DEPARTMENT OF ENVIRONMENTAL PROTECTION AND ENERGY
DIVISION OF SCIENCE AND RESEARCH
NEW JERSEY GEOLOGICAL SURVEY

INTRODUCTION

The Wanaque quadrangle is located in north-central New Jersey and includes parts of Morris, Passaic, and Bergen Counties. Surficial deposits in the quadrangle include glacial deposits of late Wisconsinan age and postglacial deposits. The glacial deposits include till, which occurs in drumlins and as a discontinuous veneer draping bedrock uplands; and stratified sand, gravel, silt, and clay partially filling valleys. The stratified glacial deposits were deposited in glacial lakes and outwash sheets and are as much as 180 feet thick. The till may be as much as 200 feet thick in drumlins. Postglacial deposits overlie the glacial deposits in places and include swamp and marsh sediment, alluvium, and alluvial fan deposits. They are generally less than 25 feet thick.

PREGLACIAL DRAINAGE

Preglacial drainage in the Wanaque quadrangle generally followed the routes of the present drainage. However, two major dislocations resulting from the deposition of stratified sediment in valleys are identified. In the Wanaque Valley south of Wanaque the axis of the preglacial valley, which has been deepened by glacial erosion, underlies the valley now occupied by Posts Brook while the present Wanaque flows in the more narrow valley to the east now occupied by Lake Inez. The second dislocation is in Pompton Lakes, where the preglacial Ramapo Valley, also deepened by glacial erosion, continues southwestward from Pompton Lakes to join the Wanaque, while the present Ramapo River flows southerly through a gap in Packanack Mountain in the Pompton Plains quadrangle.

GLACIAL ADVANCE

The orientation of drumlins and striations on uplands indicates that late Wisconsinan ice flowed to the south and southeast as it advanced across the quadrangle. This flow direction is also indicated by the location of plucked bedrock outcrops, which generally occur on south- or southeast-facing slopes; and polished and abraded bedrock outcrops, which generally occur on north- and northwest-facing slopes. Additionally, till (Qt) is generally thicker and more continuous on northwest-facing slopes, suggesting lodging of till during advance of ice to the south and southeast. One exception to this ice-flow direction is in the southeastern corner of the quadrangle, east of the Ramapo Mountains. Here, striations and landforms in areas adjacent to the quadrangle indicate that advancing ice was moving to the southwest. Ice in this part of the quadrangle was in the fringe of a major southwest-flowing lobe in the Newark Basin lowlands, which lie east and south of the Ramapo Valley.

The distribution of pebbles in till corroborates these ice-flow directions. Lithologies of pebbles in till were counted at 20 sites in the quadrangle (table 2). Till north and west of the Ramapo Valley contains a mix of gneiss pebbles derived from local bedrock, and gray shale and sandstone, some purple quartzite and conglomerate, and a few dolomite and chert pebbles. The shale, sandstone, quartzite, conglomerate, dolomite, and chert were transported southerly and southeasterly from the Green Pond outlier, a belt of Paleozoic rock to the northwest of the quadrangle, and, to a lesser extent, from the Wallkill Valley farther to the northwest. Scattered erratic boulders of dolomite, indicated by a special symbol on the map where observed, also indicate southerly to southeasterly transport. Anomalously high percentages of gray shale and sandstone at two places (sites 23 and 26) are in till that may have been deposited by melting of upper parts of the glacier containing far-travelled clasts. At site 23 this till overlies till with a 98-percent gneiss-pebble content. The predominance of local clasts in this till indicates that it was deposited at the base of the glacier. Till east and south of the Ramapo Valley contains significant percentages of red sandstone and conglomerate, and some basalt, from the Newark Basin. These rock types are absent in till north and west of the Ramapo Valley, indicating that ice did not flow westward from the Newark Basin lowlands.

RECESSIONAL DEPOSITS

Late Wisconsinan ice advanced to the Terminal Moraine, approximately 12 miles southeast of Butler. Retreat of ice from the Terminal Moraine began approximately 20,000 years ago (Cotter and others, 1986) and was accompanied by a reorientation of ice flow to the southwest, parallel to the regional topographic grain. This ice-flow direction is recorded by the northwest-southeast orientation of recessional ice margins reconstructed from the positions and elevations of stratified deposits. The positions of these recessional ice margins and the extent of their associated recessional deposits are shown on figure 1. The reorientation may have been the result of thinning of ice and consequent enhanced topographic control of ice flow.

As the ice front receded northward across the quadrangle, stratified sand, gravel, and silt were deposited in glacial lakes and fluvial plains. Glacial lakes formed where the retreating ice front blocked north-draining valleys or where open drainage down valleys was blocked by ice or by previously-deposited glacial sediment. Stratified sediment deposited in glacial lakes includes deltaic and lacustrine-fan sand and gravel deposited at the receding ice margin; and lake-bottom fine sand, silt, and minor clay which settled onto the lake floor away from the ice margin. These units are included in either the "Upland Lacustrine and Ice-Contact Deposits" or the "Fluvial and Fluvial-Lacustrine Deposits" groups in the description of map units.

Fluvial plains were deposited from successive recessional ice-margin positions in valleys where drainage was not blocked or where lakes were either filled with sediment, drained when sediment dams were eroded, or drained when ice dams melted or collapsed. Fluvial deposits include pebbly sand to boulder gravel and in places overlie deltaic and lake-bottom sand at depth. These units are grouped as "Fluvial and Fluvial-Lacustrine Deposits" in the description of map units.

Small, short-lived glacial lakes dammed by the retreating ice in north-draining valleys on uplands also contain deltaic sand and gravel and, in places, thick, sandy, bouldery diamict that may be either flow deposits from the glacier surface or collapsed lacustrine deposits. These units are grouped as "Upland Lacustrine and Ice-Contact Deposits" in the description of map units. Also included in this group are several diamict deposits (Qkm, Qhm1, Qhm2) occupying small bowl-shaped valleys bounded on their north sides by high hills. These deposits may have formed when downwasting of the glacier caused ice blocks to become isolated and stagnant in the lee of steep bedrock hills. These stagnant ice blocks melted and released sediment to form the observed diamict deposits. An exception to this rule is the diamict deposit just east of Skyline Lakes (Qsk). Here, diamict occurs in several arcuate ridges that rise well above the divide of the small north-draining valley they occupy. This morphology suggests that the deposit was emplaced by active ice.

Lithologies of pebbles in recessional deposits were counted at 56 sites (table 2). These counts show that the recessional deposits have pebble mixes that are similar to the adjacent till or that are slightly more enriched in local bedrock than the till. This pattern suggests that the recessional sediment was derived from erosion of till and bedrock by meltwater flowing beneath or along the edge of the glacier. An exception to this pattern are the deposits in the Ramapo Valley. Even though these deposits rest on sandstone and conglomerate of the Newark Basin, they contain between 61 and 83 percent gneiss and only 1 to 2 percent Newark Basin rocks. This distribution indicates that these deposits were supplied primarily by meltwater descending the east slope of the Ramapo Mountains rather than by subglacial meltwater from the valley bottom.

DEGLACIATION HISTORY

The first set of recessional ice margins in the quadrangle is marked by thick lacustrine and diamict deposits in the north-draining tributary valleys on the south side of the Pequannock Valley (Qml, Qmld, Qbu1, Qbu2, Qbu3, Qbu3d). Similar deposits on the north side of the valley (Qhc, Qhp) may have been deposited while the main valley was occupied by stagnant ice. These ice margins parallel the deep, narrow east-west trending valley of the Pequannock River and may have formed when melting back of the ice front was slowed by the much thicker ice occupying this deep valley.

As ice retreated from this valley, open drainage down the Pequannock was established and outwash was deposited along the Pequannock (Qpq) and two south-sloping tributary valleys (Qow, Qbd). Farther east the large fluvial unit (Qpp) forming the Pompton Plain south of the Wanaque quadrangle was deposited from an ice margin near the quadrangle boundary, and a small lacustrine unit (Qir) was deposited in a ponded valley north of Pines Lake. Somewhat later, the first fluvial-lacustrine unit in the Wanaque Valley (Qwq1) was deposited. Also at this time, outwash was being deposited in a south-sloping tributary valley north of Pompton Lakes (Qpl) and lacustrine deposits (Qfl) were accumulating in a glacial lake dammed by ice to the north of Preakness Mountain, just east of Oakland.

When the receding ice crossed the divide between the Pequannock and the Wanaque at the head of the valley north of Bloomingdale, a proglacial pond formed in the north-sloping valley south of Twilliger Lake. Unit Qmo was deposited in this pond. Soon thereafter, as continued recession opened drainage eastward into the Wanaque Valley, outwash deposits Qtw and, somewhat later, Qpo formed. Farther west, Qgl was deposited in a proglacial pond south of Gordon Lakes.

At approximately the same time in the Ramapo Valley, fluvial-lacustrine unit Qrm1 was deposited, probably from an ice margin just outside the quadrangle to the northeast. Later, Qrm1 was incised by a later unit (Qrm2) deposited from an ice margin farther up-valley in the Ramsey quadrangle.

The next major recessional ice margin is marked by thick lacustrine deposits in north-sloping tributaries on the south side of West Brook Valley (the earlier deposits Qmg, Qbs, Qbm1, followed by Qwb1, Qwb2, Qbm2, Qbe), by the head of fluvial-lacustrine unit Qwq2 in the Wanaque Valley, by the ice contact deposit at Skyline Lakes (Qsk), and by two small lacustrine units in north-sloping tributaries to the Wanaque (Qmv, Qsl). Like the Pequannock Valley, the West Brook Valley is a deep, east-west trending trough. The thick deposits in this valley, like those in the Pequannock, may represent slowed retreat of the ice margin in response to the thick section of ice occupying the valley.

Retreat of the ice margin from the West Brook position opened drainage down West Brook, allowing deposition of outwash (Qwb3). As the remainder of the quadrangle was deglaciated, lacustrine units (Qsn1, Qsn2, Qek1, Qek2, Qhw, Qmk) were deposited in several north-sloping valleys. Fluvial units were deposited along the south-sloping valleys of Cupsaw Brook (Qcs1, Qcs2), Ringwood Creek (Qrw1, Qrw2), and the Wanaque River (Qwq3, Qwq4). Where steeply-sloping meltwater channels debouched into valleys, coarse gravel was deposited in fans and channels (Qmf).

The far northwest corner of the quadrangle was occupied by a portion of a glacial lake partially flooding the north-draining valley of Belchers Creek, which is just northwest of the edge of the map. This lake drained across the Wanaque/Pequannock divide in the Newfoundland quadrangle, approximately 2 miles west of Melody Lake, at an elevation of approximately 850 feet (Stanford, 1991). Deltas (Quv3, Quv4) were deposited from two ice margins in this lake.

POSTGLACIAL DEPOSITS

After deglaciation, deposition of silt and clay, followed by peat and muck, began in ponds, marshes, and swamps (Qs). Most of these wetlands occupy shallow basins glacially eroded in bedrock on uplands. Several wetlands in the quadrangle occupy floodplains and former lake-bottoms in the valleys.

When meltwater deposition ended, postglacial alluvium (Qal) began to accumulate along low-gradient reaches of streams and rivers. These deposits are generally thinner, finer-grained, and of smaller extent than the meltwater deposits and in some places contain organic matter. Two small alluvial fans (Qf) of cobble- to-boulder gravel on the north side of the Pequannock valley near Apshawa are exceptions to the generally fine-grained character of postglacial deposits. These fans were probably deposited shortly after deglaciation by erosion of the loose sediment in deposits Qhc and Qhp.

REFERENCES

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. 22-49.

Stanford, S. D., 1991, Surficial geologic map of the Newfoundland quadrangle, Passaic, Morris, and Sussex Counties, New Jersey: N. J. Geological Survey Geologic Map Series 91-3, scale 1:24,000.

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.

TABLE 1.-- Selected well logs

Well No.	Permit No.[1]	Driller's Log: Depth (feet below land surface)	Driller's Log: Description	Interpretation: Depth (feet below land surface)	Interpretation: Unit
1	on file at N.J. Geological Survey	0-10	medium to fine sand	0-10	Qal
		10-42	coarse to fine sand, trace gravel	10-70	Qrmlb
		42-70	fine sand, trace gravel		
		70-116	coarse to fine sand and gravel	70-116	Qrmg
2	on file at N.J. Geological Survey	0-20	sand and gravel, large stones	0-23	Qrm1
		20-23	sand and small gravel		
		23-99	gray soupy fine sand	23-119	Qrmlb
		99-119	gray very fine sand and clay		
		119-121	gray hardpan	119-121	Qt
		121-122	brown rock	121-122	bedrock or boulder
3	23-5736 and 23-5117	0-24	coarse sand and gravel	0-24	Qwq2
		24-102	sand	24-102	Qwqlb
		102-171	sand, gravel, boulders	102-171	Qwq1
		171-228	granite	171-228	bedrock
4	23-4584	0-16	sand and gravel	0-16	Qwq2
		16-100	gray silt and sand	16-100	Qwqlb
		100-253	granite	100-253	bedrock
5	23-4679	0-15	sand	0-15	Qwq2
		15-38	sandy silt	15-55	Qwqlb
		38-45	silt, light clay		
		45-55	heavy gray clay		
		55-56	big gravel	55-56	Qwqg
		56-58	granite	56-58	bedrock or boulder
6	23-5134	0-18	dirt, stones, boulders	0-18	fill
		18-50	clay, fine sand, gravel	18-50	thin Qs over Qwq2
		50-70	gravel	50-95	Qwqg
		70-84	coarse gravel, sand, clay		
		84-90	fine sand		
		90-95	coarse sand		
		95-110	granite	95-110	bedrock
7	22-11802	0-13	overburden	0-200	interbedded diamict, deltaic, and lake-bottom sediment of unit Qmld
		13-16	boulder		
		16-110	fine sand, clay		
		110-114	coarse gravel		
		114-175	fine sand, clay, gravel		
		175-200	sand and gravel		
		200-300	granite	200-300	bedrock
8	22-5236	0-43	sand, gravel, boulders	0-43	diamict of unit Qbu2
		43-90	granite	43-90	bedrock
9	23-6978	0-50	gravel, sand	0-144	deltaic sediment of unit Qbm1
		50-100	brown sand		
		100-144	brown silt		
		144-195	granite	144-195	bedrock
10	25-13098	0-50	sand and gravel	0-50	deltaic sediment of unit Quv3
		50-100	gray clay	50-100	lake-bottom sediment associated with unit Quv3
		100-260	black granite	100-260	bedrock

[1] New Jersey Department of Environmental Protection and Energy water well drilling permit

TABLE 2.-- Lithology of pebbles in surficial units

Site	Unit	Number of pebbles	Lithology (percentages of pebbles): Gneiss(1)	Gray Shale and Sandstone(2)	Purple Quartzite and Conglomerate(3)	Red Shale and Sandstone(4)	Remarks
1	Qt	102	10	59	29	0	(5)
2	Quv3	121	8	83	9	0	
3	Quv4	140	19	64	15	1	(6)
4	Qt	141	22	54	23	0	(7)
5	Qt	205	49	34	17	0	
6	(8)	159	63	21	16	0	
	Qt	171	53	27	20	0	
7	Qmk	153	65	24	11	0	
8	Qt	131	76	22	2	0	
9	Qcs1	134	74	25	0	0	(9)
10	Qcs1	121	74	25	1	0	
11	Qcsl	145	69	30	0	0	(7)
12	Qt	213	42	52	6	0	
13	Qwb1	101	42	18	40	0	
14	Qwb1	184	25	54	21	0	
15	Qt	125	80	16	4	0	
16	Qwb1	139	72	22	6	0	
17	Qwb3	172	58	27	15	0	
18	Qt	154	48	39	13	0	
19	Qbm2	179	56	22	22	0	
20	Qbm2	180	56	26	18	0	
21	Qt	169	60	37	3	0	
22	Qbs	121	57	34	9	0	
23	Qt (10)	147	22	68	8	0	(5)
	Qt (11)	102	98	2	0	0	
24	Qgl	142	44	48	8	0	
25	Qhp	140	72	22	6	0	
26	Qt	94	5	83	12	0	
27	Qmv	140	71	29	0	0	
28	Qwq2	118	85	11	4	0	
29	Qt	154	49	39	13	0	
30	Qek2	162	62	35	2	0	(9)
31	Qt	145	63	36	1	0	
32	Qt	142	48	49	3	0	
33	Qwq2	128	78	19	2	0	(9)
34	Qwq2	126	79	17	4	0	
35	Qwq2	134	75	20	5	0	
36	Qwq2	154	65	18	17	0	
37	Qwq2	129	77	19	4	0	
38	Qwq2	136	73	23	4	0	
39	Qwq2	141	71	28	1	0	
40	Qwq2	136	73	17	9	0	(9)
41	Qwq2	140	71	29	0	0	
42	Qwq2	147	68	29	3	0	
43	Qt	153	59	40	1	0	
44	Qrm1	125	80	14	3	3	
45	Qal	130	77	18	4	1	
46	Qrm2	127	83	13	2	2	
47	Qrm2	147	68	17	14	1	
48	Qrm2	136	74	18	7	0.5	(12)
49	Qek1	182	55	44	0.5	0	(13)
50	Qhc	164	55	37	8	0	
51	Qhp	181	55	33	12	0	
52	Qhp	149	57	28	14	0	(9)
53	Qt	144	52	37	10	0	(9)
54	Qbu2	140	78	21	1	0	
55	Qmld	155	65	18	17	0	
56	Qmld	157	64	20	16	0	
57	Qmld	138	55	23	22	0	
58	Qbu1	114	71	25	3	0	(7)
59	Qbu3	137	66	26	8	0	
60	Qt	133	75	11	13	0	
61	Qbu3d	139	65	4	30	0	(7)
62	Qt	128	79	16	5	0	
63	Qmo	148	68	27	5	0	
64	Qpg	153	65	26	9	0	
65	Qwq2	143	70	27	3	0	
66	Qwq2	142	70	25	5	0	
67	Qrm1	146	68	24	0	8	
68	Qrm1	157	64	32	4	0	
69	Qrm1	287	73	18	7	2	
70	Qt	97	20	15	0	58	(14)
71	Qrm1	125	80	14	3	3	
72	Qrm2	131	77	17	5	1	
73	Qfl	146	68	20	10	1	(15)
74	Qrm1	157	64	16	19	1	
75	Qir	132	76	23	1	0	
76	Qrm1	163	61	34	5	0	

(1) Includes all igneous and metamorphic rock of Precambrian age.
(2) Includes Bellvale Sandstone, Marcellus Shale, and minor amounts of Martinsburg Formation from northwest of the quadrangle.
(3) Includes chiefly Skunnemunk and Green Pond Conglomerate.
(4) Includes sandstone, siltstone, shale, and conglomerate of the Passaic Formation.
(5) Includes 1 percent chert and 1 percent dolomite.
(6) Includes 0.5 percent chert and 0.5 percent dolomite.
(7) Includes 1 percent dolomite.
(8) Count is in a pre-advance fluvial gravel underlying till (exposed in excavation). Not a map unit.
(9) Includes 1 percent chert.
(10) Upper unit of till.
(11) Lower unit of till.
(12) Includes 0.5 percent basalt.
(13) Includes 0.5 percent chert.
(14) Includes 7 percent basalt.
(15) Includes 1 percent basalt.

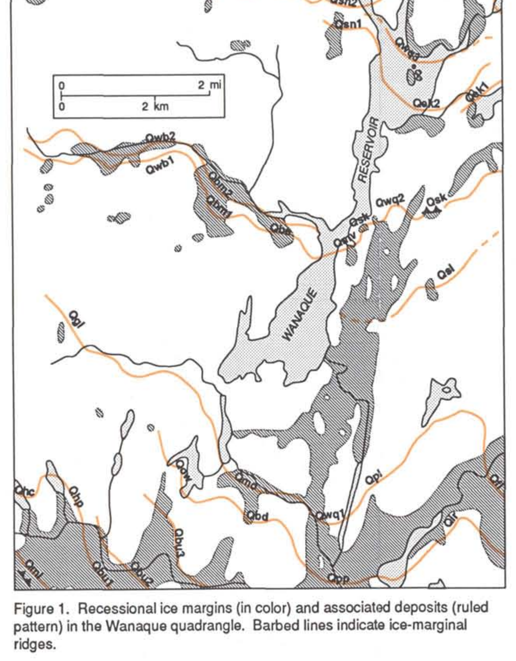


Figure 1. Recessional ice margins (in color) and associated deposits (ruled pattern) in the Wanaque quadrangle. Barbed lines indicate ice-marginal ridges.

Base map from U.S. Geological Survey, 1954
Photorevised 1971

Geology mapped 1986-1987

Reviewed by D.D. Braun, W.D. Sevon, and B.D. Stone

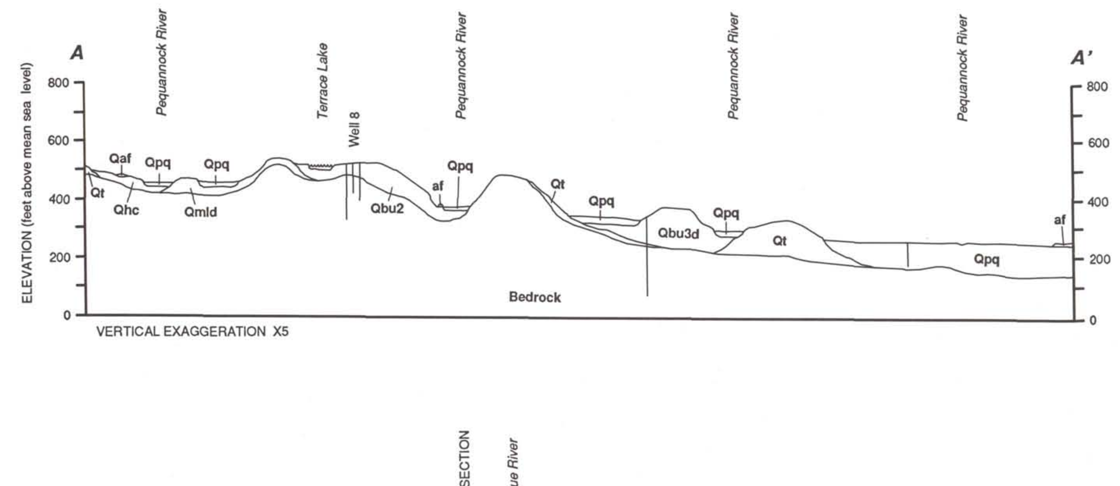
Cartography by Zehdreh Allen-Lafayette

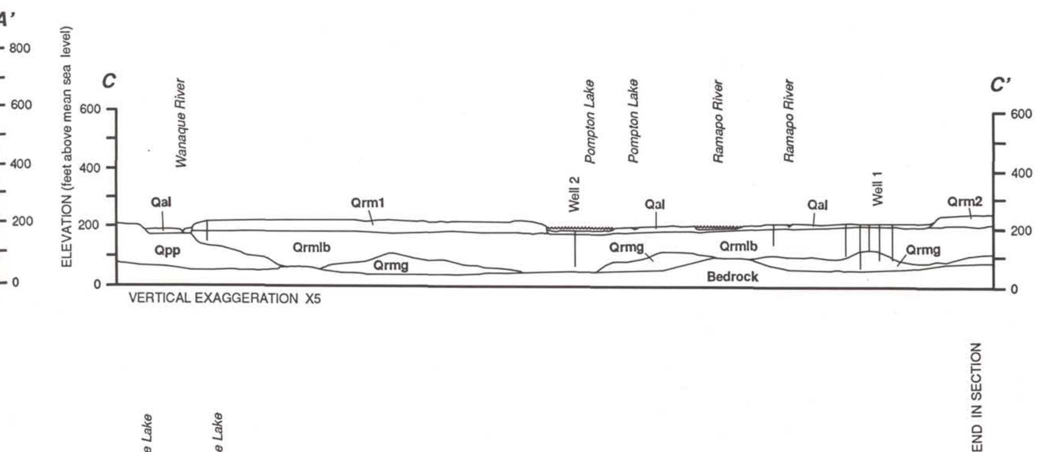
SCALE 1:24 000

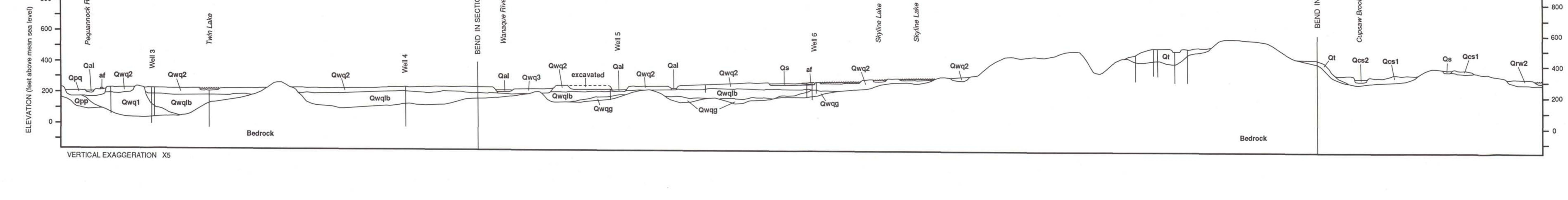
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

SURFICIAL GEOLOGIC MAP OF THE WANAQUE QUADRANGLE, BERGEN, MORRIS, AND PASSAIC COUNTIES, NEW JERSEY

by
Scott D. Stanford
1993

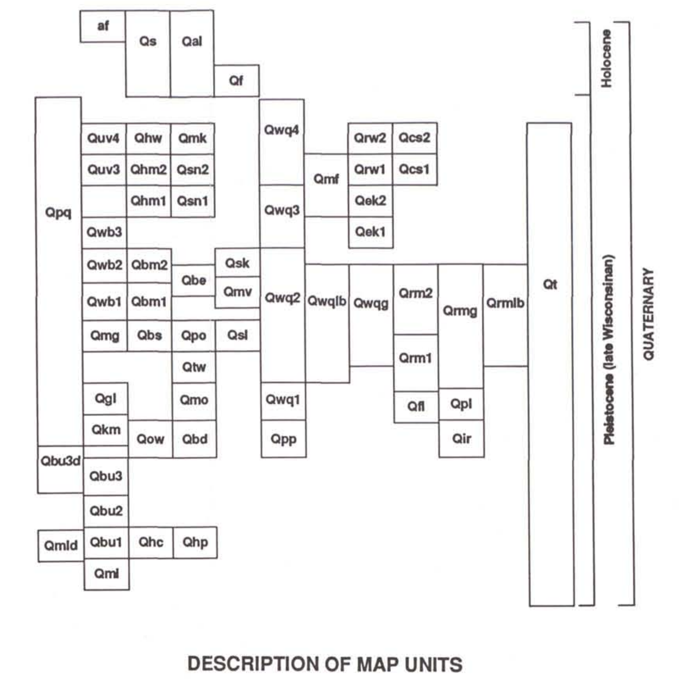






SURFICIAL GEOLOGIC MAP OF THE WANAQUE QUADRANGLE, BERGEN, MORRIS, AND PASSAIC COUNTIES, NEW JERSEY
GEOLOGIC MAP SERIES GMS 93-1

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Postglacial Deposits (Holocene and late Wisconsinan)

af — **Artificial Fill** - Excavated till, sand, gravel, and rock; construction debris, cinders and slag. In railroad and highway embankments, dams, and filled land. Generally less than 10 feet thick, as much as 70 feet thick in dams. Many small areas of fill in urban areas not mapped.

Qs — **Swamp and Marsh Deposits** - Clay and silt overlain by peat and muck. As much as 30 feet thick (Waksman and others, 1943, p. 184).

Qal — **Alluvium** - Silt, sand, pebble-to-cobble gravel. Generally less than 10 feet thick.

Qf — **Alluvial Fan Deposits** - Cobble-to-boulder gravel. Maximum thickness 20 feet (estimated).

Glacial Deposits (late Wisconsinan)

Upland Lacustrine and Ice-Contact Deposits - Bouldery, sandy diamict and deltaic sand and gravel. Includes ice-contact deposits in areas of stagnant ice (Qhm2, Qhm1, Qkm, Qhc, Qhp), collapsed lacustrine and ice-contact deposits in north-draining valleys (Quv4, Quv3, Qhw, Qmk, Qsn2, Qsn1, Qek2, Qek1, Qwb2, Qwb1, Qbm2, Qbm1, Qbe, Qsl, Qmg, Qbs, Qmv, Qgl, Qfl, Qmo, Qir, Qbu3, Qbu3d, Qbu2, Qbu1, Qml, Qmld), and ice-contact deposits possibly emplaced by active ice (Qsk).

Quv4, Quv3 — **Union Valley Deposits** - Two successive deltas of pebble-to-cobble gravel overlying sand and pebbly sand. Deposited in a glacial lake controlled by a spillway at 850 feet near Postville in the Newfoundland quadrangle. Drainage from the spillway was southward along Kanouse Brook into the Pequannock River. Units Quv1 and Quv2 occur to the southwest in the Newfoundland quadrangle (Stanford, 1991). As much as 100 feet thick.

Qhw — **Hewitt Brook Deposit** - Cobble-and-pebble gravel forming an esker and small terrace in the ponded, north-draining valley of Hewitt Brook. Probable outlet to south along Burnt Meadow Road. Maximum thickness 30 feet.

Qmk — **Monks Deposit** - Cobble-to-boulder diamict, possibly deposited in a proglacial lake south of Monks prior to opening of drainage down the Wanaque Valley. As much as 30 feet thick (estimated).

Qhm2, Qhm1 — **Harrison Mountain Deposits** - Cobble-to-boulder diamict and cobble gravel in the bottoms of two small upland valleys near Harrison Mountain Lake. May have been deposited successively from stagnant ice isolated from the active glacier by bedrock hills to the north. Qhm2 may include some collapsed lacustrine deposits. Maximum thickness 20 feet (estimated).

Qsn2, Qsn1 — **Stonetown Deposits** - Deltaic pebble-to-cobble gravel and cobble-to-boulder diamict deposited in a ponded, north-draining valley northeast of Stonetown. Outlet for Qsn1 is to the south into Burnt Meadow Brook and was succeeded by a lower outlet for Qsn2 to the east into the Wanaque Valley. As much as 60 feet thick (estimated).

Qek2, Qek1 — **Erskine Deposits** - Deltaic pebble to cobble gravel deposited successively in two separate, ponded, north-draining valleys near Erskine. Probable outlets to west into the Wanaque Valley. Maximum thickness 40 feet (estimated).

Qsk — **Skyline Lakes Deposit** - Cobble-to-boulder diamict forming several arcuate ridges on north slopes of two small hills near Skyline Lakes. Location and morphology suggest that sediment may have been deposited, in part, by active ice. Maximum thickness 80 feet (estimated).

Qwb2, Qwb1 — **West Brook Deposits** - Collapsed deltaic sand and gravel and ice-contact cobble-to-boulder diamict deposited in ponds between ice and the south wall of West Brook Valley. Qwb1consists of earlier, higher deposits confined to two north-draining tributary valleys; Qwb2 consists of later, lower deposits in the main valley. Both were controlled by spillways between ice and the north slope of the bedrock hill to the east. Maximum thickness 80 feet (estimated).

Qbm2, Qbm1 — **Blue Mine Deposits** - Deltaic sand and gravel and ice-contact cobble-to-boulder diamict deposited in ponded, north-draining valley. Outlet for Qbm1 is to the south along Blue Mine Brook; later, lower outlet for Qbm2 is to the east into West Brook. As much as 120 feet thick.

Qbe — **Blue Mine East Deposit** - Deltaic sand and gravel and ice-contact diamict filling ponded, north-draining valley to the east of the Blue Mine deposits. Outlet to the south into the Wanaque Valley. As much as 70 feet thick.

Qmg — **Mountain Glen Lakes Deposit** - Small deposits of collapsed deltaic sand and gravel and ice-contact diamict in ponded, north-draining valley around Mountain Glen Lakes. Possible outlet to south into Posts Brook near Indian Trail Lake. Maximum thickness 40 feet (estimated).

Qbs — **Boy Scout Lake Deposit** - Cobble-to-boulder diamict in ponded, north-draining valley south of Boy Scout Lake. Possible outlet to east into Blue Mine Brook. Estimated maximum thickness 20 feet.

Qsl — **Stephens Lake Deposit** - Collapsed deltaic pebbly sand-to-cobble gravel deposited in ponded, north-draining valley north of Stephens Lake. Probable outlet to south into Wanaque Valley. As much as 40 feet thick (estimated).

Qmv — **Midvale Deposit** - Deltaic cobble gravel and sand deposited in ponded north-draining valley north of Midvale Dam. Outlet to south into Wanaque Valley. Estimated maximum thickness 20 feet.

Qgl — **Gordon Lakes Deposit** - Pebble-to-cobble gravel forming several small terraces south of Gordon Lakes. Probably deposited in a small rock-basin pond with an outlet eastward into Posts Brook. Maximum thickness 20 feet (estimated).

Qkm — **Lake Kampfe Deposit** - Several small deposits of ice-contact diamict near Lake Kampfe. Possibly deposited from stagnant ice isolated from the active glacier by the bedrock hills to the north. Maximum thickness 20 feet (estimated).

Qfl — **Franklin Lakes Deposit** - Collapsed deltaic pebbly sand deposited in a proglacial lake dammed on the south by Preakness Mountain. Possible outlet at an elevation of approximately 450 feet across Preakness Mountain near Franklin Lakes in the Paterson quadrangle. As much as 100 feet thick (estimated).

Qmo — **Morse Lakes Deposit** - Ice-contact diamict in ponded, north-draining valley south of Morse Lakes. Outlet to south into Pequannock Valley. Estimated maximum thickness 30 feet.

Qir — **Indian Road Deposit** - Collapsed deltaic sand-to-cobble gravel deposited in a north-draining valley north of Pines Lake. Outlet to south. Maximum thickness 30 feet.

Qhc — **High Crest Lake Deposit** - Ice-contact diamict and collapsed deltaic sand and gravel on north side of Pequannock Valley at south end of High Crest Lake. Origin uncertain, may be a remnant of unit Qbu1 isolated by erosion along the Pequannock as eastward drainage opened, or may have been deposited in stagnant ice within the Pequannock Valley that became isolated from the active glacier during downwasting. Estimated maximum thickness 120 feet.

Qhp — **Henion Pond Deposit** - Sediment as in Qhc on north side of Pequannock Valley at south end of Henion Pond. Estimated maximum thickness 140 feet.

Qbu3d, Qbu3, Qbu2, Qbu1 — **Butler Deposits** - Deltaic sand and gravel and ice-contact diamict deposited in three successively lower proglacial lakes occupying several north-draining valleys around Butler. The diamict (Qbu3d) is mapped separately from the deltaic sediment (Qbu3) for unit Qbu3, but they are undifferentiated for Qbu2 and Qbu1. Outlets are to the east into the Newark Basin in the Pompton Plains quadrangle. Qbu1 was deposited in the earliest and highest lake, with a possible spillway at 630 feet south of Butler. Retreat of ice opened up a lower spillway at approximately 530 feet; Qbu2 was deposited in this lake. Continued retreat opened up a still lower spillway at about 410 feet; Qbu3 was deposited in this lake. Further retreat uncovered the gap in the Pequannock Valley between Bloomingdale and Riverdale, and the lakes drained as the valley opened. As much as 140 feet thick.

Qmld, Qml — **Maple Lake Deposit** - Deltaic sand and gravel (Qml) and ice-contact diamict (Qmld) filling ponded, north-draining valley around Maple Lake. Outlet to south in Boonton quadrangle at an elevation of approximately 730 feet. As much as 200 feet thick.

Fluvial and Fluvial-Lacustrine Deposits - Fluvial boulder-to-cobble gravel, minor pebble gravel and pebbly sand, deposited chiefly in south-draining valleys. Overlies lacustrine sand, silt, and gravel in places.

Wanaque Outwash - Five successive fluvial units, four of which are within the Wanaque quadrangle. The units were deposited from ice margins near Twin Lakes (Qwq1), Skyline Lakes (Qwq2), Erskine Lakes (Qwq3), and Hewitt in the Greenwood Lake quadrangle (Qwq4).

Qwq4 — Cobble-and-boulder gravel. Generally less than 30 feet thick (estimated).

Qwq3 — Cobble-and-boulder gravel, grading south to pebble gravel and pebbly sand in Pompton Lakes. Generally less than 30 feet thick (estimated). Forms terraces eroded into Qwq1 and Qwq2 and overlies Qwqlb at and south of Wanaque.

Qwq2 — Cobble-and-boulder gravel grading south to pebble gravel. As much as 40 feet thick.

Qwq1 — Cobble gravel, may include deltaic sand and gravel at depth. Entire unit as much as 180 feet thick.

Qwqlb — Lake-bottom and deltaic fine sand and silt underlying Qwq2. As much as 100 feet thick.

Qwqg — Lacustrine-fan sand and gravel underlying Qwqlb. As much as 30 feet thick. In subsurface only (section B-B').

Ringwood Outwash - Includes ice-contact diamict (Qrw1) deposited between ice and the valley sides prior to opening of drainage down-valley and a fluvial unit (Qrw2) deposited from an ice margin north of the Ringwood Mill Pond in the Greenwood Lake quadrangle.

Qrw2 — Cobble gravel. Probably less than 30 feet thick.

Qrw1 — Cobble-to-boulder diamict. Less than 30 feet thick (estimated).

Cupsaw Brook Outwash - Two fluvial units in the valley of Cupsaw Brook. Qcs1 was deposited from an ice margin just west of Cupsaw Lake and includes a possible feeding esker east of Eleanor Hewitt school. Qcs2 forms a terrace eroded into Qcs1 by later meltwater descending Cupsaw Brook from ice margins to the north in the Sloatsburg quadrangle.

Qcs2 — Cobble-and-boulder gravel. Probably less than 30 feet thick.

Qcs1 — Cobble-and-boulder gravel. Maximum thickness 50 feet (estimated).

Qwb3 — **West Brook Outwash** - Cobble-to-boulder gravel deposited by meltwater descending West Brook Valley as drainage opened to the east. Maximum thickness 20 feet (estimated).

Qpo — **Posts Brook Outwash** - Cobble-and-pebble gravel. As much as 20 feet thick (estimated).

Qtw — **Twilliger Lake Outwash** - Cobble-to-boulder gravel. As much as 20 feet thick.

Qpq — **Pequannock Outwash** - Boulder-and-cobble gravel, possibly overlying earlier lacustrine sand and pebbly sand in places, deposited by meltwater descending the Pequannock Valley as drainage opened to the east. Maximum thickness, including underlying sand, is approximately 100 feet.

Qow — **Oakwood Lake Outwash** - Cobble-to-boulder gravel, possibly overlying earlier lacustrine sand and pebbly sand. As much as 50 feet thick.

Qbd — **Bloomingdale Outwash** - Cobble gravel, possibly overlying earlier lacustrine sand and pebbly sand. As much as 50 feet thick.

Ramapo Deposits - Two fluvial-deltaic units (Qrm2, Qrm1), associated deltaic and lake-bottom sand and silt (Qrmlb), and earlier, underlying lacustrine-fan sediments (Qrmg).

Qrm2 — Cobble-to-pebble gravel and pebbly sand. As much as 50 feet thick. Includes both fluvial beds and upper deltaic foresets.

Qrm1 — Cobble-to-pebble gravel and pebbly sand, as in Qrm2. As much as 50 feet thick.

Qrmlb — Sand, silt, minor clay. As much as 150 feet thick. In subsurface only (section C-C').

Qrmg — Sand and gravel. As much as 50 feet thick. In subsurface only (section C-C').

Qpl — **Pompton Lakes Outwash** - Cobble-and-pebble gravel overlying earlier lacustrine silt, sand, and pebbly sand. Entire unit as much as 80 feet thick.

Qpp — **Pompton Plains Outwash** - Coarse cobble gravel possibly overlying lacustrine sand. Entire unit as much as 120 feet thick. Head of large fluvial plain to south in Pompton Plains quadrangle.

Qmf — **Meltwater Fan Deposits** - Cobble-and-boulder gravel deposited in and at the mouths of meltwater channels southeast of Lake Erskine and on the west shore of Wanaque Reservoir. Maximum thickness 40 feet (estimated).

Qt — **Till** - Pebbles, boulders, and cobbles in a matrix of yellowish brown (oxidized) to gray (unoxidized) silty sand to sand. May be as much as 200 feet thick in drumlins, and as much as 60 feet thick in areas of continuous till. May include till of possible Illinoian age in the cores of drumlins beneath late Wisconsinan till. Map unit also includes thin, discontinuous postglacial colluvium at the bases of some steep slopes.

MAP SYMBOLS

Contact - dashed where approximately located, dotted where excavated or concealed by artificial fill

Scarp cut by meltwater - on contact. Line at top of scarp, hachures on slope

Scarp cut by meltwater - within map unit. Line at top of scarp, hachures on slope

Striation - observation at dot

Meltwater channel - dashed where poorly defined. Narrow, linear, boulder-filled drainageway, bounded in places by cutbanks, in which present stream is underfit or absent

Scarp cut by postglacial stream - on contact. Line at top of scarp, hachures on slope

Scarp cut by postglacial stream - within map unit. Line at top of scarp, hachures on slope

Gravel pit - active in 1987

Gravel pit - inactive in 1987

Quarry

Surface accumulation of boulders - may be till surfaces washed by subglacial, proglacial, or ice-marginal meltwater

Excavation scarp - line at top of scarp, hachures on slope

Crest of ice-contact ridge or scarp - barbs on ice-contact slope

Esker

Qmo **Spillway for glacial lake** - lettering indicates associated deposit

Drumlin

300 **Elevation of bedrock surface** - contour interval 50 feet. Shown only in major buried valleys. Contours based on approximately 200 well records selected from files of the N.J. Department of Environmental Protection and Energy

Erratic boulder of carbonate bedrock - indicates southerly ice flow across belts of carbonate bedrock to the north

Surface texture of recessional deposits

cobble-to-boulder diamict, sandy matrix

coarse cobble-to-boulder gravel and sand

fine-to-medium cobble-gravel and sand

pebble gravel and sand

pebbly sand

fine sand, silt, clay

Bedrock outcrop - Solid area indicates extensive bedrock outcrop; surficial deposits generally absent. Ruled area indicates scattered bedrock outcrops; surficial deposits generally less than 10 feet thick. Small solid area indicates isolated bedrock outcrop where surficial deposits are generally greater than 10 feet thick

Well or test boring - on sections, in places projected to line of section

t 225 wr 509 **Selected well** - in upland area, with abbreviated log (t=till, g=sand and gravel, wr=weathered bedrock, cl=clay and silt). Number indicates depth of contact in feet, dashed line indicates bedrock not reached

11 **Well** - log in table 1

29 **Site of pebble lithology count** - data in table 2