
5	till			41	50	8	1
6	till			32	59	6	3
7	till			26	55	12	7
8	deltaic forsets			18	74	6	3
9	till			25	67	7	1
10	gravel			26	66	5	3
11	till			36	63		1
12	lacustrine gravel		1	42	47	6	5
13	till			36	59	2	3
14	till-lodgement		7	67	19	6	1
15	till		1	64	31		3
16	till		2	80	8	7	3
17	lacustrine gravel			86	10		4
18	till-debris flow		1	78	13	1	7
19	till - debris flow	1	1	85	9	1	3
20	till-debris flow	2	1	73	16	2	6
21	fluvial gravel		16	65	15	1	3
22	fluvial gravel	1	3	73	15	2	6
23	proximal gravel			75	18	3	4
24	gravel			81	12	3	5
25	gravel			81	13	4	2
26	gravel			74	23	1	3
27	proximal gravel			71	24		5
28	fluvial gravel		1	83	10		7
29	fluvial gravel		1	85	12		2
30	lacustrine gravel		4	89	5		2
31	fluvial gravel			88	10		3
32	fluvial gravel		1	95	4		
33	fluvial gravel			54	37	4	5
34	fluvial gravel			93	4	1	3
35	fluvial gravel		5	91	2		2
36	lacustrine gravel		44	44	10		2
37	lacustrine gravel		84	14	1		2
38	till		3	78	16	1	2
39	gravel		3	89	7		1
40	proximal gravel		86	13			1
41	fluvial gravel		4	91	5	1	

sample	surficial material	pc	cb	sh	qc	rs	ss
42	till		63	13	20	3	2
43	fluvial gravel	1		78	13	2	6
44	fluvial gravel		1	84	9		6
45	gravel		38	49	10		3
46	till	1	33	30	30	3	3
47	fluvial gravel		1	92	4		3
48	till-debris flow		3	80	13	1	4
49	till-lodgement		7	64	24	1	4
50	lacustrine gravel			98	2		
51	deltaic forsets			79	15	1	5
52	till			90	7		3
53	gravel			96	1		3
54	fluvial gravel		6	86	6		2
55	proximal gravel		20	75	3		3
56	lacustrine gravel	1	7	85	7		
57	lacustrine gravel		36	62			2
58	till		4	92	2		2

Geologic Time Scale

Years Ago	Eon	Era	Period	Life and Environment
0 to 2 million	PHANEREOZOIC *(Evident Life)*	CENOZOIC *(Recent Life)*	QUATERNARY	*First humans evolve and coexist with mammouths, mastodons, saber-toothed cats, and giant sloths.*
2 to 67 million			TERTIARY	*First large mammals appear and dominate the period. Primitive whales, rodents, primates followed by pigs, cats, horses, dogs, bears and the first hominids. Grasses and modern birds also appear.*
67 to 140 million		MESOZOIC *(Medieval Life)*	CRETACEOUS	*Heyday of dinosaurs at the start of the Cretaceous followed by their extinction (with many plants and animals) at the end of the period from volcanism and/or asteriod impact. First flowering plants.*
140 to 208 million			JURASSIC	*Earliest birds appear. Giant dinosaurs (Sauropods) flourish. Plants include ferns, cycads and gingkos.*
208 to 250 million			TRIASSIC	*Age of dinosaurs begins. First mammals appear. Mollusks are the dominant invertebrate. Many reptiles (turtles and ichthyosaurs).*
250 to 290 million		PALEOZOIC *(Ancient Life)*	PERMIAN	*Age of amphibians. Supercontinent known as Pangaea forms. Greatest mass extinction ever at end of period. Trilobites go extinct.*
290 to 365 million			PENNSYLVANIAN AND MISSISSIPPIAN (Carboniferous)	*Widespread coal swamps. Large primitive trees. First winged insects and reptiles. Many ferns. Amphibians common.*
365 to 405 million			DEVONIAN	*Age of Fishes. Fish and land plants become abundant and diverse. First shark. Earliest amphibians, ferns and mosses.*
405 to 430 million			SILURIAN	*First insects, jawed fish and vascular plants on land (plants with water-conducting tissue).*
430 to 500 million			ORDOVICIAN	*First corals. Primitive fishes, seaweed and fungi. First non-vascular land plants (like mosses).*
500 to 570 million			CAMBRIAN	*Age of Trilobites. The Cambrian Explosion of life occurs. All Phyla that exist today develop. First vertebrates and earliest primitive fish. First shells appear on shellfish, mollusks, echinoderms, brachiopods, trilobites.*
570 to 2500 million	PROTEROZOIC (Early Life)	PRECAMBRIAN		*First soft-bodied invertebrates and colonial algae. Oxygen build-up: Mid Proterozoic.*
2500 to 3800 million	ARCHEAN (Ancient)			*Life appears. First bacteria and blue-green algae begins to free oxygen to atmosphere.*
3800 to 4600 million	PRE-ARCHEAN			*Earth molten.*

Dark shading (bedrock) and light shading (surficial materials) indicate that geologic deposits from these time periods are present in the Newton West quadrangle.