DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WATER RESOURCES
NEW JERSEY GEOLOGICAL SURVEY

INTRODUCTION

The Boonton quadrangle is located in northeastern Morris County, New Jersey. Surficial deposits in the quadrangle record at least two glaciations. Deposits on uplands consist of till and colluvium. They are generally less than 20 feet thick but may be as much as 60 feet thick. Valley-fill sediment consists of sand, gravel, silt, and clay deposited in glacial lakes and outwash sheets, and till deposited in the Terminal Moraine. The valley-fill deposits are as much as 400 feet thick. Post-glacial alluvium, swamp and marsh sediment, and talus overlie older deposits in place. They are generally thin and of small extent.

GEOLOGIC SETTING

The Boonton quadrangle includes parts of the New Jersey Highlands, the Newark Basin and the Green Pond Outlier (fig. 1). The New Jersey Highlands lie north and west of a line extending from Montville through Boonton to Fox Hill. The Newark Basin lies south and east of this line. The Green Pond Outlier includes only the Copperas Mountain-Green Pond area in the far northwestern corner of the quadrangle.

The New Jersey Highlands in the Boonton quadrangle are underlain primarily by Precambrian hornblende granite, alaskite, amphibolite, quartz diorite, and biotite-feldspar gneiss, with minor skarn, granite pegmatite, and Mesozoic diabase (Sims, 1958). The Precambrian units are interlayered, folded, and have a predominant northeast-southwest foliation and strike. In the central and eastern parts of the quadrangle the strike of the rock is expressed by northeast-southwest trending ridges and valleys. To the northwest variation in strike around fold noses creates irregular upland topography.

The Highlands are bounded on the southeast by the Highland escarpment. This 200- to 400-foot high escarpment marks the Ramapo Fault, which separates resistant Precambrian rocks on the west from more easily eroded, downdropped Jurassic sedimentary rocks of the Newark Basin to the east. The Jurassic rocks include interbedded red siltstone, sandstone, and conglomerate (Olsen, 1980). Gently-sloping bedrock uplands are developed on the siltstone and sandstone; sharper bedrock hills and ridges form on the conglomerate.

In the Boonton quadrangle, the Green Pond Outlier is downfaulted into Precambrian rock along a northeast-southwest trending fault (Barnett, 1976). Bedrock in the outlier within the quadrangle is conglomerate and quartzite of the Silurian Shawangunk Formation. The strike of the formation is subparallel to the fault.

Pre-glacial drainage followed the same routes as present drainage. The only major difference is that the pre-glacial Rockaway River occupied a valley trending across the Highland escarpment southeastward from Denville (as supposed, based on regional geomorphologic considerations, by Davis and Wood, 1889). This valley has become filled with as much as 400 feet of sediment and the Rockaway now flows northeastward from Denville, then eastward through a gap in the Highlands near Boonton.

GLACIAL HISTORY

Deposits of at least two glaciations are preserved in the Boonton quadrangle. The younger deposits are of late Wisconsinan age. The southernmost extent of this glaciation is generally marked by the Terminal Moraine, which extends across the southwestern part of the quadrangle from Fox Hill to Rockaway Borough. The late Wisconsinan deposits were first described in some detail by Cook (1880) and were mapped and described in more detail by Salisbury (1902) and Darton and others (1908).

The older deposits are from a pre-late Wisconsinan glaciation and occur in the Highlands south of, and in places beneath, the Terminal Moraine. The pre-late Wisconsinan deposits were first described by Salisbury (1892), who considered them to be post-Kansan and, in places, Wisconsinan, in age, in contrast to the more deeply-weathered Kansan-age deposits further south in the state (Salisbury, 1902). Leverett (1934) and MacClintock (1940), based on the intensity of weathering, considered the deposits to be of Illinoian age. Ridge (1983), based on weathering characteristics and soil development, also postulated an Illinoian age for glacial deposits immediately south of the Terminal Moraine in the Delaware valley to the west of the Boonton quad-

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lands. Jurassic and Triassic lithologies are confined to the area of Jurassic bedrock in the far southeastern corner of the quadrangle, where they compose between 8 and 80 percent and average 43 percent of the total. The restriction of these lithologies to east of the Highland escarpment further indicates southwestward flow of ice within the Newark Basin, generally parallel to regional strike. This data is in agreement with striations in the eastern part of the quadrangle. The absence of pebbles of Mesozoic rock within the Highlands indicates that ice did not flow westward or southwestward out of the Newark Basin into the Highlands.

Maximum Ice Advance and the Terminal Moraine

The farthest advance of late Wisconsinan ice is marked by a sharp boundary between till to the north and older colluvium and fractured and rubbly bedrock outcrops to the south. Colluvium north of the late Wisconsinan limit is neither as widespread nor as thick as that south of the limit. Bedrock outcrops are less numerous south of the late Wisconsinan limit and, where present, display abundant residual rubble and extensive disintegration along joint and foliation planes. These features contrast with largely unweathered polished and plucked outcrops within the late Wisconsinan limit. Southwest of Denville the late Wisconsinan limit lies approximately one mile beyond the southern edge of ridge-and-kettle topography of the Terminal Moraine, indicating that the ice front retreated from its furthest position in places before stabilizing at the Terminal Moraine.

As ice advanced to its furthest position, the southwesterly-flowing lobe occupying the Newark Basin extended approximately five miles beyond the edge of the south-flowing lobe in the Highlands, as indicated by the embayment of the Terminal Moraine along the Highland escarpment between Morristown and Denville. This advancing ice on the east blocked the pre-glacial Rockaway drainage at Boonton and Fox Hill, creating glacial Lake Denville (Harper, unpub.). Lake Denville spilled over a gap in a bedrock ridge at an elevation of approximately 525 feet, near Tabor in the Morristown quadrangle (fig. 2). Ice in the Highlands advancing through this lake caused deposition of three interbedded units: deltaic and sublacustrine sand and gravel (Qld1), lake-bottom and deltaic silt and fine sand (Qldlb1), and till (Qlwt). This sequence attains thicknesses of 200 feet beyond and beneath the Terminal Moraine.

The Terminal Moraine is a belt of ridge-and-kettle topography mostly in till. In the Boonton quadrangle it is as much as 1.5 miles wide and has as much as 50 feet of relief. The topography consists of closed depressions separated by short, narrow-crested, steep-sided ridges or broader, more gently sloping ridges. The ridges within the moraine lack any preferred orientation, although west of Rainbow Lakes and at the hospital east of Denville tall, continuous ridges define the distal edge of the moraine. No such ridges occur on the northern edge of the moraine, where the ridge-and-kettle topography terminates gradually against bedrock ridges and smooth, till-mantled slopes. Several flat-topped, roughly circular, plateau-like mounds up to 800 feet across bounded steep scarps also occur within the moraine.

Well records and exposures show that till of the moraine ranges from approximately 20 to 150 feet thick. Good exposures in the moraine are sparse, but where observed the sediment is a massive, cobbly to bouldery, sand to silty sand, matrix-supported diamict, similar to till outside the moraine. Stratified sediment has been observed at the surface in the moraine in several places, but these deposits are of very small extent. In the vicinity of Denville and along the buried Rockaway valley, till of the moraine overlies the earlier late Wisconsinan and pre-late Wisconsinan units Qld1, Qldlb1, Qplwt, and Qplwg, described above (table 1 and sections AA′, CC′). Apparent discontinuities of the moraine in this area, noted by Salisbury (1902) and cited by Connally and Sirkin (1973) as evidence for a younger moraine on the east overprinting an older moraine to the west, are the result of erosion of the moraine by later meltwater descending the Rockaway River and, in places, burial of the moraine by deposition of outwash (sections AA′, CC′).

Deglaciation

Deglaciation from the Terminal Moraine began before 18,000 years ago. This age is based on radiocarbon dates of basal post-glacial sediments at Francis Lake in Warren County (Cotter and others, 1983) and Budd Lake in Morris County (Harmon, 1968). Radiocarbon dates on concretions from glacial Lake Passaic sediment south of Morristown (Reimer, 1984) also suggest deglaciation at about this time.

Although no continuous ice margin positions are traceable across uplands north of the Terminal Moraine, stepwise retreat of a single ice front is indicated by the distribution of ice-marginal and proglacial meltwater channels, which generally slope to the south, and the location of small lacustrine sand and gravel deposits (Qml, Qbr, some of Qgu), which are generally confined to north-draining valleys. If ice had stagnated on a large scale, these features would occur in more scattered orientations controlled by the locations of stagnant ice masses rather than topography. However in several steep-walled, east-west trending valleys, notably at Deer Pond near Taylortown and in the valley of Hibernia Brook south of Marcella, the occurrence of meltwater channels and gravel terraces on both the north and south valley walls well above the level of any open drainage down the valleys suggests the presence of local stagnant ice blocks occupying the valley bottom. Stagnant ice in this topographic setting would be produced as downwasting of the glacier surface caused ice on the south sides of steep bedrock hills to become detached from the active glacier.

As the ice melted back from the Terminal Moraine, sublacustrine sand and gravel (Qld2), which may include sublacustrine fan deposits, collapsed deltaic deposits, and ice-contact diamict, were deposited at the ice front on the bottom of Lake Denville. In places, small deltas were built into the lake by meltwater flowing between the glacier and the side of the valley. These deltas extend along the valley walls and are contiguous in the subsurface with the sublacustrine gravel. They are included in Qld2. Lake-bottom and deltaic fine sand and silt (Qldlb2) were deposited on the lake bottom above the gravel when ice had receded further to the north (sections AA′, DD′)

Glacial Lake Denville extended up the valleys of Beaver Brook and Stony Brook, as indicated by the extent of gravel terraces (Qld2) graded to lake level. The lake drained when retreating ice in the Newark Basin on the east uncovered the gap in the Highland escarpment at Boonton. At this time the spillway at Tabor was abandoned and meltwater in the Rockaway basin was diverted eastward through the gap at Boonton. This meltwater deposited thin fluvial sand and gravel sheets (Qh, Qb, Qsb, and Qr) atop the Lake Denville sediments. These fluvial sheets form terraces that are graded to the Boonton gap and that are lower in elevation and texturally finer than the Qld2 terraces. Near the northern ends of the Beaver Brook and Stony Brook valleys, at Hibernia, Meriden, and Lake Juliet, the outwash units feather out where the valleys steepen onto bedrock uplands. Thus, meltwater carrying the outwash issued from ice margins on the bedrock uplands to the north of these locations but within the Rockaway drainage basin.

East of the Highland escarpment the retreating ice margin is marked by a succession of deltas (Qlp1, Qlp2, Qlp3, Qlp4) deposited in the Madison stage of glacial Lake Passaic (fig. 2) (Kummel, 1895). Glacial Lake Passaic was a large proglacial lake that filled the Passaic River basin when advancing ice blocked a pre-glacial gap through the Watchung Mountains at Summit, 12 miles southeast of Boonton. The outlet of Lake Passaic at this time was at an elevation of about 345 feet at Moggy Hollow near Liberty Corner in Somerset County, approximately 20 miles southwest of Boonton. In the Boonton quadrangle the elevation of the Madison stage shoreline is known, from the contact of deltaic topset and foreset beds exposed in the gravel pit in delta Qlp4, to be at an elevation of about 390 feet. The 45-foot increase in elevation between Moggy Hollow and the Boonton quadrangle is due to isostatic rebound of between 2 and 3 feet/mile to the north.

The lobate shape of the ice margin marked by the configuration of the Terminal Moraine was maintained during deglaciation. As the ice margin descended along the Highland escarpment into the Newark Basin it traversed to the southwest. A minimum length for this traverse of approximately 4 miles is indicated by the position of outwash graded to the Boonton gap. These outwash units, as described above, were deposited from ice margins north of Lake Juliet, and could not have formed until the Boonton gap was uncovered. Therefore, at this time ice in Lake Passaic had just receded past the Boonton gap and could be no further south than delta Qlp2. Thus Qh, Qb, Qr, and Qsb in the Highlands are synchronous with or slightly younger than unit Qlp2 in Lake Passaic.

After the ice receded across the Rockaway-Pequannock divide, north-draining tributary valleys to the Pequannock were dammed to create small proglacial lakes draining to the south over bedrock ridges. In the Boonton quadrangles, Qbr and Qml are deltaic sand and gravel deposited in two such valleys; thin sand and gravel units south of Stickle Pond and along Stone House Brook may have been deposited in a similar setting.

When the retreat of the ice front uncovered the outlet of the Pequannock River through the Highland escarpment at Riverdale, approximately 8 miles northeast of Boonton, meltwater in the Highlands was diverted eastward down the Pequannock and southward meltwater drainage through the Rockaway Basin ceased. At about the same time, the gap in the Watchung Mountains at Paterson was uncovered, Lake Passaic drained, and glacial deposition in the Boonton quadrangle ended.

POST-GLACIAL HISTORY

Four units of alluvium deposited by the Rockaway River, including the modern alluvium, postdate the retreat of ice from the Rockaway basin. The oldest (Qgn) is a delta at an elevation of 320 feet on the northwest side of Boonton Reservoir. This delta was deposited in the Great Notch stage of Lake Passaic. At the Great Notch stage (postulated by Kummel, 1895), Lake Passaic drained through a gap at an elevation of approximately 310 feet in First Watchung Mountain at Great Notch, approximately 10 miles east of Boonton. Downstream from the Boonton Reservoir gravel terraces at elevations of 220 to 260 feet (Qst1) occur 20 to 40 feet above the present floodplain. These terrace deposits are younger than Qgn and post-date complete draining of Lake Passaic through the gap at Paterson. The youngest stream-terrace deposits (Qst2) are notably finer-grained than Qgn and Qst1, and occur 5 to 10 feet above the modern floodplain (Qal). Alluvium deposited on the modern floodplain is also chiefly fine-grained.

In addition to alluvium, post-glacial deposits include pond and swamp sediment and talus. Following deglaciation, silt and clay, then peat and muck (Qs), was, and continues to be, deposited in ponds, marshes, and swamps. On uplands these wetlands commonly occupy shallow basins eroded in bedrock; in the valleys of Beaver Brook, Stony Brook, and the Rockaway River, they occupy floodplains and, more rarely, kettle-hole depressions.

On the southeast side of Copperas Mountain glacial plucking of the resistant, coarsely-jointed quartzite and conglomerate bedrock produced or enhanced cliffs. Coarse, angular talus (Qta) has accumulated at the base of these cliffs. Along most of the cliff the talus is unvegetated and probably still accumulating, but at places it has nearly reached the top of the cliff and the cliff is no longer shedding debris to the deposit.

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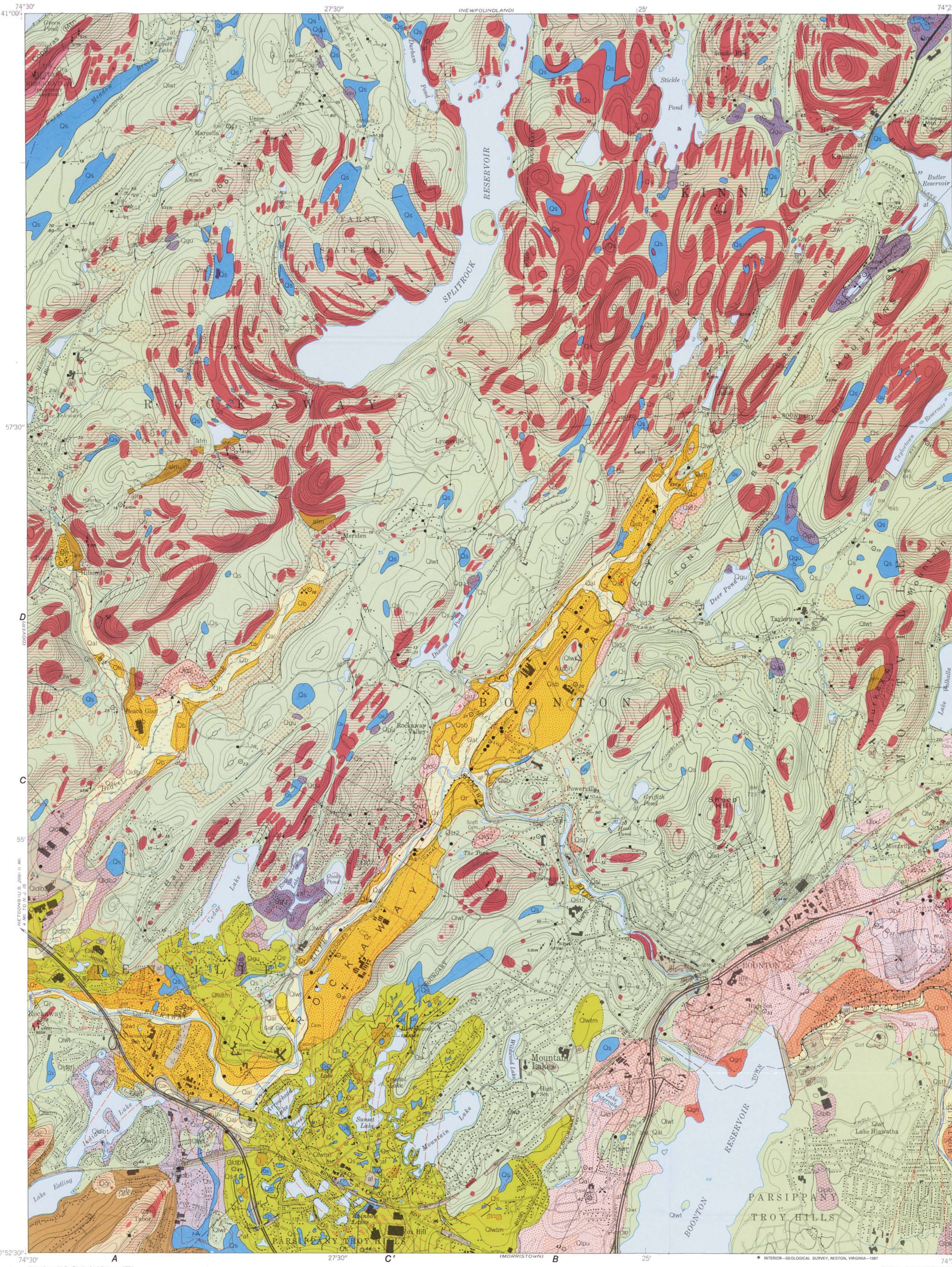

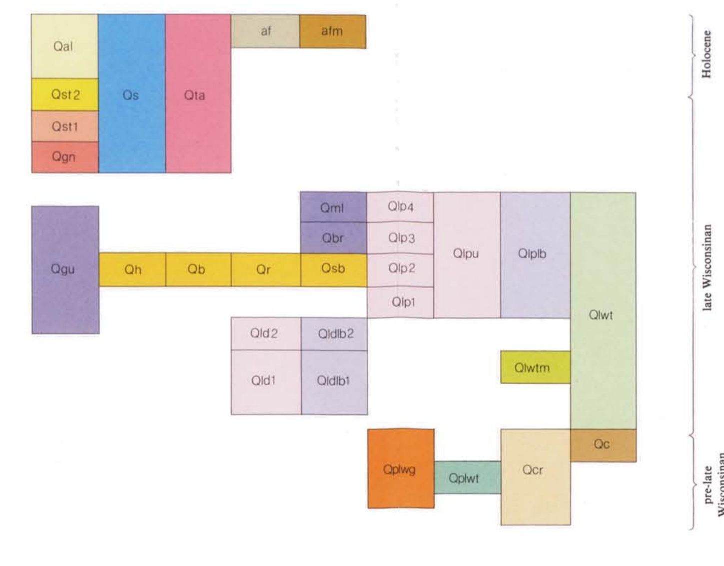

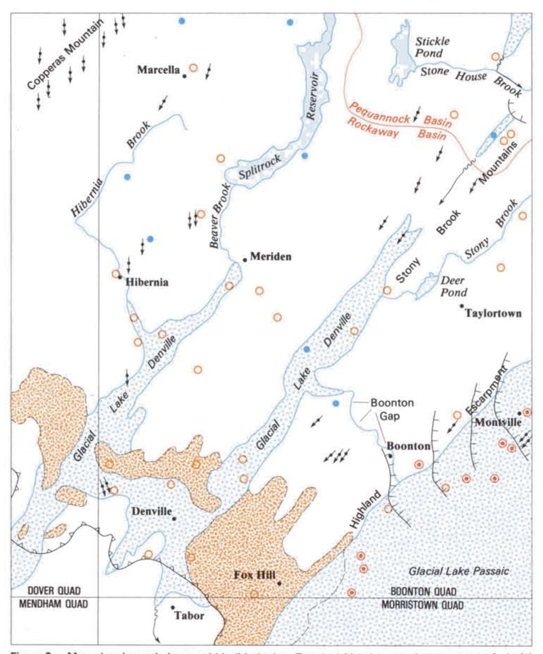

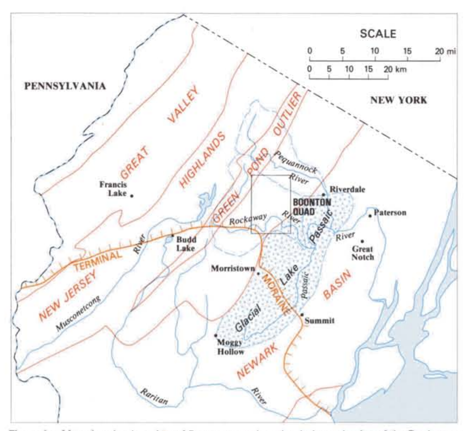

SURFICIAL GEOLOGY OF THE BOONTON QUADRANGLE, NEW JERSEY

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1989