DESCRIPTION OF MAP UNITS

for

Bedrock Geologic Map of Northern New Jersey

By

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DESCRIPTION OF MAP UNITS

COASTAL PLAIN

The New Jersey Coastal Plain is underlain by unconsolidated and semi-consolidated siliciclastic sediments of Cretaceous and Cenozoic age. These sediments constitute a gently dipping, seaward-thickening wedge that is more than 1,920 m (6,300 ft) thick in the southern part of the State. Coastal Plain sediments accumulated along the Atlantic continental margin in a variety of nonmarine, marginal marine, and marine environments. Only marginal marine and nonmarine deposits of the Raritan Formation, as much as 13 m (43 ft) thick, are exposed in the southeastern part of the map area.

Kr Raritan Formation (Upper Cretaceous) (Cook, 1868) - Consists of upper clayey-silt (Woodbridge Clay Member) and lower sand (Farrington Sand Member) in map area. Woodbridge Clay Member is pale-red-orange weathering, grayish-black to dark-gray micaceous silt, very clayey; interbedded and locally interbedded with light-gray, very clayey, fine- to very-fine-grained micaceous sand containing primarily quartz and feldspar. Abundant layers of small, pyrite-coated wood fragments. Siderite in discontinuous beds and in flattened slab concretions as much as 1 m (3 ft) in diameter are common. Mollusk casts common in siderite near top of formation. Typically about 24 m (80 ft) thick. Farrington Sand Member is white, fine-to medium-grained, very micaceous, crossbedded sand, interbedded with thin to thick, dark-gray, silty beds. Exposed only in pits dug below the overlying Woodbridge Clay Member. Typically about 8 m (25 ft) thick. Fossils include late Cenomanian ammonites *Metoicoceras bergquisti* and *Metengonoceras* sp. in upper part of Woodbridge (Cobban and Kennedy, 1990) and pollen of the *Complexipollis-Atlantopollis* assemblage zone (= Zone IV) of late Cenomanian to early Turonian age (Christopher, 1979; 1982).

NEWARK BASIN

The Newark basin, containing rocks of Late Triassic to Early Jurassic age, is a northeast-trending half-graben bounded on the northwest by normal faults. The faults are braided, have subordinate splays, and are en echelon in many places. The Hopewell and Flemington faults comprise two major intrabasinal fault systems. The basin is filled with a thick sequence of fluvial and lacustrine rocks and lava flows, the composite thickness of which is approximately 7,500 m (24,600 ft). Diabase sills as much as 480 m (1,575 ft) thick, and diabase stocks and dikes intruded about the time of the earliest lava flows during the Early Jurassic. Triassic sedimentary rocks unconformably overlie crystalline rocks of the Manhattan prong along the eastern margin of the basin. The Newark basin is unconformably overlain by Cretaceous sediments of the Coastal Plain in the southeastern part of the map area.

Intrusive Rocks

Jd, Jg Diabase and granophyre (Early Jurassic) – Fine-grained to aphanitic dikes; medium- to coarse-grained, subophitic discordant stock-like intrusions of dark-greenish-gray to black diabase; and plugs of dark gray, concordant to discordant sheetlike, medium- to coarse-grained, quartz-rich to albite-rich granophyre (map unit Jg). The chilled margins of diabase masses are aphanitic to very fine grained. Diabase is dense, hard, and sparsely fractured. It is composed mostly of plagioclase (An_{50-70}), clinopyroxene (mostly augite) and magnetite±ilmenite. Accessory minerals include apatite, quartz, alkali feldspar, hornblende, titantite, and zirocon. Olivine is rare. Within about 200 m (655 ft) above and 150 m (490 ft) below the large diabase sheets, red mudstones are typically metamorphosed into indurated, bluish-gray hornfels commonly with clots or crystals of tourmaline or cordierite, whereas argillitic siltstone is metamorphosed into brittle, black, very fine grained hornfels, Sheetlike intrusions are as much as 360 to 400 m (1,180-1,310 ft) thick. Dikes range in thickness from 3 to 15 m (10-50 ft) and several kilometers (miles) long. Thickness of the stocklike bodies is unknown.

Sedimentary and Bedded Volcanic Rocks

Newark Supergroup (Lower Jurassic and Upper Triassic)

Brunswick Group (Lower Jurassic and Upper Triassic) (Lyttle and Epstein, 1987)

Jb, Jbcq Boonton Formation (Lower Jurassic) (Olsen, 1980) - Reddish-brown to brownish-purple, fine-grained sandstone, siltstone, and mudstone; sandstone commonly micaceous, interbedded with siltstone and mudstone in fining-upward sequences mostly 1.5 to 4 m (5-13 ft) thick. Red, gray and brownish-purple siltstone and black, blocky, partly dolomitic siltstone and shale common in lower part. Irregular mudcracks, symmetrical ripple marks, and burrows, as well as gypsum, glauberite, and halite pseudomorphs are abundant in red mudstone and siltstone. Gray, fine-grained sandstone may have carbonized plant remains and reptile footprints in middle and upper parts of unit. Near Morristown, beds of quartz-pebble conglomerate (unit Jbcq) as much as 0.5 m (1.6 ft) thick interfinger with beds of sandstone, siltstone, and shale. Northeast of Boonton, beds of quartz-pebble conglomerate (not mapped separately as **Jbcq**) occur locally with conglomerate containing abundant clasts of gneiss and granite in matrix of reddish-brown sandstone and siltstone. Maximum thickness is about 500 m (1,640 ft).

Jc Basalt-clast conglomerate (Lower Jurassic) - Dark to very-dark-gray conglomerate with clasts mostly of sub-angular to subrounded greenish-black basalt cobbles and boulders. Other clasts (about 10 to 15%) are pebbles to boulders of hornblende granite with pink feldspar. Matrix is dark-pinkish-gray arkosic sand. Locally onlaps the Hook Mountain Basalt along the Ramapo Fault in northeast part of map area. Maximum thickness of unit unknown.

Jh Hook Mountain Basalt (Lower Jurassic) (Olsen, 1980) - Light- to dark-greenish-gray, medium- to coarse-grained, amygdaloidal basalt composed of plagioclase (typically An_{65} and commonly porphyritic), clinopyroxene (augite and pigeonite), and iron-titanium oxides such as magnetite and ilmenite. Locally contains small spherical to tubular cavities (gas-escape vesicles), some filled by zeolite minerals or calcite. Consists of two major flows. Base of lowest flow is intensely vesicular. Tops of flows are weathered and vesicular. Maximum thickness is about 110 m (360 ft) (Olsen and others, 1989).

Jt, Jtc Towaco Formation (Lower Jurassic) (Olsen, 1980) - Reddish-brown to brownish-purple, fine- to medium-grained micaceous sandstone, siltstone, and silty mudstone in upward-fining sequences 1 to 3 m (3-10 ft) thick. Distributed throughout formation are eight or more sequences of gray to greenish- or brownish-gray, fine-grained sandstone, siltstone and calcareous siltstone and black, microlaminated calcareous siltstone and mudstone containing diagnostic pollen, fish and dinosaur tracks. Sandstone is commonly trough cross laminated; siltstone is commonly planar laminated or bioturbated, but can be indistinctly laminated to massive. Thermally metamorphosed into hornfels where in contact with Hook Mountain Basalt. Conglomerate and conglomeratic sandstone with subrounded quartzite and quartz clasts in matrix of light-red sand to brownish-red silt (**Jtc**) interfingers with rocks of the Towaco Formation north and west of New Vernon. Maximum thickness is about 380 m (1,250 ft).

Jp, Jps Preakness Basalt, (Lower Jurassic) (Olsen, 1980) - Dark-greenish-gray to black, very-fine-grained, dense, hard basalt composed mostly of intergrown calcic plagioclase (An_{55-60}) and clinopyroxene (pigeonite and augite). Crystals are generally less than 1 mm (0.04 in) long, but locally feldspar crystals are larger than 1.3 cm (0.5 in.). Small spherical to tubular cavities (gas-escape vesicles) may be filled by zeolite minerals or calcite. Consists of at least three major flows. Prominent amydaloidal zones occur at most contacts between flows. A thin, 2 to 8 m (6.6-26 ft) bed of siltstone (**Jps**) separates the lower flows. The basal 20 m (66 ft) of the lowest flow is commonly highly vesicular or brecciated. Radiating slender columns 20 to 71 cm (8-28 in) wide, caused by shrinkage while cooling, are most abundant in the highest flow. The small, circiular extrusive body forming Round Top west of Oldwick is identified as Preakness Basalt by geochemistry and position above the Orange Mountain Basalt (Houghton and others, 1992). Thickness ranges from 250 m (820ft) (Olsen and others, 1989) to 320 m (1,050 ft).

Jf, Jfc Feltville Formation (Lower Jurassic) (Olsen, 1980) - Interbedded brownish-red to light-grayish-red, fine- to coarse-grained sandstone, gray and black, coarse siltstone in upward-fining cycles, and silty mudstone. Fine-grained sandstone and siltstone are moderately well sorted, commonly cross-laminated, and have 15 percent or more feldspar; interbedded with brownish-red, indistinctly laminated, bioturbated calcareous mudstone. Thermally metamorphosed into hornfels where in contact with Preakness Basalt. Near the base are two thin, laterally continuous beds of black, carbonaceous limestone and gray,

calcareous siltstone, each up to 3 m (10 ft) thick. These contain abundant fish, reptile, anthropod, and diagnostic plant fossils. Three or four, thin, gray to black siltstone and mudstone sequences occur in upper part of unit. Near Oakland, subrounded pebbles to cobbles of quartzite and quartz in a red siltstone and sandstone matrix (**Jfc**) interfinger with sandstone and siltstone of the Feltville Formation. Maximum thickness about 155 m (510 ft).

Jo Orange Mountain Basalt, (Lower Jurassic) (Olsen, 1980) - Dark-greenish-gray to greenish-black basalt composed mostly of calcic plagioclase (typically An_{65}) and clinopyroxene (augite and pigeonite); crystals are generally less than 1 mm (0.04 in) long. Consists of three major flows. The flows are separated in places by a weathered zone or by a thin, up to 3-m- (10-ft-) thick bed of red siltstone (not shown on map) or volcaniclastic rock. Lowest flow is generally massive and has widely spaced curvilinear joints; columnar joints in lowest flow become more common toward the northeast. Middle flow is massive or has columnar jointing. Lower part of the uppermost flow has pillow structures; upper part has pahoehoe flow structures. Tops and bottoms of flow layers are vesicular. Maximum thickness is about 182 m (597 ft).

JTrp, JTrpms, JTrps, JTrpsc, JTrpcq, JTrpcl, Trpg Passaic Formation (Lower Jurassic and Upper Triassic) (Olsen, 1980) - Reddish-brown to brownish-purple and grayish-red siltstone and shale (**JTrp**) maximum thickness 3,600 m (11,810 ft). At places contains mapped sandy mudstone (**JTrpms**), sandstone (**JTrps**), conglomeratic sandstone (**JTrpsc**) and conglomerate containing clasts of quartzite (**JTrpcq**), or limestone (**JTrpcl**). Formation coarsens up section and to the southwest. Quartzite conglomerate unit (**JTrpcq**) is reddish-brown pebble conglomerate, pebbly sandstone, and sandstone, in upward-fining sequences 1 to 2 m (3-6 ft) thick. Clasts are subangular to subrounded, quartz and quartzite in sandstone matrix. Sandstone is medium to coarse grained, feldspathic (up to 20 percent feldspar), and locally contains pebble and cobble layers. Conglomerate thickness exceeds 850 m (2,790 ft). Limestone conglomerate unit (**JTrpcl**) is medium-bedded to massive, pebble to boulder conglomerate. Clasts are subangular dolomitic limestone in matrix of brownish- to purplish-red sandstone to mudstone; matrix weathers light-gray to white near faults. Maximum thickness unknown.

Conglomeratic sandstone (**JTrpsc**) is brownish-red pebble conglomerate, medium- to coarse-grained, feldspathic sandstone and micaceous siltstone; unit is planar to low-angle trough cross laminated, burrowed, and contains local pebble layers. Unit forms upward-fining sequences 0.5 to 2.5 m (1.6-8 ft) thick. Conglomeratic sandstone thickness exceeds 800 m (2,625 ft). Sandstone (**JTrps**) is interbedded grayish-red to brownish-red, medium- to fine-grained, medium- to thick-bedded sandstone and brownish- to purplish-red coarse-grained siltstone; unit is planar to ripple cross-laminated, fissile, locally calcareous, containing desiccation cracks and root casts. Upward-fining cycles are 1.8 to 4.6 m (6-15 ft) thick. Sandstone beds are coarser and thicker near conglomerate units (**JTrpcq**, **JTrpcl**). Maximum thickness about 1,100 m (3,610 ft).

Sandy mudstone (**JTrpms**) is reddish-brown to brownish-red, massive, silty to sandy mudstone and siltstone, which are bioturbated, ripple cross-laminated and interbedded with lenticular sandstone. To southwest where similar lithologic units also occur, they have not been mapped separately, but have been included in undivided unit **JTrp**. Rhythmic cycles 2 to 7 m (7-23 ft) of thick gray-bed sequences (**Trpg**), termed Van Houten cycles by Olsen (1985), contain basal thin-bedded to finely laminated shale to siltstone, which grade upward through laminated to microlaminated, locally calcareous mudstone to siltstone and finally into massive silty mudstone. Lowest part of cycle has some desiccation features and local fossils; middle part has highest organic content and the most fossils; highest part contains mudcracks, burrows, and root casts. Gray-bed cycles are abundant in lower half of Passaic Formation and less common in upper half. Rocks of the Passaic Formation have been locally thermally metamorphosed to hornfels where in contact with the Orange Mountain Basalt, diabase dikes, and sheetlike intrusions. Total thickness of formation ranges from 3500 to 3600 m (11480-11810 ft).

Trl, Trlr, Trla, Trls, Trlcq Lockatong Formation (Upper Triassic) (Kümmel, 1897) - Cyclically-deposited sequences consisting of light- to dark-gray, greenish-gray, and black, dolomitic or analcime-bearing silty argillite, laminated mudstone, silty to calcareous, argillaceous, very-fine-grained pyritic sandstone and siltstone, and minor silty limestone (**Trl**). Grayish-red, grayish-purple, and dark-brownish-red sequences (**Trlr**) common in upper half. Two types of cycles are recognized: detrital and chemical.

Detrital cycles average 5.2 m (17 ft) thick and consist of basal, argillaceous, very fine grained sandstone to coarse siltstone; medial, dark-gray to black, laminated siltstone, silty mudstone, or silty limestone; and upper, light- to dark-gray, silty to dolomitic or analcime-rich mudstone, argillitic siltstone, or very-fine-grained sandstone. Chemical cycles are similar to detrital cycles, but thinner, averaging 3.2 m (10.5 ft). Cycles in northern Newark basin are thinner and have arkosic sandstone in lower and upper parts. Upper part of formation in northern basin composed mostly of light-gray to light-pinkish-gray or light-brown, coarse- to fine-grained, thick- to massive-bedded arkosic sandstone (**Trla**). Thermally metamorphosed into hornfels where intruded by diabase (**Jd**). Interfingers laterally and gradationally with quartz sandstone and conglomerate (**Trls**) and quartzite conglomerate (Trlcq) near Triassic border fault in southwestern area of map. Maximum thickness of Lockatong Formation about 1,070 m (3,510 ft).

Trs, Trss, Trscq Stockton Formation (Upper Triassic) (Kümmel, 1897) - Light-gray, light-grayish-brown, yellowish- to pinkish-gray, or violet-gray to reddish-brown, medium- to coarse-grained arkosic sandstone and reddish- to purplish-brown mudstone, silty mudstone, argillaceous siltstone, and shale. Mudstone, siltstone and shale beds thicker and more numerous in central Newark basin west of Round Valley Reservoir. Sandstones mostly planar-bedded, with scoured bases containing pebble lags and mudstone rip-ups. Unit is coarser near Newark basin border fault, where poorly exposed, reddish-brown to pinkish-white, medium- to coarse-grained, feldspathic pebbly sandstone and conglomerate (**Trss**) and pebble to cobble quartzite conglomerate (**Trscq**). Maximum thickness of formation about 1,240 m (4,070 ft).

GREEN POND MOUNTAIN REGION

The Green Pond Mountain region, extending from Greenwood Lake to Califon, is a northeast-trending, narrow belt of Paleozoic rocks within the New Jersey Highlands. Lower Cambrian through Middle Devonian rocks are downwarped and block faulted in a half-graben that is complexly faulted along its northwest border. An overturned syncline dominates the northeast part of the region, whereas upright anticline and syncline pairs occur in the central and southwest parts. Moderate- to high-angle reverse faults that are subparallel to the regional fold axes occur on the southeast sides of large anticlines in the central part of the region. Cambrian and Ordovician rocks of the Kittatinny Valley sequence are mostly dolomite and lesser amounts of siliciclastic rocks. They are absent In the central part due to erosion, where the Silurian Green Pond Conglomerate rests unconformably on Middle and Late(?) Proterozoic rocks. The Silurian and Devonian rocks are lithologically unique to this region, but have been correlated with rocks of equivalent age in the Valley and Ridge Province (Barnett, 1970; Herman and Mitchell, 1991) to the northwest.

Dsk Skunnemunk Conglomerate, (Middle Devonian) (Darton, 1894) - Grayish-purple to grayish-red, thin- to very thick bedded, locally cross-bedded, polymictic conglomerate and sandstone containing clasts of white vein quartz, red and green quartzite and sandstone, red and gray chert, and red shale; interbedded with medium-gray, thin-bedded sandstone and greenish-gray and grayish-red, mud-cracked shale. Conglomerate and sandstone matrix is primarily hematite and microcrystalline quartz. Conglomerate cobbles range to 16.5 cm (6.5 in) long, and average cobble size increases in upper part of unit. Lower contact conformable and gradational as defined by Kimmel and Weller (1902). About 915 m (3,000 ft) thick.

Dbv Bellvale Sandstone (Middle Devonian) (Bellvale Flags of Darton, 1894; Willard, 1937) - Upper beds are grayish-red to grayish-purple sandstone containing quartz pebbles as large as 3 cm (1.2 in) in diameter. Lower beds are light-olive-gray- to yellowish-gray- and greenish-black-weathering, medium-gray to medium-bluish-gray very thin to very thick bedded siltstone and sandstone cross-bedded, graded and interbedded with black to dark-gray shale that is locally fossiliferous. More sandstone in upper beds becomes finer downward. Lower contact conformable and placed where beds thicken and volume of shale and siltstone are about equal. The unit is 535 to 610 m (1,750-2,000 ft) thick.

Dcw Cornwall Shale, (Middle Devonian) (Hartnagel, 1907) - Black to dark-gray, very-thin- to thick-bedded, fissile shale, fossiliferous, interbedded with medium-gray and light-olive-gray to yellowish-gray,

laminated to very-thin-bedded siltstone, that increases in upper part of unit. Lower contact probably conformable. About 290 m (950 ft) thick.

Dkec Kanouse Sandstone, Esopus Formation, and Connelly Conglomerate, undivided (Lower Devonian)

Kanouse Sandstone (Kümmel, 1908) - Medium-gray, light-brown, and grayish-red, fine- to coarse-grained, thin- to thick-bedded sparsely fossiliferous sandstone and pebble conglomerate. Basal conglomerate beds are interbedded with siltstone similar to the upper part of the Esopus Formation and contain well-sorted, subangular to subrounded, gray and white quartz pebbles less than 1 cm (0.4 in.) long. Lower contact gradational. About 14 m (46 ft) thick.

Esopus Formation - (Vanuxem, 1842; Boucot, 1959) - Light- to dark-gray, laminated to thin-bedded siltstone interbedded with dark-gray to black mudstone, dusky-blue sandstone and siltstone, and yellowish-gray fossiliferous siltstone and sandstone. Lower contact probably conformable with the Connelly Conglomerate. The formation is about 100 m (330 ft) thick at Greenwood Lake and estimated at 55 m (180 ft) thick in Longwood Valley.

Connelly Conglomerate (Chadwick, 1908) - Grayish-orange weathering, very light gray to yellowish-gray, thin-bedded quartz-pebble conglomerate. Quartz pebbles average 1 to 2 cm (0.4-0.8 in.), are subrounded to well rounded, and well sorted. The unit unconformably overlies the Berkshire Valley Formation. About 11 m (36 ft) thick.

Sbp Berkshire Valley and Poxono Island Formations, undivided (Upper Silurian) - Thickness ranges from 76 m (250 ft) at Greenwood Lake to 122 m (400 ft) in Longwood Valley.

Berkshire Valley Formation (Barnett, 1970) - Commonly yellowish-gray weathering, medium-gray to pinkish-gray, very thin to thin-bedded fossiliferous limestone interbedded with gray to greenish-gray calcareous siltstone and silty dolomite, medium-gray to light-gray dolomite conglomerate, and grayish-black, thinly laminated shale. Lower contact conformable. Thickness ranges from 27 to 38 m (90-125 ft) thick.

Poxono Island Formation, (White, 1882; Barnett, 1970) - Very thin to medium-bedded sequence of medium-gray, greenish-gray, or yellowish-gray, mud-cracked dolomite; light-green, pitted, medium-grained calcareous sandstone, siltstone, and edgewise conglomerate containing gray dolomite; and quartz-pebble conglomerate containing angular to subangular pebbles as much as 2 cm (0.8 in.) long. Interbedded grayish-green shales at lower contact are transitional into underlying Longwood Shale. Thickness ranges from 49 to 84 m (160-275 ft) thick.

Sl Longwood Shale, (Middle (?) and Upper Silurian) (Darton, 1894) – Dark-reddish-brown, thin- to very thick bedded shale interbedded with cross-bedded, very dark red, very thin to thin-bedded sandstone and siltstone. Lower contact conformable. About 100 m (330 ft) thick.

Sg Green Pond Conglomerate (Lower (?) and Middle Silurian) (Rogers, 1836) - Medium- to coarse-grained quartz-pebble conglomerate, quartzitic arkose and orthoquartzite, and thin- to thick-bedded reddish-brown siltstone. Grades downward into gray, very dark-red, or grayish-purple, medium- to coarse-grained, thin- to very thick bedded pebble to cobble conglomerate containing clasts of red shale, siltstone, and chert; yellowish-gray sandstone and chert; dark-gray shale and chert; and white-gray and pink milky quartz. Quartz cobbles are as long as 10 cm (4 in.), and rare red shale clasts as much as 46 cm (18 in.) across. Milky quartz pebbles average 2.5 cm (1 in.) in length. Red arkosic quartz-pebble conglomerate and quartzite are more abundant than gray and grayish-green quartzite. Unconformably overlies Martinsburg Formation, Allentown Dolomite, Leithsville Formation, or Proterozoic rocks. About 305 m (1000 ft) thick.

Om Martinsburg Formation (Middle and Upper Ordovician) - Yellowish-gray weathering, light-olive- to dark-gray, phyllonitic shale containing thin, discontinuous silty lenses. Crops out in two locations along

the Reservoir fault north of Bowling Green Mountain (Barnett, 1976; Herman and Mitchell, 1991). Contact relations and thickness unknown.

OCa Allentown Dolomite (Lowest Lower Ordovician and Upper Cambrian) (Wherry, 1909) - Medium- to very light gray, fine- to medium-grained, very thin to very thick bedded dolomite containing minor orthoquartzite and shale. Oolites and algal stromatolites occur throughout unit. Shaly dolomite increases downward towards lower conformable contact with the Leithsville Formation. Unit does not crop out but is known from subsurface borings near Flanders (Volkert and others, 1990). Thickness ranges from 0 to 73 m (0-240 ft) due to erosion.

Cl Leithsville Formation (Middle and Lower Cambrian) (Wherry, 1909) - Light- to dark-gray and light-olive-gray, fine- to medium-grained, thin- to medium-bedded dolomite. Grades downward through medium-gray, grayish-yellow, or pinkish-gray dolomite and dolomitic sandstone, siltstone and shale to medium-gray, medium-grained, medium-bedded dolomite containing quartz sand grains as stringers and lenses near the base. Lower contact gradational. Thickness ranges from 0 to 56 m (0-185 ft) due to erosion.

Ch Hardyston Quartzite (Lower Cambrian) (Wolff and Brooks, 1898) - Light- to medium-gray and bluish-gray conglomeratic sandstone. Varies from pebble conglomerate, to fine-grained, well-cemented quartzite, to arkosic or dolomitic sandstone. Conglomerate contains subangular to subrounded white quartz pebbles up to 2.5 cm (1 in.). Lower contact unconformable. About 0 to 9 m (1-30 ft) thick.

VALLEY AND RIDGE PROVINCE

The Valley and Ridge Province of northwestern New Jersey trends northeast and contains Lower Cambrian through Upper Ordovician rocks of the Kittatinny Valley Sequence to the southeast and Lower Silurian through Middle Devonian rocks to the northwest. The Taconic unconformity separates the Middle and Upper Ordovician Martinsburg Formation from the Lower and Middle Silurian Shawangunk Formation along the base of Kittattinny Mountain. Cambrian and Ordovician rocks consist of basal clastics, overlain by carbonates and a flysch to molasse clastic sequence. Above the Taconic unconformity, basal quartzite and conglomerate grade upward through interbedded sandstone and shale, interbedded carbonate and fine-grained clastics, and shale. These rocks were principally deformed principally during the Taconic and Alleghanian orogenies. Deformation generally decreases northwestward. Throughout the Valley and Ridge Province, folds are open to tight and upright, overturned, and gently inclined to recumbent. Within Kittatinny Valley, gently-dipping to high-angle faults are commonly exposed at the surface, whereas northwest of the Taconic unconformity, faults only locally are exposed at the present erosion surface.

Dm Marcellus Shale (Middle Devonian) (Vanuxem, 1840) - Medium-gray weathering, dark-gray to grayish-black, thin- to thick-bedded, fossiliferous, fissile and limonite-stained locally arenaceous shale. Lower contact grades downward over 12 m (40 ft) from black shale through limy shale, into silty limestone of the Buttermilk Falls Limestone (documented in drill core data of Fletcher and Woodrow, 1970). Approximately 274 m (900 ft) thick.

Db Buttermilk Falls Limestone and Onondaga Limestones, undivided (Middle Devonian) - Buttermilk Falls Limestone in southwestern part of outcrop belt grades into Onondaga Limestone along strike to northeast. The transition occurs north of Millville.

Buttermilk Falls Limestone (Middle Devonian) (Willard, 1938) - Light- to medium-light-gray-weathering, medium- to dark-gray, thin- to medium-bedded, fossiliferous, flaggy, clayey to silty limestone and nodular black chert. Lower contact grades downward through several meters (feet) of silty limestone to interbedded limestone and calcareous siltstone of the Schoharie Formation. Thickness is approximately 82 m (270 ft).

Onondaga Limestone (Middle Devonian) (Vanuxem 1840) - Light-medium-gray- weathering, medium gray, fine-grained, thin- to thick-bedded fossiliferous limestone. Black chert more abundant in upper half of unit. Lower contact grades into interbedded limestone and calcareous siltstone of the Schoharie

Formation. Thickness approximately 60 m (200ft).

Ds Schoharie Formation (Lower Devonian) (Vanuxem, 1840) - Yellowish-gray- to locally pale-olive-weathering, medium- to dark-gray, medium- to thick-bedded, calcaeous siltstone and lesser amounts of silty limestone. Locally contains thin ribs or pods of black chert in limestone. Limestone content decreases in lower part of unit. Contains the trace fossil *Taonurus*, a grazing trail. Lower contact gradational and placed at top of highest massive siltstone below lowest limestone. Thickness approximately 53 m (175 ft).

De Esopus Formation (Lower Devonian) (Vanuxem, 1842) - Medium-gray weathering, medium- to dark-gray, laminated to medium-bedded, partly massive, shaly to finely arenaceous siltstone, containing minor calcareous siltstone near top, locally limonite stained. Contains Taonurus. Rocks are cleaved in southwest and extreme northeast part of outcrop belt but not in central region. Lower contact sharp and unconformable where underlying Oriskany Group is coarse quartz sandstone. Elsewhere, lower contact conformable; fine sandstone to siltstone grades downward several meters into silty limestone. Thickness approximately 91 m (300 ft).

Do Oriskany Group, undivided (Lower Devonian) (Willard, 1938) - Thickness ranges from 38 m (125 ft) in southwest to 52 m (170 ft) in northeast.

Ridgely Sandstone (Swartz and others, 1913) – White-weathering, medium-gray, medium- to thick-bedded, carbonate-cemented quartz-pebble conglomerate and coarse quartz sandstone, which contain abundant brachiopods. Moderately well sorted, subrounded sand gains. Unit thins northeastward and pinches out at Peters Valley. Lower contact abrupt. Thickness ranges from 0 to 10 m (0-32 ft).

Shriver Chert (Swartz and others, 1913) - Medium- to dark-gray-weathering, black to dark-gray, medium- to thick-bedded siltstone and shale containing interbedded black chert and local chert-bearing limestone. Present only in southwestern part of outcrop area where lower contact is gradational with silty limestone of Glenarie Formation. Thickness ranges from 0 to 9 m (0-30 ft).

Glenarie Formation (Chadwick, 1908) - Medium-gray-weathering, medium- to dark-gray, fine-grained, thin- to medium-bedded, fossiliferous, silty limestone, and local chert lenses. Unit thickens to northeast. Lower contact probably gradational. Thickness ranges from 17 to 52 m (55-170 ft).

Helderberg Group (Lower Devonian and Upper Silurian)

Dp Port Ewen Shale (Lower Devonian) (Clarke, 1903) - Upper part is medium-gray- weathering, dark- to medium-dark-gray, thin- to medium-bedded, fossiliferous, calcareous siltstone and shale. Lower part is medium-dark-gray, irregularly bedded nonfossiliferous, calcareous silty shale. Lower contact abrupt and placed at top of uppermost medium-gray, argillaceous limestone in Minisink Limestone. Thickness approximately 46 m (150 ft).

Dmn Minisink Limestone and New Scotland Formation, undivided (Lower Devonian)

Minisink Limestone (Epstein and others, 1967) - Light-medium-gray-weathering, medium-gray, fine-grained, medium-bedded, partly massive, argillaceous fossiliferous limestone. Some nodules and lenses of purer limestone occur locally. Lower contact gradational. Thickness uniformly 7 m (23 ft).

New Scotland Formation (Clarke and Schuchert, 1899) - Upper part is dark-gray, very fine grained, laminated to thin-bedded siliceous shale containing pods of medium-dark-gray, very fine grained limestone; scattered thin beds and lenses of medium-gray, fine-grained argillaceous fossiliferous limestone; and small dark-gray chert nodules. Lower part is medium-dark-gray, thin-bedded, siliceous, fossiliferous calcareous shale. Contains thin beds and lenses of medium-gray, fine-grained, highly fossiliferous, argillaceous limestone containing nodules, lenses and, locally, irregular beds of dark-gray chert. Lower contact abrupt and placed at top of calcareous quartz sandstone. Total thickness is

approximately 23 m (75 ft).

Dc Coeymans Formation, Kalkberg Limestone, Coeymans Limestone, Manlius Limestone, undivided (Lower Devonian) - At New York border consists of fine-grained, chert-bearing, argillaceous limestone (Kalkberg Limestone) grading downward through coarse-grained limestone (Coeymans Limestone) into fine-grained limestone (Manlius Limestone). Toward southwest these units grade into fine- to coarse-grained limestone with a marked increase in quartz sand that comprises the Coeymans Formation (Epstein and others, 1967). Total thickness 27 m (90 ft).

Kalkberg Limestone (Chadwick, 1908) - Medium-gray-weathering, medium-dark-gray, fine-grained, very thin to massively bedded fossiliferous limestone. Grades downward into fine- to medium-grained, thin-bedded, fossiliferous argillaceous limestone containing nodules and lenses of dark-gray chert. Grades to the southwest into calcareous and arenaceous rocks of the upper part of the Coeymans Formation near Wallpack Center. Lower contact placed at base of lowest black chert. Approximately 12 m (40 ft) thick.

Coeymans Limestone (Clarke and Schuchert, 1899) - Medium-gray weathering, medium-dark-gray, fine- to coarse-grained, medium- to massively bedded fossiliferous limestone and local argillaceous limestone lenses. Unit is approximately 9 m (30 ft) thick. Between Duttonville and Millville, grades into biohermal and nonbiohermal facies of medium- to coarse-grained limestone of Coeymans Formation of Epstein and others (1967).

Manlius Limestone (Vanuxem, 1840) - Medium-gray weathering, medium-dark- to dark-gray, very fine to fine-grained, unevenly bedded fossiliferous limestone. Some local medium-grained limestone, yellowish-gray shale partings and biostromes. Near Hainesville, unit grades into lower part of Coeymans Formation. Lower contact abrupt and placed at top of uppermost very fine grained argillaceous limestone. Thickness approximately 11 m (35 ft).

Coeymans Formation (Epstein and others, 1967) - Medium-light-gray, fine- to coarse-grained calcareous sandstone and medium-gray, fine- to coarse-grained, medium- to thick-bedded, locally irregularly-bedded, argillaceous to arenaceous limestone containing lenses of quartz sand and nodules of black chert. Grades downward into medium-gray, fine-grained, argillaceous and arenaceous limestone containing local beds of fine- to coarse-grained pebbly calcareous sandstone. Local bioherms consisting of light-gray to light-pinkish-gray, coarse-grained to very coarse biogenic limestone are unbedded and have sharp boundaries. Lower contact of unit abrupt. Formation thickness varies from 11 m (35 ft) in northeast to 24 m (80 ft) in southwest.

DSrd Rondout and Decker Formations, undivided (Lower Devonian and Upper Silurian)

Rondout Formation (Clarke and Schuchert, 1899) - Upper part is medium-gray weathering, medium-dark-gray, very fine to fine-grained, medium-bedded, fossiliferous, argillaceous limestone. Middle part is light-medium-gray-weathering, medium-gray, laminated to medium-bedded, argillaceous dolomite. Locally contains deep desiccation polygons. Lower part is medium-gray-weathering, medium- to dark-gray, very fine to medium-grained, medium-bedded fossiliferous limestone. Silurian-Devonian boundary placed in middle of formation (Denkler and Harris, 1988). Lower contact abrupt and placed at top of highest calcareous quartz sandstone. Thickness approximately 12 m (40 ft).

Decker Formation (White, 1882) - Light-gray- to yellowish-gray-weathering, light- to medium-gray, calcareous quartz siltstone, sandstone, and fine-pebble conglomerate locally interbedded with fossiliferous medium-gray, medium- to coarse-grained limestone and very fine grained, thin- to medium-bedded dolomite. Lower contact gradational. Thickness varies from 15 m (50 ft) near Duttonville to 25 m (82 ft) at Wallpack Center.

Sbv Bossardville Limestone (Upper Silurian) (White, 1882) - Light-gray to yellowish- gray-weathering, medium-gray to medium-dark-gray, very fine grained, locally fossiliferous, laminated to thin-bedded limestone and argillaceous limestone. Desiccation polygons occur in southwest. Lower contact is gradational and placed at top of uppermost dolomite. Thickness approximately 30 m (100 ft) in

southwest, thinning to 3.1 m (10 ft) at New Jersey-New York State boundary.

Sp Poxono Island Formation (Upper Silurian) (White, 1882) - Greenish-gray, finely crystalline to aphanitic, thin- to medium-bedded, flaggy dolomite containing discontinuous lenses of disseminated, rounded quartz grains. Some local quartz sandstone beds and argillaceous dolomite. Lower contact gradational (Epstein, 1973). Formation poorly exposed; located by drill data. Thickness estimated at 183 m (600 ft) from well data.

Sb Bloomsburg Red Beds (Upper Silurian) (White, 1883) (High Falls Shale of previous usage) - Grayish-red, thin- to thick-bedded, poorly to moderately well sorted, massive siltstone, sandstone, and local quartz-pebble conglomerate containing local planar to trough crossbedded laminations. Conglomerate consists of matrix-supported quartz pebbles in grayish-red, fine-grained sandstone matrix. Locally, near base of unit, is greenish-gray, light-gray, or grayish-orange, massive, planar tabular to trough crossbedded quartz sandstone to siltstone with subrounded grains. Lower part of formation marked by several upward-fining sequences of light-gray sandstone grading through grayish-red, fine-grained sandstone and siltstone to grayish-red, mudcracked siltstone and mudstone. Each sequence is 1 to 3 m (3-10 ft) thick. Lower contact placed at bottom of lowermost red sandstone. Thickness approximately 460 m (1,510 ft).

Ss Shawangunk Formation (Middle and Lower Silurian) (Mather, 1840; Epstein and Epstein, 1972) - Upper part is medium- to medium-dark-gray, or dark-greenish-gray, medium- to thick-bedded sandstone and pebble conglomerate having well rounded grains, some of which are limonite stained. Conglomerate consists of matrix-supported quartz and subordinate shale pebbles as long as 5 cm (2 in.) in poorly to well-sorted, planar tabular to trough crossbedded sandstone. Local black to dark-greenish-gray, thin-bedded shale near upper contact. Middle part, occurring in southwest and sporadically in northeast, is light- to medium-dark-gray, greenish-gray, interbedded thin- to medium-bedded, planar tabular to trough cross-bedded shale and sandstone. Grains are well rounded and moderately to well sorted. Contains sparse graphite flakes. Lower part is light- to medium-gray to light-olive-gray, thin- to thick-bedded quartz and feldspathic sandstone, quartzite, and quartz-pebble conglomerate, which is matrix-supported, poorly to well sorted, cross to planar bedded. Clasts are primarily quartz and sparse dark-gray argillite and black chert. Sandstone is feldspathic and locally approaches an arkose in compostion. Lower contact unconformable and, at places, is a fault of small displacement. Thickness approximately 427 m (1,400 ft).

Beemerville Intrusive Suite (Early Silurian? and Late Ordovician) (Drake and Monteverde, 1992)

SObs Nepheline syenite - Medium- to dark-gray, medium- to coarse-grained, alkalic to alkalic-calcic nepheline syenite. Composed principally of nepheline, orthoclase, biotite, and clinopyroxene, and accessory minerals are magnetite, apatite, titanite, zircon, and pyrite. Restricted to two small bodies northwest of Beemerville. Intrudes the Martinsburg Formation, but appears to be unconformably overlain by the Shawangunk Formation. K-Ar and Rb-Sr ages of 435±20 Ma from biotite (Zartman and others, 1967) and a fission track date from titanite of 422±14 Ma (Eby and others, 1992) suggest emplacement in Late Ordovician to Early Silurian.

SObb Ouachitite breccia - Medium-dark-gray, fine-grained ouachitite (olivine-free biotite lamprophyre) containing pebble- to cobble-size xenoliths of Middle Proterozoic rock, dolomite of the Kittatinny Supergroup(?), the Martinsburg Formation, and autoliths of potassic syenite, lamprophyre, and carbonatite. Found in numerous diatremes in the Beemerville area; largest of at Rutan Hill.

SObl Lamprophyre, tinguaite (phonolite with acicular acmite crystals), phonolite, bostonite (trachyte), and malignite (mafic nepheline syenite), undifferentiated - Light-medium- to medium-dark-gray, aphanitic to fine-grained, alkalic to calc-alkalic dikes and sills. Unit intrudes rocks from the Middle Proterozoic to the High Point Member of the Martinsburg Formation, but does not intrude the Shawangunk Formation. K-Ar date of 422±14 Ma from biotite phenocrysts in a minette (lamprophyre with biotite phenocrysts) dike (Charles Milton, written commun., 1972) suggests a Early Silurian age for some of these rocks.

KITTATINNY VALLEY SEQUENCE

Rocks of Cambrian through Ordovician age within the Kittatinny Valley and valleys infaulted into the Highlands are assigned to the Kittatinny Valley sequence. These rocks were previously ascribed to the Lehigh Valley sequence of MacLachlan (1979). The Kittatinny Valley sequence includes the carbonate and siliciclastic rocks of the Hardyston Quartzite and Kittatinny Supergroup, the localized clastic and carbonate rocks of the sequence at Wantage, the Jacksonburg Limestone, and the Martinsburg Formation. Principal differences between the Kittatinny Valley and Lehigh Valley sequences, northeast from Pennsylvania to New York are: 1) thinning of the Kittatinny Supergroup, 2) dominance of dolomite relative to limestone in the Kittatinny Supergroup, 3) thinning to total absence of the argillaceous facies of the Jackonsburg Limestone, and 4) thinning and coarsening of the Martinsburg Formation.

Om Martinsburg Formation, undivided (Upper and Middle Ordovician) (Bayley and others, 1914) - Interbedded light-olive-gray, greenish-gray-, or dark-yellowish-brown- weathering, medium-dark- to dark-gray, laminated to medium-bedded graywacke and siltstone and olive-gray- to dark-yellowish-brown-weathering, medium-dark- to dark-gray slate. Turbidite cycles are common. Mapped only east of Lafayette and west of Lake Grinnell where thickness is at least 305 m (1000 ft).

Omh High Point Member (Upper Ordovician) (Drake, 1991) - Medium-dark-gray, thin-bedded shale, siltstone and fine-grained sandstone, containing turbidite sequences T_{bcde} to T_{cde} of Bouma (1962). Interbedded with less abundant, light-yellowish-gray-weathering, medium-gray to medium-dark-gray, medium-grained, medium- to thick-bedded and massive, quartz- and calcareous-cemented quartz sandstone containing rip-ups of medium- to dark-gray shale and siltstone that commonly consist of Bouma (1962) turbidite sequences T_{ab} to T_a. Restricted to northeast section of Martinsburg outcrop belt. Thermally metamorphosed near intrusive bodies. Grades along strike to the southwest into Ramseyburg Member by decrease in average grain size, absence of shale rip-ups, and lack of siliceous cement. Lower contact gradational and placed at base of lowermost thick-bedded graywacke or amalgamated graywacke containing shale rip-ups. Unit assigned to *Orthograptus ruedemanni* zone to *Climacograptus spiniferus* zone of Riva (1969, 1974) using graptolites collected by Parris and Cruikshank (1992). Thickness ranges from 0 to 1,370 m (0-4,500 ft).

Omr Ramseyburg Member (Upper and Middle Ordovician) (Drake and Epstein, 1967) - Interbedded medium- to dark-gray, to brownish-gray, fine- to medium-grained, thin- to thick-bedded graywacke sandstone and siltstone and medium- to dark-gray, laminated to thin-bedded shale and slate. Unit may form complete turbidite sequences, T_{abcde} (Bouma, 1962), but basal cutout sequences T_{cde} dominate. Basal scour, sole marks, and soft-sediment distortion of beds are common in graywacke. Thermally metamorphosed near intrusive bodies. Lower contact placed at bottom of lowest thick- to very thick bedded graywacke, but contact locally grades through sequence of dominantly thin-bedded shale and slate and minor thin- to medium-bedded discontinuous and lenticular graywacke beds in the Bushkill member. Parris and Cruikshank (1992) correlate unit with *Orthograptus ruedemanni* to lowest part of *Climacograptus spiniferus* zones of Riva (1969, 1974). Thickness ranges from 640 m (2,100 ft) in Delaware River Valley, to 1,524 m (5,000 ft) near Stillwater, to 1067 m (3,500 ft) at New York State line.

Omb Bushkill Member (Middle Ordovician) (Drake and Epstein, 1967) - Interbedded medium- to dark-gray, thinly laminated to thick-bedded shale and slate and less abundant medium-gray to brownish-gray, laminated to thin-bedded siltstone. To the southwest, fine-grained, thin dolomite lenses occur near base. Complete turbidite sequences (Bouma, 1962) occur locally, but basal cutout sequences (T_{bcde}, T_{cde} or T_{de}) dominate. Conformable lower contact is placed at top of highest shaly limestone; elsewhere, lower contact is commonly strain slipped. Correlates with graptolite *Climacograptus bicornis* to *Corynoides americanus* zones of Riva (1969, 1974) (Parris and Cruikshank, 1992). Thickness ranges from 1,250 m (4,100 ft) in Delaware River Valley to 457 m (1,500 ft) at New York State line.

Oj Jacksonburg Limestone (Middle Ordovician) (Kümmel, 1908; Miller, 1937) - Upper part is medium- to dark-gray, laminated to thin-bedded shaly limestone and less abundant medium-gray arenaceous limestone containing quartz-sand lenses. Upper part thin to absent to northeast. Lower part is interbedded medium- to dark-gray, fine- to medium-grained, very thin to medium-bedded fossiliferous

limestone and minor medium- to thick-bedded dolomite-cobble conglomerate having a limestone matrix. Unconformable on Beekmantown Group and conformable on the discontinuous sequence at Wantage in the Paulins Kill area. Contains conodonts of North American midcontinent province from *Phragmodus undatus* to *Aphelognathus shatzeri* zones of Sweet and Bergstrom (1986). Thickness ranges from 41 to 244m (135-800 ft).

Ow Sequence at Wantage (Middle Ordovician) (Monteverde and Herman, 1989) – Restricted, discontinuous sequence of interbedded limestone, dolomite, conglomerate, siltstone, and shale. Upper part is medium-yellowish-brown- to olive-gray-weathering, medium- to dark-gray, very fine to fine-grained, laminated to massive limestone and dolomite that grade down into underlying clastic rocks of lower part. Upper part locally absent. Lower part ranges from grayish-red, medium-gray, pale-brown, and greenish-gray to pale-green mudstone and siltstone containing disseminated subangular to subrounded chert-gravel, quartz-sand lenses, and chert-pebble conglomerate. Lower contact unconformable. Thickness ranges from 0 to 46 m (0-150 ft).

Kittatinny Supergroup (Lower Ordovician and Cambrian) (Drake and Lyttle, 1980)

Beekmantown Group (Lower Ordovician) (Clarke and Schuchert, 1899)

Obu Upper part - Locally preserved upper beds are light- to medium-gray- to yellowish-gray-weathering, medium-light- to medium-gray, aphanitic to medium-grained, thin- to thick-bedded, locally laminated, slightly fetid dolomite. Medium-dark to dark-gray, fine-grained, medium-bedded, sparsely fossiliferous limestone lenses occur locally. Lower beds are medium-dark- to dark-gray, medium- to coarse-grained, mottled surface weathering, medium- to thick-bedded, strongly fetid dolomite that contains pods and lenses of dark-gray to black chert. Cauliflower-textured black chert beds of variable thickness occur locally. Gradational lower contact is placed at top of laminated to thin-bedded dolomite of the lower part (**Obl**) of the Beekmantown Group. Contains conodonts high in the *Rossodus manitouensis* zone to low zone D of the North American midcontinent province as used by Sweet and Bergstrom (1986). Upper beds are included in Epler Formation; lower beds are included in Rickenbach Dolomite of Drake and Lyttle (1985) and Drake and others (1985); entire upper part (**Obu**) is Ontelaunee Formation of Markewicz and Dalton (1977). Thickness ranges from 0 to 244 m (0-800 ft).

Obl Lower part - Very thin to thick-bedded, interbedded dolomite and minor limestone. Upper beds are light-olive-gray to dark-gray, fine- to medium-grained, thin- to thick-bedded dolomite. Middle part is olive-gray-, light-brown-, or dark-yellowish-orange- weathering, dark-gray, aphanitic to fine-grained, laminated to medium-bedded dolomite and light-gray to light-bluish-gray-weathering, medium-dark- to dark-gray, fine-grained, thin- to medium-bedded limestone, that is characterized by mottling with reticulate dolomite and light-olive-gray to grayish-orange, dolomitic shale laminae surrounding limestone lenses. Limestone grades laterally and down section into medium- gray, fine-grained dolomite. Lower beds consist of medium-light- to dark-gray, aphanitic to coarse-grained, laminated to medium-bedded, locally slightly fetid dolomite having thin black chert beds, quartz-sand laminae, and oolites. Lenses of light-gray, very coarse to coarse-grained dolomite and floating quartz sand grains and quartz-sand stringers at base of sequence. Lower contact placed at top of distinctive medium-gray quartzite. Contains conodonts of *Cordylodus proavus* to *Rossodus manitouensis* zones of North American Midcontinent province as used by Sweet and Bergstrom (1986). Unit **Obl** forms Stonehenge Formation of Drake and Lyttle (1985) and Drake and others (1985), upper and middle beds are included in Epler Formation, and lower beds are in Rickenbach Dolomite of Markewicz and Dalton (1977). Unit is about 183 m (600 ft) thick.

OCa Allentown Dolomite (Lower Ordovician and Upper Cambrian) (Wherry, 1909) – Very thin to very thick bedded dolomite containing minor orthoquartzite and shale. Upper part is medium-light- to medium-dark-gray, fine- to medium-grained, locally coarse-grained, medium- to very thick bedded dolomite. Floating quartz sand grains and two sequences of medium-light- to very light gray, thin-bedded quartzite and discontinuous, dark-gray chert lenses occur directly below upper contact. Rhythmically bedded lower dolomite beds alternate between light and dark gray weathering, medium and very light gray, fine and medium grained, and thin and medium bedded, which are interbedded with shaly dolomite. Ripple marks, crossbeds, edgewise conglomerate, mud cracks, oolites, and algal stromatolites occur

throughout unit, but more typically in lower part. Shaly dolomite increases downward toward lower conformable contact with the Leithsville Formation. Oldest beds contain trilobite fauna of early Late Cambrian age; younger beds contain latest Cambrian fauna (Howell, 1945; Howell and others, 1950). Thickness about 580 m (1,900 ft).

Cl Leithsville Formation (Middle to Lower Cambrian) (Wherry, 1909) - Thin- to thick-bedded dolomite containing subordinate siliciclastic rocks. Upper part is medium- to medium-dark-gray, fine- to medium-grained, pitted, friable, mottled and massive dolomite. Middle part is medium-gray, stylolitic, fine-grained, thin- to medium-bedded dolomite that is interbedded with shaly dolomite and, less commonly, varicolored quartz sandstone, siltstone, and shale. Lower part is medium-gray, medium-grained, medium-bedded dolomite containing quartz-sand grains in stringers and lenses near the contact with the Hardyston Quartzite. Archaeocyathids of Early Cambrian age suggest an intraformational disconformity separating rocks of Middle and Early Cambrian age (Palmer and Rozanov, 1976). Thickness approximately 305 m (1,000 ft).

Ch Hardyston Quartzite (Lower Cambrian) (Wolff and Brooks, 1898) - Medium- to light-gray, fine- to coarse-grained, medium- to thick-bedded quartzite, arkosic sandstone and dolomitic sandstone. Basal pebble to cobble conglomerate typically contains clasts of local basement affinities. Contains fragments of the trilobite *Olenellus thompsoni* of Early Cambrian age. Thickness approximately 0.5 to 62 m (1.6-200 ft).

JUTLAND KLIPPE SEQUENCE

Rocks of the Jutland klippe sequence occur in six isolated fragments of the Jutland klippe east of Jutland and two fragments of the Peapack klippe along the Peapack-Ralston fault in the New Jersey Highlands hinterland. The sequence is largely varicolored shale and sandstone, but contains lesser amounts of limestone, dolomite and pebble conglomerate. Lash and Drake (1984) correlate this sequence with the accretionary prism deposits of the Greenwich slice of the Hamburg klippe in eastern Pennsylvania. Rocks of the Jutland klippe sequence were folded and thrust over rocks of the Kittatinny Valley sequence during the Taconic orogeny and then were deformed during the Alleghanian orogeny and again during Mesozoic rifting of eastern North America.

OCjt Rocks of the Jutland klippe sequence, undifferentiated (Middle Ordovician to Upper Cambrian?)

Ojtb Unit B of Perissoratis and others (1979) (Middle Ordovician) - Heterogeneous sequence of interbedded red, green, tan and gray shale; interlaminated dolomite and shale; interbedded fine-grained graywacke siltstone and beds or lenses of sandstone; light-gray to pale-pinkish-gray quartzite; and interbedded fine-grained, thin-bedded limestone and red and green shale. Limestone locally resembles an intraformational conglomerate because it is disrupted, boudinaged, and surrounded by shale beds. Lower contact gradational and within interbedded sequence of thin- to medium-bedded sandstone, siltstone, and limestone. Perissoratis and others (1979) placed this contact at boundary between graptolite faunas *Isograptus caduceus* and *Paraglossograptus etheridgei* of Berry (1968). The youngest graptolites occur within *Climacograptus bicornis* zone of Berry (1968). Some shale beds contain conodonts (Ethington and others, 1958; Karklins and Repetski, 1989) and brachiopod fragments. Carbonate and pelitic rocks locally contain conodonts of *Prioniodus triangularis* to *Pygodus anserinus* faunas of North Atlantic Realm. Thickness varies due to structural complexity, but may be about 460 to 550 m (1,500-1,800 ft).

OCjta Unit A of Perissoratis and others (1979) (lower Middle Ordovician to Upper Cambrian) - Interbedded red, green, and tan shale, sandstone, and dark-gray, aphanitic to fine-grained limestone, which contains floating quartz-sand grains. Grades downward through interbedded sequence of red, green and brown shale to medium-gray to brown, fine- to coarse-grained sandstone and quartz-pebble conglomerate. Lower beds are dark-gray shale and siltstone containing minor dark-gray, aphanitic to fine-grained, medium-bedded limestone. Lower contact is a fault. Contains graptolites in the span of *Anisograptus* to *Isograptus caduceus* of Berry (1968) (Perissoratis and others, 1979) and conodonts of

the Cordylodus proavus to *Paroistodus proteus* faunas of the North Atlantic Realm. Thickness is unknown.

MANHATTAN PRONG

CZm Manhattan Schist (Lower Cambrian and (or) Late Proterozoic) (Hall, in press) - Medium-dark-gray, medium- to coarse-grained schist and gneiss composed of biotite, muscovite, quartz, and plagioclase, and local accessory minerals sillimanite, kyanite, tourmaline, and garnet. Contains some interlayered amphibolite. Unit is not exposed in the map area, but is present in boring logs.

CZs Serpentinite (Cambrian and Late Proterozoic) - Light-yellowish-green to dark-green, fine-grained, massive serpentinite containing locally abundant magnetite where fresh. Contains a variety of serpentine minerals and alteration products where sheared or weathered. Exposed only along the Hudson waterfront in Hoboken but present elsewhere in boring logs.

NEW JERSEY HIGHLANDS

Rocks of Middle and Late Proterozoic age occur in the New Jersey Highlands. Middle Proterozoic rocks consist of heterogeneous metasedimentary and metavolcanic gneisses and granofels intruded by the synkinematic Byram and Lake Hopatcong Intrusive Suites and the postkinematic Mount Eve Granite. The oldest rocks are plagioclase-rich gneiss and associated amphibolite of the Losee Metamorphic Suite, which is a metamorphosed sequence of dacite, quartz keratophyre, basalt, and intrusive tonalite and trondhjemite. They are associated with charnockitic gneisses and granulites that probably have a metavolcanic protolith. These rocks are unconformably overlain by quartz-feldspar gneisses of arkosic and graywacke composition, felsic volcanic rocks, quartzite, calc-silicate gneiss, and marble. Rocks of the Lake Hopatcong and Byram Intrusive Suites and the Mt. Eve Granite intrude all of these lithologies. Middle Proterozoic rocks were regionally metamorphosed to upper amphibolite to hornblende granulite facies. The Late Proterozoic Chestnut Hill Formation is a weakly to nonmetamorphosed sequence of interbedded clastic, metavolcanic rocks, and metasaprolite locally preserved as erosional remnants and small slices along faults. Diabase dikes of probable Late Proterozoic age intrude all Middle Proterozoic rocks of the Highlands geologic province.

Zd Diabase dikes (Late Proterozoic) (Ratcliffe, 1987; Puffer and others, 1991) - Medium- to dark-greenish-gray, aphanitic to fine-grained dikes that are dense and hard. Contacts are typically chilled and sharp against enclosing country rock. Tholeiitic to alkalic composition; and hypersthene a normative mineral. Composed principally of plagioclase (labradorite to andesine), augite, and ilmenite and (or) magnetite. Locally occurring pyrite blebs are ubiquitous. Dikes range from a few cm to 20 m (an in.-65 ft) wide and as much as 5 km (3 mi) long. Occur throughout the Highlands, but intrude only Middle Proterozoic rocks.

Zch Chestnut Hill Formation (Late Proterozoic) (Drake, 1984) - Interbedded arkose, ferruginous quartzite, quartzite conglomerate, metarhyolite, and metasaprolite. Confined to a few small areas north and east of Phillipsburg, on the western side of Bowling Green Mountain, northwest of High Bridge, and a few areas too small to show at this map scale.

Ygm Mount Eve Granite (Middle Proterozoic) (Drake and others, 1991a) - Light-pinkish-gray or grayish-tan-weathering, light-gray to pinkish-gray, medium- to coarse-grained granite containing microcline microperthite, quartz, oligoclase, and biotite. Common accessory minerals include hornblende, biotite, magnetite, and allanite. Most of the rock is a syenogranite. Upper intercept U-Pb age of 1,020±4 Ma (Drake and others, 1991a). Occurs in Pochuck Mountain area along New York boundary.

Byram Intrusive Suite (Middle Proterozoic) (Drake, 1984)

Ybh Hornblende granite - Pinkish-gray- to medium-buff-weathering, pinkish-white or light-pinkish-gray, medium- to coarse-grained, gneissoid to indistinctly foliated granite and sparse granite gneiss composed principally of microcline microperthite, quartz, oligoclase, and hornblende. Some phases are quartz

syenite or quartz monzonite. Includes small bodies of pegmatite and amphibolite not shown on map. U-Pb age approximately 1,090 Ma (Drake and others, 1991b).

Ybs Hornblende syenite – Tan- to buff-weathering, pinkish-gray or greenish-gray, medium- to coarse-grained, gneissoid syenite and lesser amounts of quartz syenite containing microcline microperthite, oligoclase, quartz, and hornblende. Some phases are monzonite or monzodiorite.

Ybb Biotite granite – Pink- to buff-weathering, light-pinkish-gray, medium-grained, massive, moderately foliated granite composed of microcline microperthite, quartz, oligoclase, and biotite.

Yba Microperthite alaskite – Pink- to buff-weathering, light-pinkish-gray or pinkish-white, medium- to coarse-grained, gneissoid to indistinctly foliated granite composed principally of microcline microperthite, quartz and oligoclase. Includes small bodies of amphibolite not shown on map.

Lake Hopatcong Intrusive Suite (Middle Proterozoic) (Drake and Volkert, 1991)

Ypg Pyroxene granite – Gray- to buff- or white-weathering, greenish-gray, medium- to coarse-grained, massive, gneissoid to indistinctly foliated granite containing mesoperthite to microantiperthite, quartz, oligoclase, and clinopyroxene. Common accessory minerals include titanite, magnetite, apatite, and trace amounts of pyrite. Some phases are monzonite, quartz monzodiorite, or granodiorite. Locally includes small bodies of amphibolite not shown on map.

Yps Pyroxene syenite – Gray- to buff- or tan-weathering, greenish-gray, medium- to coarse-grained, massive, indistinctly foliated syenite composed of mesoperthite to microantiperthite, oligoclase and clinopyroxene. Contains sparse amounts of quartz, titanite, magnetite, and trace amounts of pyrite.

Ypa Pyroxene alaskite - Light-gray- or tan-weathering, greenish-buff to light-pinkish-gray, medium- to coarse-grained, massive, moderately foliated granite composed of mesoperthite to microantiperthite, oligoclase, and quartz. Common accessory minerals are clinopyroxene, titanite and magnetite. Locally includes small bodies of amphibolite not shown on map.

Ys Syenite gneiss - Light-pinkish-white- to buff-white-weathering, greenish-gray, medium-grained, moderately foliated rock consisting of two distinct phases: hornblende syenite gneiss containing microcline microperthite, oligoclase, hornblende, and opaque minerals; and pyroxene syenite gneiss containing microcline microperthite, oligoclase, clinopyroxene, accessory amounts of titanite, and opaque minerals. Despite the co-mingling of these two phases, they appear to belong respectively to the Byram and Lake Hopatcong Intrusive Suites. In Hamburg Mountain area.

Metasedimentary Rocks (Middle Proterozoic)

Yk Potassium-feldspar gneiss - Light-gray- to pinkish-buff-weathering, pinkish-white to light-pinkish-gray, fine- to medium-grained, moderately foliated gneiss and lesser amounts of granofels composed of quartz, microcline, microcline microperthite and local accessory amounts of biotite, garnet, sillimanite, and opaque minerals.

Ym Microcline gneiss - Light-gray- to pinkish-white-weathering, tan to pinkish-white, fine- to medium-grained, well-layered gneiss composed principally of quartz, microcline, and lesser amounts of oligoclase. Common accessory minerals include biotite, garnet, magnetite, and, locally, sillimanite.

Yb Biotite-quartz-feldspar gneiss - Gray-weathering, locally rusty, gray to tan or greenish-gray, fine- to medium-coarse-grained, moderately layered and foliated gneiss that is variable in texture and composition. Composed of oligoclase, microcline microperthite, quartz, and biotite. Locally contains garnet, graphite, sillimanite, and opaque minerals.

Ymh Hornblende-quartz-feldspar gneiss - Pinkish-gray- to buff-weathering, light- pinkish-white to pinkish-gray, fine- to medium-grained, massive to moderately well layered gneiss containing microcline,

quartz, oligoclase, hornblende, and magnetite. Locally contains garnet and biotite.

Ymp Clinopyroxene-quartz-feldspar gneiss - Pinkish-gray- or pinkish-buff-weathering, white to pale-pinkish-white or light-gray, fine- to medium-grained, massive to moderately well-layered gneiss composed of microcline, quartz, oligoclase, clinopyroxene, and trace amounts of epidote, biotite, titanite, and opaque minerals. Commonly interlayered with amphibolite or pyroxene amphibolite.

Yp Pyroxene gneiss – White- to tan-weathering, greenish-gray, fine- to medium-grained, well-layered gneiss containing oligoclase, clinopyroxene, variable amounts of quartz, and trace amounts of opaque minerals and titanite. Some phases contain scapolite and calcite. Commonly interlayered with pyroxene amphibolite or marble.

Yf Franklin Marble – White- to light-gray-weathering, white, grayish-white, or, less commonly pinkish-orange, coarse- to locally fine-crystalline calcite marble with accessory amounts of graphite, phlogopite, chondrodite, clinopyroxene, and serpentine. Contains pods and layers of clinopyroxene-garnet skarn, hornblende skarn, and clinopyroxene-rich rock. Thin layers of metaquartzite occur locally. Intruded by the Mount Eve Granite in the Pochuck Mountain area. Franklin Marble is host to the Franklin and Sterling Hill zinc ore bodies; exploited for talc and asbestiform minerals near Easton, Pennsylvania. Subdivided into an upper marble, "Wildcat marble," and a lower marble, "Franklin marble," by New Jersey Zinc Co. geologists (Hague and others, 1956).

Yq Quartzite - Light-gray, medium-grained, massive- to well-layered, vitreous, partly feldspathic quartzite having sparse flakes of graphite. Associated with potassium-feldspar gneiss (**Yk**), biotite-quartz-feldspar gneiss (**Yb**), pyroxene gneiss (**Yp**), Franklin Marble (**Yf**), and pyroxene-epidote gneiss (**Ype**).

Ype Pyroxene-epidote gneiss - White- to light-gray-weathering, light-greenish-gray or greenish-buff, fine- to medium-grained, moderately layered and foliated gneiss composed principally of quartz, microcline, plagioclase, clinopyroxene, epidote, and sparse amounts of titanite. Some phases of this unit are quartz-rich. May be interlayered and probably related to pyroxene gneiss (**Yp**).

Ye Epidote gneiss – Light-gray- to pinkish-white-weathering, light-grayish-pink to pinkish-white, medium-grained, moderately layered and foliated gneiss containing quartz, microcline, and epidote. Some phases contain scapolite. May be interlayered with and related to potassium-feldspar gneiss (**Yk**), and (or) clinopyroxene-quartz-feldspar gneiss (**Ymp**). Two elongate bodies mapped east of Franklin.

Losee Metamorphic Suite (Middle Proterozoic) (Drake, 1984)

Ylo Quartz-oligoclase gneiss – White-weathering, light-greenish-gray, medium- to coarse-grained, moderately layered to indistinctly foliated gneiss and lesser amounts of granofels composed of quartz, oligoclase or andesine, and, locally, biotite, hornblende and (or) clinopyroxene. Contains thin amphibolite layers.

Yla Albite-oligoclase granite – White-weathering, light-greenish-gray, medium- to coarse-grained granite composed of albite or oligoclase, quartz, and sparse amounts of hornblende or clinopyroxene. Petrogenetically related to quartz-oligoclase gneiss (**Ylo**) but **Yla** has a more granulitic texture. Includes small bodies of pegmatite not shown on map.

Ylb Biotite-quartz-oligoclase gneiss – White- to light-gray-weathering, light- to medium-gray or greenish-gray, fine- to coarse-grained, massive to moderately well layered, foliated gneiss composed of oligoclase or andesine, quartz, biotite, and, locally, garnet. Commonly interlayered with amphibolite.

Rocks of Uncertain Origin (Middle Proterozoic)

Yh Hypersthene-quartz-plagioclase gneiss – Gray- to tan-weathering, greenish-gray to greenish-brown, medium-grained, moderately well layered and foliated, greasy-lustered gneiss of charnockitic affinity composed of andesine or oligoclase, quartz, clinopyroxene, hornblende, hypersthene, and sparse

amounts of biotite. Commonly interlayered with amphibolite and mafic-rich quartz-plagioclase gneiss.

Yd Diorite – Gray- to tan-weathering, greenish-gray to brownish-gray, medium- to coarse-grained, greasy-lustered, massive diorite containing andesine or oligoclase, clinopyroxene, hornblende, hypersthene, and sparse amounts of biotite and magnetite. Amphibolite layers common.

Ya Amphibolite - Gray- to grayish-black, medium-grained amphibolite composed of hornblende and andesine. Some phases contain biotite and (or) clinopyroxene. Ubiquitous and associated with almost all other Middle Proterozoic units. Some amphibolite is clearly metavolcanic in origin, some is metasedimentary, and some appears to be metagabbro.

Yam Migmatite - Mixed rock consisting of amphibolite containing veins, lenses, layers, and irregular clots of albite-oligoclase granite or microperthite alaskite.

Ymg Monazite gneiss - Buff-weathering, light-greenish-gray to greenish-buff, fine- to medium-grained, moderately well-foliated, well-lineated gneiss composed of microcline microperthite, quartz, oligoclase, biotite, and monazite. Accessory minerals include hornblende, zircon and opaque minerals. Mapped in Fox Hill Range area

Yhp Hornblende-plagioclase gneiss - White- to gray-weathering, greenish-gray, medium-grained, moderately well foliated gneiss containing hornblende, clinopyroxene, plagioclase and trace amounts of apatite, titanite and opaque minerals.

Ybp Biotite-plagioclase gneiss - White- to light-gray weathering, greenish-gray, medium-grained, moderately well layered gneiss composed of biotite, plagioclase and accessory amounts of hornblende, clinopyroxene, and, locally, garnet.

Yma Microantiperthite alaskite – White-weathering, locally rusty, light-greenish-gray medium- to coarse-grained, gneissic granite and alaskite containing microantiperthite, quartz, oligoclase, and sparse amounts of hornblende, clinopyroxene, biotite, and magnetite.