Upper Silurian and Lower Devonian Stratigraphy of Northeastern Pennsylvania, New Jersey, and Southeasternmost New York

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By ANITA G. EPSTEIN, JACK B. EPSTEIN, WALTER J. SPINK, *and* DAVID S. JENNINGS

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A description and partial revision of the physical stratigraphy and interpretations of depositional environments

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UPPER SILURIAN AND LOWER DEVONIAN STRATIGRAPHY OF NORTHEASTERN PENNSYLVANIA, NEW JERSEY, AND SOUTHEASTERNMOST NEW YORK

By Anita G. Epstein, Jack B. Epstein, Walter J. Spink, and David S. Jennings

ABSTRACT

Complex lateral and vertical facies changes involving lagoonal, barrier-beach, biohermal, and shallow- to deep-water neritic lithofacies occur within Upper Silurian and Lower Devonian strata in southeasternmost New York, New Jersey, and northeastern Pennsylvania. The Decker to Oriskany interval increases in clastic content from the New York-New Jersey border to southwest of Bossardsville, Pa. Recognition of these diverse facies has resulted in a modification and refinement of Upper Silurian and Lower Devonian nomenclature in New Jersey and northeastern Pennsylvania. The Decker Formation is divided into two members: the Wallpack Center Member (new name) and the Clove Brook Member (new name). Three members are recognized within the Rondout Formation: the Duttonville Member (new name), Whiteport Dolomite Member, and Mashipacong Member (new name). The Manlius Limestone has been restricted to northeasternmost New Jersey and New York and includes only the Thacher Member.

The Coeymans Formation includes, from bottom to top, a slightly arenaceous limestone (Depue Limestone Member, new name), an arenaceous limestone to calcareous pebbly sandstone (Peters Valley Member, new name), an arenaceous and argillaceous limestone (Shawnee Island Member, new name), and a calcareous sandstone and calcareous quartz-pebble conglomerate (Stormville Member) in northeastern Pennsylvania and most of New Jersey. Biohermal and nonbiohermal facies are recognized in the Shawnee Island Member. In southeasternmost New York, the Coeymans is restricted to approximately 30–40 feet of slightly argillaceous medium- to coarse-grained limestone (Ravena Member). The Kalkberg Limestone grades into the Stormville and Shawnee Island Members of the Coeymans near Wallpack Center, N.J. The New Scotland Formation has been divided into two members, the Flatbrookville (new name) below and the Maskenozha (new name) above. Argillaceous limestone between the New Scotland and Port Ewen Formations has been designated the Minisink Limestone (new name).

INTRODUCTION

Complex facies changes occur within Upper Silurian and Lower Devonian strata between Cuddebackville, N.Y., and Bossardsville, Pa., a distance of approximately 55 miles (fig. 1). Recent mapping by the

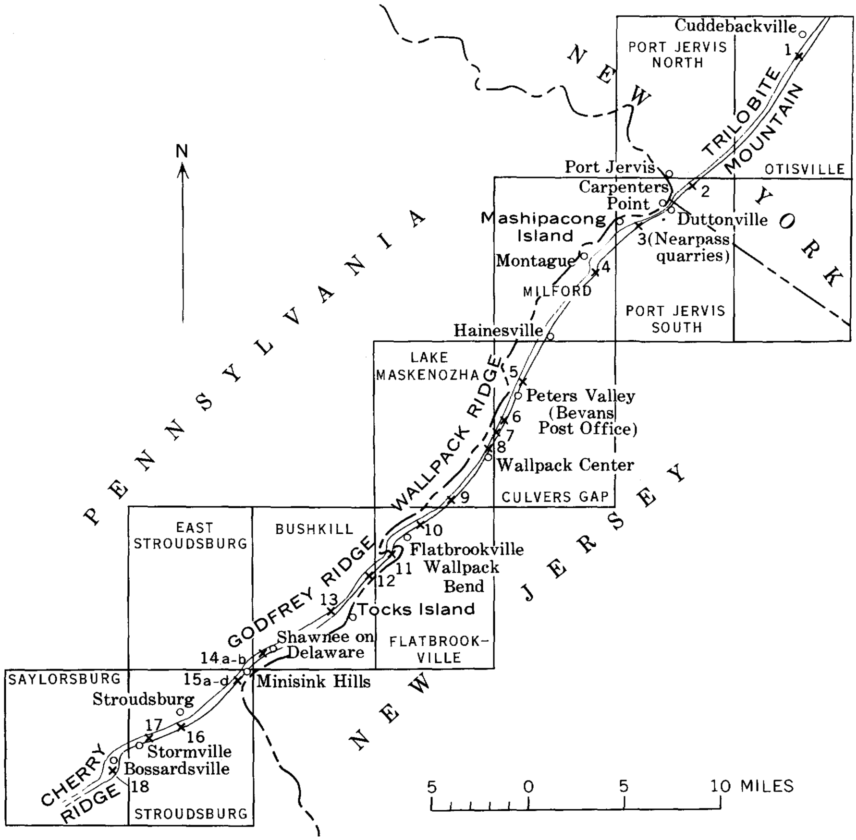

Figure 1.—Outcrop belt of uppermost Silurian and lowermost Devonian rocks and location of measured sections.

U.S. Geological Survey in the Bushkill and Stroudsburg quadrangles of Pennsylvania and New Jersey and in the Saylorsburg quadrangle, Pennsylvania, and mapping by the New Jersey Geologic and Topographic Survey in the Port Jervis South, Milford, and Culvers Gap quadrangles has necessitated tracing rock units of late Cayuga and Helderberg age from southeastern New York, across New Jersey, and into eastern Pennsylvania in order to solve lithostratigraphic and nomenclatural problems.

Stratigraphic studies of Upper Silurian and Lower Devonian strata in New York by Rickard (1962) provide the basis for a reexamination of these beds in New Jersey and northeastern Pennsylvania. Where lateral similarity with New York rock units is demonstrable, formation names are retained and new member names are proposed for lithic variants. Where evidence of similarity is lacking, older names, which might be lithologically and chronologically misleading, have been dropped and new names proposed.

Rocks formerly assigned to the Cayuga Group in this area are dissimilar to type Cayuga rocks in west-central New York. Therefore, the term Cayuga Group is not used in this report.

White (1882) published an early stratigraphic report concerning northeastern Pennsylvania. He correlated a generalized Upper Silurian and Lower Devonian section for northeastern Pennsylvania with the Nearpass quarries section in New Jersey and recognized the increase in quartz sand and pebbles southwest of the quarries. He believed that rocks in the Decker to Port Ewen interval "gradually change their character, lose their fossils and assume typical Oriskany character, when traced through the district to the southwest." White identified the waterlime bed of northeastern Pennsylvania and the Nearpass quarries with the Rondout of New York but maintained a distinct nomenclature for the entire "Lower Helderberg."

Weller (1903) recognized most of the New York Upper Silurian and Lower Devonian formations in New Jersey and accordingly employed the New York nomenclature. Eventually the New York names were carried into northeastern Pennsylvania (Swartz, 1929; Willard, 1938), and most of White's nomenclature was dropped. The development of Upper Silurian and Lower Devonian nomenclature in northeastern Pennsylvania and New Jersey is shown in figures 2 and 3.

More than 500 feet of Upper Silurian and Lower Devonian limestone, dolomite, shale, sandstone, and conglomerate is exposed in roadcuts, steep riverbanks, cliffs, and quarries between Cuddebackville, N.Y., and Bossardsville, Pa. Exposures are rare northeast of Cuddebackville because of thick drift cover, and are also rare southwest of Bossardsville because of thick drift cover and deeply weathered bedrock—saprolites more than 100 feet thick have been reported. Many of the Upper Silurian and Lower Devonian units in Godfrey Ridge are either absent or are represented by strikingly different facies southwest of Bossardsville.

In the Culvers Gap, Milford, and Port Jervis South quadrangles, strata generally dip northwestward at moderate angles. Southwest and northeast of these quadrangles, the strata are tightly folded and have numerous overturned beds. Both slaty and fracture cleavages are conspicuous planar features and in many places obscure the bedding. Relative thinning of as much as 50 percent has been recognized in more incompetent rocks in limbs of folds. For these reasons, the structural setting is noted for each section described in this report. Slight variations in thickness of units between sections may be the result of structural thickening and thinning rather than of original variation in thickness.

Weller (1900)	Weller (1903)	Shimer (1905)	Herpers (1951)	Swartz and Whitmore (1956)	This report
? Becraft Limestone	Kingston Beds	Port Ewen Beds			Port Ewen Shale
New Scotland Beds: Cherty limestone; Shale; Impure cherty ls	Becraft Limestone New Scotland Beds: Calcareous shale; Cherty limestone	Becraft Limestone New Scotland Beds			Minisink Limestone New Scotland Formation: Maskenozha Member; Flatbrookville Member
Stormville Ss Coeymans Limestone	Stormville Ss Coeymans Limestone	Coeymans Limestone	? Coeymans Limestone	? Coeymans Limestone	Coeymans Formation: Stormville Mbr; Kalkberg Limestone (Kalk-berg Ls); Shawnee Island Member; Ravena Member (Coey-mans Ls); Peters Valley Mbr; Depue Ls Member; Thacher Member (Manlius Ls)
Manlius Limestone	Manlius Limestone	Manlius Limestone ?	Manlius Limestone	Manlius Limestone	
Rondout Water-Lime Formation	Rondout Formation		Rondout Limestone	Rondout Limestone	Rondout Formation: Mashipacong Member; Whiteport Dolomite Member; Duttonville Member
Decker Ferry Formation	Decker Ferry Formation		Decker Sandstone; Decker Limestone	Decker Limestone	Decker Formation: Wallpack Center Member; Clove Brook Member
Bossardville Limestone	Bossardville Limestone			Bossardville Limestone	Bossardville Limestone

FIGURE 2.—Development of uppermost Silurian and lowermost Devonian nomenclature in New Jersey and southeasternmost New York.

White (1882)	Swartz (1929)	Willard (1938)	Swartz (1939)	Swartz and Swartz (1941)	This report
Stormville Shales	"Stormville Shale"	Port Ewen ↕ New Scotland	Port Ewen Shale	Port Ewen Shale	Port Ewen Shale
			Becraft Limestone	Becraft(?) Limestone	Minisink Limestone
			New Scotland Fm: New Scotland shale and limestone	New Scotland Fm: Shale Member	New Scotland Fm: Maskenozha Member
			Kalkberg Member	Limestone Member Kalkberg(?)	Flatbrookville Member
Stormville Conglomerate	Coeymans Limestone	Coeymans Formation: Stormville Ss Mbr	Coeymans Formation: Stormville Ss Mbr	Stormville Conglomerate	Coeymans Formation: Stormville Member
Stormville Limestone		Coeymans Limestone	Coeymans Limestone	Coeymans Limestone	Shawnee Island Member
					Peters Valley Member
	Keyser Limestone: Manlius Limestone	Keyser Limestone: Manlius Limestone Member	Keyser Limestone: Manlius Limestone Member ?	Keyser Group: Manlius Limestone ?	Depue Limestone Member
Stormville hydraulic cement bed (Waterlime)	Rondout Limestone	Rondout Limestone Member	Rondout Limestone Member	?	Rondout Formation: Mashipacong Member
				Rondout Limestone	Whiteport Dolomite Mbr
Decker Ferry Limestone		?			Duttonville Member
Decker's Ferry Sandstone	Decker Limestone	Decker Sandstone Member	Decker Sandstone Member	Decker Sandstone	Wallpack Center Member of Decker Formation
Decker's Ferry Shale					
Bossardville Limestone		Bossardville Limestone	Bossardville Limestone	Bossardville Limestone	Bossardville Limestone

FIGURE 3.—Development of uppermost Silurian and lowermost Devonian nomenclature in northeastern Pennsylvania.

A. G. Epstein has traced the Lower Devonian rocks from Port Jervis, N.Y., to the southwest tip of Godfrey Ridge, Pa., in conjunction with conodont and ostracode faunal studies. The investigation was supported, in part, by a National Science Foundation Cooperative Fellowship (1963–64) at The Ohio State University. J. B. Epstein has mapped the Stroudsburg and Saylorsburg quadrangles for the U.S. Geological Survey. Part of this work was supported by the Bownocker Fellowship, Department of Geology, The Ohio State University. W. J. Spink has mapped the Port Jervis South, Milford, and Culvers Gap quadrangles in New Jersey for the New Jersey Geologic and Topographic Survey. D. S. Jennings has mapped Silurian and Lower Devonian strata in the Flatbrookville and Lake Maskenozha quadrangles in New Jersey for the New Jersey Geologic and Topographic Survey.

PRE-HELDERBERG ROCKS

BOSSARDVILLE LIMESTONE

The type locality of the Bossardville Limestone—is at Bossardsville, Pa. In previous reports the name has been spelled Bossardsville and Bossardville. The spelling used herein conforms to the Code of the American Commission on Stratigraphic Nomenclature (1961, p. 652, art. 12a). White (1882) originally spelled the formation name without the last "s." The formation was first described by White (1882, p. 141–145) who did not designate a type section, but whose description (p. 240) of the limestone at the north Croasdale quarry at the east end of Godfrey Ridge in the Stroudsburg quadrangle (2,000 ft north of the intersection of State Route 402 and U.S. 611) could serve such a purpose. At this locality, White reported a basal 25-foot unit of bluish-gray laminated impure limestone, a middle ("quarry") part of 65 feet of dark, almost black, massive limestone, and an upper 20 feet of siliceous shaly beds. Overlying these shaly beds is 12 feet of green limy shales which were not seen by Swartz and Swartz (1941, p. 1183) or the present authors. These beds may be the transitional sandy limestones between the Bossardville Limestone and the Decker Formation.

In New Jersey, Cook (1868) referred to these rocks as the "Ribbon Limestone" or "Tentaculite Limestone" and identified them with Mather's (1843) division of the Waterline Group of Vanuxem (1842) and Hall (1843) in New York. Clarke and Schuchert (1899) divided the Water Lime Group into a younger Manlius Limestone (Tentaculite Limestone of Mather) and an older Rondout Waterlime (Water Limestone of Mather). Cook's correlation was erroneous because the Bossardville Limestone is separated from the Manlius Limestone by the Decker and Rondout Formations.

In the report area the basal part of the Bossardville Limestone, about 20 feet thick, consists of very fine grained to sublithographic argillaceous laminated limestone and dolomitic limestone. The laminae consist of dark-gray limestone that weathers light gray and slightly dolomitic, dark-gray limestone that weathers yellowish gray. Near Minisink Hills, Pa., these basal beds contain two intervals of desiccation columns as much as 6 feet in depth (fig. 4), which are separated by about 10 feet of laminated calcareous shale and scattered desiccation breccias. At Shawnee on Delaware, Pa., the entire basal 20 feet consists of argillaceous limestone with virtually continuous desiccation columns. The upper 70 feet consists predominantly of medium- to dark-gray very fine grained to sublithographic laminated limestone that weathers to light gray and also of scattered beds of argillaceous limestone and dolomitic limestone. Pyrite euhedra are scattered throughout. Desiccation cracks and columns occur at different levels within this upper 70 feet.

From Bossardsville, Pa., to near Wallpack Center, N.J., the Bossardville Limestone ranges in thickness from 92 to 110 feet. Weller (1903) reported 12 feet of Bossardville Limestone at the Nearpass quarries. Only the uppermost few inches are now exposed. At Cuddebackville, N.Y., the entire Bossardville is 10.9 feet thick.

At the Bossardsville quarry, fossils are restricted to the upper 25 feet of the formation. Coarser grained laminae contain numerous leperditiid ostracodes as well as abundant small euhedral pyrite. The uppermost 5 feet contains beds of reddish-gray fine-grained arenaceous limestone having fragments of crinoid columnals, brachiopods, and rugose corals.

In the report area, the boundary between the Bossardville Limestone and the underlying Poxono Island Formation of White (1882) is gradational and is placed at the top of the uppermost dolomite. The unit was originally designated the Poxono Island Shale by White (1882), but is herein designated the Poxono Island Formation because of its heterogeneous lithic character. White's Poxono Island is generally concealed in the report area but is probably about 800 feet thick in easternmost Pennsylvania. The upper half of the formation consists predominantly of laminated calcareous and dolomitic shale and dolomite that have some desiccation-crack horizons and minor amounts of fine-grained sandstone and laminated limestone. Southwest of Wallpack Center, N.J., the Bossardville Limestone grades up into the Wallpack Center Member of the Decker Formation. Northeast of Wallpack Center, it grades up into the Clove Brook Member of the Decker Formation (pl. 1).

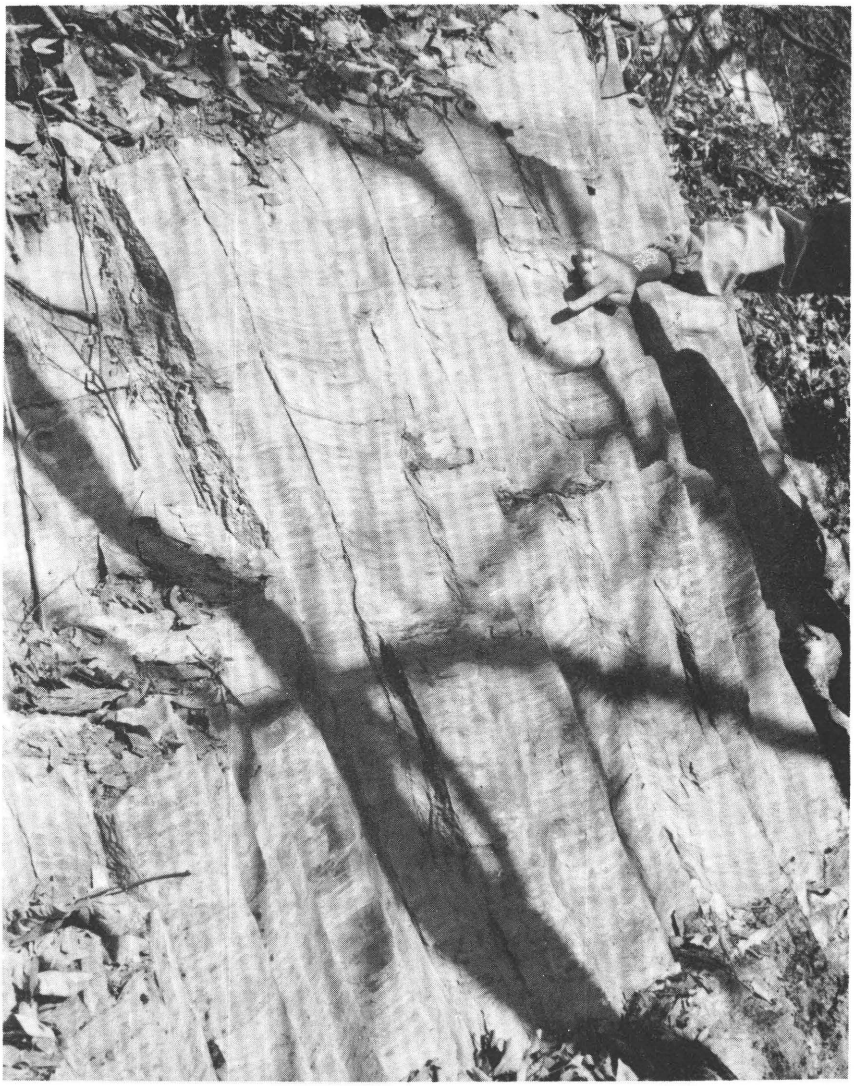

FIGURE 4.—Desiccation columns, about 6 feet deep, in the lower beds of the Bossardville Limestone at north Croasdale quarry, about 0.5 mile southwest of Minisink Hills, Pa. (section 15–a).

The Bossardville has not been reported northeast of Cuddebackville where it is presumably covered by drift; it has been traced southwestward as far as Schuylkill County, Pa. (Swartz and Swartz, 1941). Swartz and others (1942) believe it to be correlative with the upper part of the Tonoloway Limestone of central Pennsylvania and Maryland.

An excellent section of the Bossardville Limestone (section 18) has recently been exposed at the quarry of the Hamilton Stone Co., Inc., at Bossardsville, Pa.

DECKER FORMATION

White (1882, p. 140–141) proposed the names "Decker's Ferry Shale" and "Decker's Ferry Sandstone" for beds exposed above the Bossardville Limestone near Wallpack Bend, N.J.-Pa. Overlying these units is about 20 feet of shaly limestone and calcareous shale containing abundant leperditiid ostracodes. White (1882, p. 137) designated these beds the Decker Ferry Limestone but did not specify a type section. Weller (1900, p. 7) proposed the name Decker Ferry Formation for White's Decker's Ferry Shale and Decker's Ferry Sandstone and placed the Decker Ferry Limestone in the Rondout Water-Lime Formation (figs. 2 and 3). Kümmel (in Spencer and others, 1908) applied the name Decker Limestone to strata probably equivalent to Weller's Decker Ferry Formation in the Green Pond area of New Jersey. Later authors applied the term Decker Limestone to the calcareous facies of the Decker Ferry Formation of Weller, which becomes dominant northeast of Hainesville, N.J. Swartz (1939, p. 91) assigned 62 feet of calcareous, somewhat conglomeratic sandstone, and arenaceous limestone to the Decker Sandstone Member of the Keyser Limestone at Decker's Ferry (Wallpack Bend, N.J.-Pa.). Later, Swartz and Swartz (1941, p. 1173) excluded the Decker's Ferry Shale of White (1882) from the Decker Sandstone at the type locality and included it within the Bossardville Limestone.

Because the nomenclature of this interval of strata has had a confused history, it is proposed that (1) the name Decker Formation (= Decker Ferry Formation of Weller) be applied to strata lying between the Bossardville Limestone and the Rondout Formation in northeastern Pennsylvania and New Jersey, (2) the calcareous facies northeast of the Hainesville area, New Jersey, be designated the Clove Brook Member, and (3) the arenaceous facies southwest of the Hainesville area be designated the Wallpack Center Member. Conspicuous lateral changes occur in the character of the rock of the two members within a few miles.

CLOVE BROOK MEMBER

The Clove Brook Member of the Decker Formation, herein named for Clove Brook in New Jersey (Port Jervis South quadrangle), includes the interval between the Bossardville Limestone and the Duttonville Member of the Rondout Formation (pl. 1). It is predominantly a medium-gray to medium-dark-gray medium- to coarse-grained flaggy to massive even-bedded fossiliferous (generally crinoidal) limestone. Light-olive-gray silty shale partings occur near the top. Silt content increases upward. Megafossils are generally more abundant in the coarser grained limestone beds. A massive bed of moderate-reddish-brown to dark-reddish-brown coarse-grained iron-rich fossiliferous limestone forms an excellent marker bed within this member. The Clove Brook Member is 50.2 feet thick at the type section. It becomes more arenaceous southwest of the type locality, and near Hainesville, N.J., it is almost entirely replaced by the Wallpack Center Member of the Decker Formation. However, discontinuous lenses of Clove Brook-type limestone are found near the base of the Wallpack Center Member southwest of Wallpack Center.

The Clove Brook Member contains an abundant fauna including brachiopods, tabulate and rugose corals, crinoid debris, ostracodes, and scattered bryozoans. The varietal abundance of the fauna decreases in the Wallpack Center Member. Weller (1903) presented a faunal list for beds of the Clove Brook Member and indicated a Late Silurian age.

Type section.—The abandoned William Nearpass quarry, 1.8 miles southwest of Duttonville, N.J., in the Port Jervis South quadrangle (section 3), is the type section for the Clove Brook Member. The member is named for Clove Brook, 0.5 mile northeast of the quarry. The section is on the southeast slope of Wallpack Ridge.

WALLPACK CENTER MEMBER

The Wallpack Center Member of the Decker Formation is herein named for the village of Wallpack Center, N.J. It consists of medium-dark- to medium-light-gray generally fine-grained calcareous sandstone that weathers yellowish gray to grayish orange, lenses of calcareous quartz-pebble conglomerate, fine- to coarse-grained calcareous standstone, calcareous siltstone, fine- to coarse-grained arenaceous limestone, medium-dark-gray calcareous shale, and dark-gray to medium-dark-gray very fine grained dolomite. Limestone beds typical of the Clove Brook Member occur in the Wallpack Center Member but are more prevalent toward the base of the unit. The upper boundary of the Wallpack Center Member with the Duttonville Member of the Rondout Formation is abrupt and is placed at the top of the first arenaceous limestone or calcareous sandstone found downward in the section. The lower contact with the Bossardville Limestone is gradational through an interval as much as 18 feet thick. At the type section, near Wallpack Center, N.J., the member is 81.8 feet thick. It is 80 feet thick near Haney's Mill, N.J., 3 miles northeast of Flatbrookville, 54 feet near Tocks Island, N.J., and 85 feet thick at the south Croasdale quarry, about 0.8 mile southwest of Minisink Hills, Pa. It is increasingly arenaceous and conglomeratic to the southwest; near Minisink Hills it contains quartz pebbles as much as 1½ inches long. Northeast of the type section, the Wallpack Center Member grades into and is replaced by the Clove Brook Member. The Wallpack Center Member persists to the southwest tip of Godfrey Ridge and into Cherry Ridge. (See section 18.) In Cherry Ridge, the Wallpack Center Member contains a greater proportion of limestone than in Godfrey Ridge, approximately half a mile to the north. Both white and pink quartz pebbles occur in the member in Cherry Ridge, whereas at all exposures to the northeast only white quartz pebbles were found.

A typical Decker fauna, including stropheodontid brachipods, corals, and ostracodes, is present in the limestone beds in the member (Weller, 1903). The conglomerate and sandstone beds contain poorly preserved fossils.

Type section.—The type section of the Wallpack Center Member of the Decker Formation is 1 mile northeast of Wallpack Center, N.J., on the southeast slope of Wallpack Ridge, in the Culvers Gap quadrangle (section 7).

RONDOUT FORMATION

In New York, Mather (1843) divided the Waterlime Group of Vanuxem (1842) and Hall (1843) into two divisions, a younger "Tentaculite Limestone" and an older "Water Limestone". Clarke and Schuchert (1899) named the younger the Manlius Limestone and the older the Rondout Waterlime. The Rondout Waterlime was considered by Ulrich and Schuchert (1902) to be the basal part of the Manlius. Schuchert (1903) subsequently included the Manlius Limestone and Rondout Waterlime of Clarke and Schuchert (1899) and the underlying Cobleskill Limestone of Hartnagel (1903) within the Manlius Formation. Until 1962, the New York Geological Survey had continued to use the term Rondout Waterlime in the restricted sense of Hartnagel (1903), that is, for the strata lying between the older Cobleskill Limestone of Hartnagel (1903) and the younger Manlius Limestone of Clarke and Schuchert (1899). In New Jersey (Lewis and Kümmel, 1915; Kümmel, 1940) and in Pennsylvania (Swartz, 1939; Swartz and Swartz, 1941), the term Rondout Limestone had been used to include beds above the Decker formation and below the Depue Limestone Member of the Coeymans or the Thacher Member of the Manlius Limestone.

In 1962, Rickard restricted the Cobleskill to central and western New York. In the Hudson Valley and southeastern New York, he divided the Rondout Formation into five members. They are, from oldest to youngest: the Fuyk (sandstone) (of Chadwick, 1944), Wilbur (limestone), Rosendale (dolomite), Glasco (limestone), and

Whiteport Dolomite Members. Because of its varied lithology, Rondout Formation instead of Rondout Limestone, is adopted for use in this report, following Rickard (1962). The Fuyk and Wilbur Members are present only in the Kingston area. Southwest of Kingston the three youngest members are identifiable but with increasing difficulty. At Accord, N.Y., the Glasco Member is difficult to distinguish from the Rosendale Member, which there is calcitic. The Rosendale Member can be correlated with the middle part of the Decker Formation (Rickard, 1962). The upper 7.5 feet of the Clove Brook Member of the Decker Formation contains faunal elements which are typical of the Glasco Member. The Whiteport Dolomite Member retains its character from the Kingston area into Pennsylvania. At Cuddebackville, N.Y., and to the southwest, the Whiteport Dolomite Member is underlain by the Duttonville Member (new name) and overlain by the Mashipacong Member (new name) of the Rondout Formation. At Cuddebackville and to the southwest, only the Duttonville, Whiteport, and Mashipacong Members are present.

The Rondout Formation is about 39 feet thick in the Rosendale quadrangle in New York, 91.4 feet thick at Cuddebackville, N.Y., 43.0 feet thick at the Nearpass quarries, New Jersey, and 28.5 feet near Minisink Hills, Pa.

DUTTONVILLE MEMBER

The Duttonville Member is here named for the village of Duttonville, N.J. Strata now assigned to the Duttonville were designated the Decker Ferry Limestone by White (1882). Swartz (1939) and Swartz and Swartz (1941) placed these beds in the Rondout Limestone. Weller (1900) included all the Duttonville within the Rondout Formation, but in 1903 he placed the lower 4 feet of the Duttonville in the Decker Formation. Hartnagel (1905) considered these 4 feet as basal Rondout immediately overlying the Cobleskill Limestone, which in this report is the upper part of the Clove Brook Member of the Decker Formation.

The Duttonville Member of the Rondout Formation is composed of interbedded limestone, dolomitic limestone, calcareous shale, calcareous dolomite, and dolomite. Limestone and dolomitic limestone beds are dark gray to medium dark gray, very fine grained to medium grained, and argillaceous, and they weather medium gray. The calcareous shale is medium dark gray, weathers medium gray, and contains desiccation cracks. At the type section in the William Nearpass quarry, New Jersey, at Cuddebackville, N.Y., and at some sections in Pennsylvania, the uppermost beds contain desiccation cracks. In Pennsylvania the lower 4± feet contains desiccation cracks. Beds of dolomite and calcareous dolomite are medium gray, very fine grained, argillaceous, flaggy to massive, laminated, and pyritic, and they weather yellowish gray. Beds range from laminae to 1.1 feet in thickness. Graded bedding and cut-and-fill structure are evident in many beds. At the William Nearpass quarry, the Duttonville is 22.5 feet thick and is composed of 45 percent limestone, 42 percent calcareous shale, and 13 percent dolomite. Fossils, especially ostracodes, are common in the lower 4 feet and at 2–4 feet below the top of the member at section 13. At Cuddebackville, N.Y., leperditiid ostracodes occur in all beds except the upper and lower few feet of the member. Brachiopods, pelecypods, and one gastropod have been noted by Weller (1903). Minute algal structures have been noted in several limestone beds at section 13. In Pennsylvania and northeastward to the Wallpack Center area of New Jersey, a limestone biostrome, 1.5–2 feet thick, containing predominantly fragmented corals, stromatoporoids, and trepostomatous bryozoans occurs approximately 8–10 feet below the top of the member. Both upper and lower contacts of the Duttonville Member are abrupt.

Near Port Jervis, northeast of the type section, the Duttonville thickens to 56.9 feet at Cuddebackville, N.Y. The member is 13 feet thick at Wallpack Center, N.J., 14 feet thick in the Lake Maskenozha quadrangle, 8 feet at Wallpack Bend, 17 feet near Shawnee on Delaware, Pa., and 11.5 feet near Minisink Hills, Pa. Thinning of the Duttonville Member between the Nearpass quarries in New Jersey and Minisink Hills, Pa., occurs as the Decker Formation thickens.

Type section.—The type section of the Duttonville Member of the Rondout Formation is in the abandoned William Nearpass quarry, 1.8 miles southwest of Duttonville, N.J., and 0.5 mile due west of Clove School, in the Port Jervis South quadrangle (section 3).

WHITEPORT DOLOMITE MEMBER

The name Whiteport was proposed by Rickard (1962, p. 36) for 14 feet of buff-weathering argillaceous and calcitic dolomite between the Glasco Member and Manlius Limestone 1 mile southwest of Whiteport, N.Y. These strata were first described in New Jersey as the "peth-stone" by Cook (1868, p. 159), "a local name, applied to a thick-bedded argillaceous limestone; light-blue color; fine-grained containing iron pyrites in small and detached crystals. It is used to make water-lime when burned." White (1882) described these beds as the "Stormville hydraulic cement bed." Later workers (Weller, 1900, 1903; Hartnagel, 1903, 1905; Swartz, 1939; Swartz and Swartz, 1941) have included these beds in the Rondout Formation.

In the report area, the herein-adopted Whiteport Dolomite Member is a medium-gray to medium-dark-gray very fine grained argillaceous grayish-orange-weathering massive to platy partly laminated pyritic unfossiliferous dolomite having locally formed deep desiccation columns (fig. 5). This lithic type is continuous from the Catskill 15-minute quadrangle, New York, southwestward through the report area. The thickness of the member ranges from 5 feet in the Catskill quadrangle to 14 feet at Whiteport and approximately 10 feet at LeFever Falls, Rosendale, and Accord (Rickard, 1962). Between Accord and Cuddebackville, the member is not exposed. Just south of Cuddebackville it is 27 feet thick. At the William Nearpass quarry, New Jersey, the Whiteport Dolomite Member is 5.5 feet thick. Southwest of the William Nearpass quarry, the Whiteport ranges from 5.5 to 9.0 feet in thickness. It persists to the southwest end of Godfrey Ridge. It is overlain abruptly by the Mashipacong Member of the Rondout Formation and is underlain either sharply or gradationally by the Duttonville Member of the Rondout Formation.

MASHIPACONG MEMBER

The Mashipacong Member of the Rondout Formation is herein named for Mashipacong Island in the Delaware River, near the type section. The member consists of medium-dark-gray shale and calcareous shale and light-, medium-light, and medium-dark-gray very fine grained to medium-grained argillaceous limestone, which commonly exhibit curly bedding, weather yellowish gray, and are generally mud cracked. Beds range from laminae to 3 inches in thickness. Many beds are graded. Some beds exhibit cut-and-fill structure. The upper 1.5 feet is medium-dark- to medium-light-gray and grayish-orange to pale-yellowish-orange calcareous mud-cracked shale ("paper shales"). The lower contact of the Mashipacong Member with the Whiteport Dolomite Member is abrupt. Its contact with the overlying Thacher Member of the Manlius Limestone, northeast of Hainesville, N.J., and the Dupue Limestone Member of the Coeymans Formation, southwest of Hainesville, is sharp or gradational at different places.

Clarke and Schuchert (1899), Schuchert (1903), Grabau (1906), Smith (1929), Ruedemann (1930), R. M. Logie,[1] Goldring (1935, 1943), Chadwick (1944), Berdan (1949), and Rickard (1962) have included strata of this interval within the Manlius Limestone in either the general sense of Schuchert (1903) or the restricted sense of Mather (1843) and Clarke and Schuchert (1899). White (1882) included this interval in his Stormville Limestone, but Weller (1900, 1903), Swartz (1939), Herpers (1951), and Swartz and Whitmore (1956) considered these strata to be the upper beds of the Rondout Limestone. In this report, these beds are included within the Rondout Formation because of similarity to the Duttonville Member of the Rondout.

[1] Logie, R. M., 1933, Stratigraphy of the Manlius Group of New York: Manuscript on file in Yale University Geology Dept.

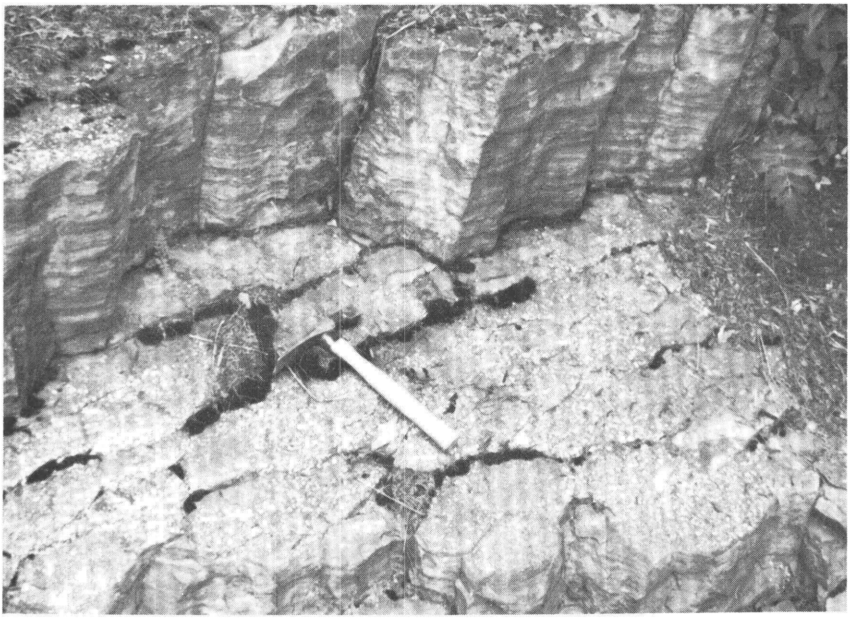

FIGURE 5.—Compressed desiccation columns, about 7 feet deep, in the Whiteport Dolomite Member of the Rondout Formation on the north side of Cherry Valley Road, 2,000 feet northeast of Stormville Church.

Between the William Nearpass quarry, New Jersey, and Accord, N.Y. (a distance of approximately 35 miles), the only exposure of the Mashipacong Member is in the Otisville sand and gravel quarry at Cuddebackville, N.Y. At and northeast of Accord, the Mashipacong may be represented in the basal 2 feet of the Thacher Member of the Manlius Limestone, which was characterized by R. M. Logie [1] as "paper shales." This section of shaly to flaggy limestone at Cuddebackville, N.Y., is 7.5 feet thick. In New Jersey, the Mashipacong is 15 feet thick at the Nearpass quarry and 13 feet at Wallpack Center. Farther southwest in Pennsylvania, near Tocks Island, the Mashipacong is 11 feet thick, and near Shawnee on Delaware and along Brodhead Creek, 0.8 mile southwest of Minisink Hills, it is 8 feet thick. The member is thickest in New Jersey and thins slightly to the southwest and persists to the southwest end of Godfrey Ridge.

Type section.—The type section of the Mashipacong Member is in the abandoned William Nearpass quarry 1.8 miles southwest of Duttonville, N.J., in the Port Jervis South quadrangle (section 3). It is

[1] See facing page.

named for its proximity to Mashipacong Island in the Delaware River, 1.7 miles west-northwest of the William Nearpass quarry.

HELDERBERG GROUP

MANLIUS LIMESTONE

Vanuxem (1840, p. 372) introduced the term Manlius in defining his Waterlime Group near Manlius, N.Y. Later authors (see Rickard, 1962, p. 42–43, and Berdan, 1964, for a summary of development of Manlius nomenclature) referred to the Manlius Limestone as the Waterlime Group either in a general sense to include the present Cobleskill, Rondout, and Manlius Formations of New York or in a restricted sense for the "Tentaculite Limestone" of Mather (1843) and the Manlius Limestone as used by Clarke and Schuchert (1899).

In New Jersey, Cook (1868) referred to strata in this interval as a lower "slaty rock," a middle "blue limestone," and an upper "quarry stone." In Pennsylvania, White (1882) placed these strata within his Stormville Limestone. In 1900, Weller included 13 feet of bluish-black limestone (Thacher Member of the Manlius Limestone of this report) which overlies 15 feet of "fissile gray shales, sometimes much crumpled by pressure" (Mashipacong Member of the Rondout Formation of this report) in the Rondout Formation. In 1903, Weller included the 13 feet of bluish-black limestone in the Manlius Limestone. Grabau (1906) correlated the Manlius Limestone, in the general sense of Schuchert (1903), and part of the Coeymans Limestone of New York with the Stormville Limestone of White (1882). Swartz (1939) correlated the Manlius Limestone of Pennsylvania and New Jersey as Weller did in 1903, that is in the restricted sense of Clarke and Schuchert (1899).

The Manlius Limestone of New Jersey as herein redefined is restricted to the Thacher Member (Rickard, 1962) northeast of Hainesville, N.J. The Manlius is absent to the southwest. The Thacher Member consists of medium-dark-gray to dark-gray very fine grained massive "ribbon" limestone. Southwest of Hainesville, the Thacher becomes arenaceous and argillaceous and grades gradually into the Depue Limestone Member of the Coeymans Formation. To facilitate mapping, an arbitrary cutoff is used to separate the Thacher from the Depue.

The age of the Thacher Member is still questionable. At present, the New York Geological Survey considers it Devonian because younger members of the Manlius in central and western New York are demonstrably Devonian in age. The faunal assemblage of the Thacher is diagnostic of neither a Silurian nor a Devonian age but does include some forms which are common in the Coeymans Limestone. For a more complete discussion of the problem see Berdan (1964).

THACHER MEMBER

Rickard (1962) proposed the name Thacher Limestone Member of the Manlius Formation for the 42-foot interval, 20 feet of dark-bluish-black very fine grained "ribbon" limestone below and 22 feet of interbedded stromatoporoid biostromes and argillaceous limestones above, which lies between the Rondout and Coeymans Limestones at Thacher Park, N.Y. In New Jersey, Weller (1900) included the lower 13 feet of the Thacher Member in the Rondout Formation, and Weller (1903), Swartz (1939), and Swartz and Swartz (1941) included the Thacher in the Manlius Limestone.

The Thacher Member is a dark-gray fine- to medium-grained limestone. Bedding is uneven and has thin yellowish-gray shale partings.

Near Kingston, N.Y., the Thacher Member, as described by Rickard (1962, p. 130–131), averages 51 feet thick. The lower 14.5 feet is dense platy argillaceous limestone and dolomitic limestone. Southwest of Kingston, the Thacher Member thins to 35 feet at Cuddebackville, N.Y. Southwest of Cuddebackville the Thacher Member maintains its thickness into New Jersey. The Thacher grades laterally into the Depue Limestone Member of the Coeymans Formation near Hainesville, N.J. The upper contact with the Ravena Member of the Coeymans Limestone northeast of the William Nearpass quarry and the Shawnee Island Member of the Coeymans Formation southwest of the quarry varies from abrupt to gradational. At sections 1, 2, and 4, the uppermost 1–2 feet of the Thacher is a stromatoporoid-coral-crinoid columnal-brachiopod biostrome which produces an undulatory contact with the overlying Coeymans Formation. The basal contact with the Mashipacong Member of the Rondout Formation is abrupt.

The Thacher Member contains stromatoporoids, rugose and tabulate corals, brachiopods, tentaculitids, and ostracodes.

SILURIAN-DEVONIAN BOUNDARY

The location of the Silurian-Devonian boundary in Pennsylvania, New Jersey, and New York has been a problem for many years. Swartz (1939, p. 47–50), Swartz and Swartz (1941, p. 1188–1190), Rickard (1962, p. 113–119), and Berdan (1964) present summaries of the subject. According to Rickard (1962), the brachiopod fauna of the Coeymans Limestone in New York is diagnostic of an Early Devonian age. Elements of this fauna occur in the Shawnee Island and Stormville Members of the Coeymans in northwestern New Jersey and eastern Pennsylvania. In New York, the underlying Thacher Member of the Manlius Limestone was placed in the Devonian by Rickard (1962, p. 119) because, even though diagnostic Devonian forms are lacking, fossils from the Thacher facies recur in beds of demonstrable Devonian age but are absent in older beds. However, Rickard (1962, p. 118) believes it is possible that the Thacher is Silurian in eastern New York. Weller (1900) placed the Manlius of New Jersey in the Devonian on the basis of the change from a restricted marine fauna in the Rondout to a more normal marine fauna in the Manlius and the occurrence in the Manlius of species prevalent in overlying beds. However, in a later report, Weller (1903) placed the Manlius in the Silurian because of the transitional nature of the Rondout-Manlius sequence.

The lateral equivalent of the Thacher Member of the Manlius Limestone in southwestern New Jersey and northeastern Pennsylvania is included in the Coeymans Formation by the present authors. Hence, in this area, the Coeymans may straddle the Silurian-Devonian boundary or may be wholly Devonian in age. Work on conodonts now in progress by A.G. Epstein suggests the boundary lies at the top of the Thacher Member of the Manlius Limestone and within the Peters Valley Member of the Coeymans Formation in the report area.

COEYMANS FORMATION

The term Coeymans was first used by Clarke and Schuchert (1899, p. 877) for strata between the Manlius and New Scotland Limestones, near Coeymans, N.Y. A type section was not designated. This was the "Lower Pentamerus Limestone," of earlier geologists. In 1900, Weller applied the name to lateral equivalents in New Jersey. Strata in eastern Pennsylvania that White (1882) assigned to his Stormville Conglomerate and upper Stormville Limestone were later correlated with the Coeymans by Grabau (1906). In 1908, Chadwick (p. 348) proposed the name Kalkberg Limestone for cherty limestone that had been previously assigned either to the upper part of the Coeymans or the lower part of the overlying New Scotland. Chadwick's restricted definition of the Coeymans Limestone in New York has been generally accepted by succeeding geologists. Because the Coeymans of the Pennsylvania and New Jersey parts of the report area is divisible into members of different lithologies, Coeymans Formation, following Rickard (1962), is used instead of Coeymans Limestone in these areas.

In New York, the Coeymans has been divided into three members by Rickard (1962): the Ravena Member in eastern New York and the Deansboro and Dayville Members in the central part of the State. The Ravena Member, which in New York consists of medium-gray fine-to coarse-grained irregularly bedded limestone characterized by abundant crinoid columnals and valves of the brachiopod *Gypidula coeymanensis* Schuchert, persists as far southwest as Trilobite Mountain, 0.75 mile northeast of Port Jervis, N.Y. To the southwest, it and the overlying Kalkberg Limestone grade into the Shawnee Island and Stormville Members of the Coeymans Formation, whereas the underlying Thacher Member of the Manlius Limestone grades into the oldest member of the Coeymans, the Depue Limestone Member. In addition, traced through New Jersey into eastern Pennsylvania, the Coeymans becomes increasingly arenaceous and conglomeratic and two sandy and pebbly members are recognized: the Stormville at the top of the formation and the Peters Valley between the Depue and Shawnee Island Members. The Coeymans thickens from 34 feet near Port Jervis, N.Y., to 93 feet at Shawnee on Delaware, Pa., primarily by incorporation of suprajacent and subjacent strata within the formation (pl. 1).

Throughout the area of this report, the Coeymans Formation is generally abruptly underlain by the fine-grained limestone of the Thacher Member of the Manlius Limestone or the calcareous shale and platy limestone of the Mashipacong Member of the Rondout Formation. In New York and northeastern New Jersey, the Coeymans grades up into cherty slightly argillaceous limestone of the Kalkberg Limestone, whereas in eastern Pennsylvania the cherty calcareous shale beds of the New Scotland Formation overlie it with sharp contact. The quartzose nature of the Coeymans in the report area is unlike the type Coeymans in New York. Nevertheless, because of widespread use of the name in New Jersey and Pennsylvania (Weller, 1900, 1903; Swartz, 1929; Willard, 1938; Kümmel, 1940; Swartz and Swartz, 1941; Herpers, 1951; Swartz and Whitmore, 1956), it is retained here and assigned several members. In eastern Pennsylvania and in the southwest part of the New Jersey area, these are, in ascending order, the Depue Limestone Member (new name), Peters Valley Member (new name), Shawnee Island Member (new name), and Stormville Member. In the northeastern part of the New Jersey area, only the Ravena Member of the Coeymans Limestone is present; the other units either pinch out or grade into formations above or below.

DEPUE LIMESTONE MEMBER

White (1882, p. 128) included the Mashipacong Member of the Rondout Formation and the Depue, Peters Valley, and Shawnee Island Members of the Coeymans Formation in his Stormville Limestone. The rocks of the Depue Limestone Member were included in the Manlius Limestone by Weller (1900), Swartz (1929, 1939), Willard (1938), Swartz and Swartz (1941), Herpers (1951), and others. As herein defined, the Depue Limestone Member is placed in the Coeymans Formation, overlies the Mashipacong Member of the Rondout Formation, and is overlain by the Peters Valley Member of the Coeymans Formation. The member is here named for an island in the Delaware River south of its type section.

The Depue consists of medium-gray to medium-dark-gray dominantly fine-grained slightly argillaceous and arenaceous, fairly evenly bedded limestone that weathers medium light gray. Southwest of Bevans, N.J., it is overlain abruptly or gradationally by the Peters Valley Member. Northeast of Bevans, it grades upward into the Shawnee Island Member. The Depue persists from the southwest end of Godfrey Ridge to the vicinity of Montague, N.J., where it grades laterally into the Thacher Member of the Manlius Limestone where the interval becomes very evenly bedded and very fine grained. The sand and silt content decreases to the northeast. Near Minisink Hills, Pa., this quartz sand and silt content averages 10 percent, whereas near Wallpack Center, N.J., it averages 1 percent. The Thacher and Depue Members are separated by an arbitrary cutoff between Montague and Hainesville in order to facilitate mapping. The units are poorly exposed in that area.

The Depue Limestone Member is 29 feet thick at Wallpack Center, N.J., 17 feet thick at Wallpack Bend, Pa., 13 feet at its type locality near Shawnee on Delaware, and 16 feet on Brodhead Creek, near Minisink Hills, Pa. Variations in thickness are accredited to: (1) interposition of a thin sand bed at the base of and included in the Depue in eastern Pennsylvania, (2) assignment of variable thicknesses of highly arenaceous limestone to the Peters Valley Member above the Depue, (3) rise and fall of the lower contact of the Depue as a result of thickening and thinning of the underlying Mashipacong Member of the Rondout Formation, and (4) structural thickening and thinning. The variation in thickness of the Mashipacong-Depue-Peters Valley occurs as expected in a restricted-lagoon, open-lagoon, and barrier-beach sequence represented by these rocks (p. 40).

The Depue contains numerous thin layers that have abundant stropheodontid brachiopods. Leperditiid ostracodes are numerous in the basal beds. Stromatoporoid and rugose and tabulate coral fragments occur in the uppermost beds. Tentaculitids are abundant in some intervals near Montague, N.J., but are rare to the southwest.

Type section.—The type section of the Depue Limestone Member of the Coeymans Formation is in a cut along the northwest side of the road, 0.6 mile southwest of Shawnee on Delaware, Pa., in the Bushkill quadrangle (section 14–b).

PETERS VALLEY MEMBER

Herpers (1951, p. 6) and Swartz and Swartz (1941, p. 1170, 1171) recognized sandy limestone at the base of the Coeymans Limestone of their usage, at Wallpack Center, N.J., and at Wallpack Bend, Pa. These rocks are herein included in the Peters Valley Member of the Coeymans Formation. The Peters Valley is here named for the village of Peters Valley, N.J., 1.4 miles northeast of Wallpack Center. It varies laterally from medium-gray arenaceous limestone to light-medium-gray fine- to coarse-grained pebbly calcareous sandstone that weathers light tannish gray to medium light gray. It contains 15–65 percent subangular to subrounded quartz sand grains. The Peters Valley is locally crossbedded and contains fragments of rugose corals, *Favosites* sp., stromatoporoids, and brachiopods. In most places, it occurs as one massive bed and grades into the Shawnee Island Member above and the Depue Limestone Member below. The Peters Valley thickens gradually from a feather edge near Port Jervis, N.Y., to 9 feet at Shawnee on Delaware, Pa. It persists to the southwest end of Godfrey Ridge.

Type section.—The type section of the Peters Valley Member (section 10) is in a cut on the northwest side of the county road that extends along the southwest side of Wallpack Ridge, 1.5 miles northwest of Flatbrookville, N.J., and 0.1 mile southwest of a V-shaped bend in the road, in the Flatbrookville quadrangle.

Reference sections.—Section 14–b, the type section of the Shawnee Island and Depue Limestone Members of the Coeymans Formation, also serves as a reference section for the Peters Valley Member. An additional reference section is in the woods on the northeast side of a secondary road along the ascent of Wallpack Ridge in Pennsylvania, immediately southwest of where the Delaware River cuts through the ridge, in the Flatbrookville quadrangle (section 11).

SHAWNEE ISLAND MEMBER

A biohermal and a nonbiohermal facies are distinguished within the Shawnee Island Member, herein named for an island in the Delaware River southeast of the type section. The more prevalent nonbiohermal facies consists of medium-gray fine- to medium-grained argillaceous and arenaceous slightly limonitic irregularly bedded limestone which has weak fracture cleavage and weathers medium light tannish gray. It contains 1–30 percent quartz sand, and the uppermost 10–25 feet contains nodules and lenses of dark-gray chert. Crinoid columnals and the brachiopod *Gypidula coeymanensis* are abundant.

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The biohermal facies has been recognized at four localities (sections 4, 9, 11, and 13) and changes rapidly, both laterally and vertically, into the nonbiohermal facies. It is a very coarse grained to coarse-grained medium-light-gray to light-pinkish-gray slightly limonitic unbedded to crudely bedded biogenic limestone that weathers light gray and forms large spheroidal blocks upon weathering. Tabulate and rugose corals, trepostomatous bryozoans, and crinoid columnals dominate the fauna, but there are sporadic occurrences of *Gypidula coeymanensis* and other brachiopods.

The Shawnee Island Member grades up into the cherty more argillaceous Kalkberg Limestone northeast of Wallpack Center, N.J. Southwest of Wallpack Center, however, the Kalkberg is more arenaceous and grades into the Shawnee Island Member. The Kalkberg is also replaced from above by the Stormville Member of the Coeymans Formation, so that in the western part of the Stroudsburg quadrangle, chert beds and nodules occur within Stormville conglomerates. The Stormville disconformably overlies the Shawnee Island southwest of Wallpack Center, N.J.

Northeast of Peters Valley, N.J., the Shawnee Island is underlain locally by biostromal layers at the top of the Thacher Member of the Manlius Limestone. In most places, however, the contact is gradational and separates medium-dark-gray very fine grained to fine-grained evenly bedded limestone below from medium-gray fine- to medium-grained argillaceous and arenaceous irregularly bedded limestone above. Southwest of Peters Valley, the Peters Valley Member intervenes between the Depue and Shawnee Island Members and grades up into the latter.

Northeast of the Nearpass quarries, New Jersey, the Shawnee Island Member grades laterally into the Ravena Member of the Coeymans Limestone. This transition takes place over a distance of 3 miles along strike between Nearpass quarries, New Jersey, and Trilobite Mountain, N.Y. In order to facilitate mapping, an arbitrary cutoff northeast of Nearpass quarries was used to separate these two members.

The percentage of silt and sand in the Shawnee Island Member increases steadily southwest from an average of 2 percent near Bevans, N.J., to 8 percent near Flatbrookville, N.J., and 13 percent at Shawnee on Delaware, Pa. The member thins irregularly southwest of Bevans, N.J., as a result of thickening of the Stormville above and the Peters Valley below. The thickness of the Shawnee Island is variable because of its disconformable relation with the overlying Stormville Member and as a result of local development of bioherms. Northeast of Shawnee on Delaware, for example, there are at least 60 feet of biohermal and nonbiohermal Shawnee Island, whereas there are only 36 feet at Minisink Hills, 6 miles southwest, where there is no biohermal facies.

Oliver (1960) and Rickard (1962) described nine biohermal structures in the Deansboro Member of the Coeymans Limestone between Oriskany Falls and Manlius, N.Y. These reefs are identical in lithic character with those of the New Jersey-Pennsylvania area. According to age relations shown by Rickard, the New York reefs are slightly younger than those described here. Whereas the New York bioherms have an average height and diameter of 20 and 100 feet, respectively (Oliver, 1960, p. 60), the New Jersey-Pennsylvania bioherms have comparable dimesions of 40 and at least 3,000 feet. The bioherms in New York were perhaps as large as those in New Jersey and Pennsylvania but have been truncated by pre-Oriskany erosion.

Four bioherms have been recognized in the report area. Each is a separate body within the more typical argillaceous and arenaceous limestone of the Shawnee Island Member, except at Cuddebackville, N.Y., where the Ravena Member appears to represent an interfingering of biohermal and nonbiohermal facies. The northeasternmost bioherm is near Montague, N.J., where it rests on biostromal layers of the Thacher Member of the Manlius Limestone. The southwesternmost bioherm is northeast of Shawnee on Delaware (section 13) and is the largest and best exposed (fig. 6). It crops out on the southeast side of Wallpack Ridge opposite Tocks Island in the Bushkill quadrangle and can be traced for at least 2,000 feet from an outcrop on the northwest side of the road at the foot of the ridge 1.95 miles northeast of Shawnee on Delaware, northeastward and uphill, beneath a powerline, and into the woods. The bioherm is at least 45 feet thick and has a very irregular upper surface with a relief as much as 20 feet within a horizontal distance of 200 feet. Within a few hundred feet, it passes laterally and vertically into nonbiohermal rocks in a zone of mixed biohermal and nonbiohermal layers. This bioherm and the one at section 11 grade downward into the Peters Valley Member. The Thacher biostromal beds and Peters Valley sandy limestone probably provided an advantageous substrata on the sea floor upon which the colonizing organisms of the bioherm could establish a firm hold.

Type section.—The type section of the Shawnee Island Member of the Coeymans Formation is in a cut along the northwest side of the road, 0.6 mile southwest of Shawnee on Delaware, Pa., in the Bushkill quadrangle (section 14–b).

FIGURE 6.—Biohermal and nonbiohermal facies of the Shawnee Island Member of the Coeymans Formation overlain by the Stormville Member of the Coeymans; southeast slope of Wallpack Ridge, north of Tocks Island (section 13); elevation about 750 feet. Bedding distorted because of foreshortening in photograph.

Reference section.—Section 11, located in the woods on the northeast side of a secondary road along the ascent of Wallpack Ridge in Pennsylvania, immediately southwest of where the Delaware River cuts through the ridge, in the Flatbrookville quadrangle, is a reference section for the biohermal facies of the Shawnee Island Member.

RAVENA MEMBER (OF COEYMANS LIMESTONE)

The Ravena Limestone Member, named by Rickard (1962, p. 67) for 20 feet of medium- to massively bedded medium- to coarse-grained limestone at Ravena, N.Y., is herein adopted for use by the U.S. Geological Survey as the Ravena Member of the Coeymans Limestone in New York. It occurs from Cherry Valley to Albany, N.Y., southwest to the New York-New Jersey border and probably into New Jersey. It grades upward into the Kalkberg Limestone and is distinguished from it by the absence of lenses and nodules of dark-gray chert and by its lesser shale content. Its contact with the underlying Thacher Member of the Manlius Limestone is gradational in some places, but abrupt where the top of the Thacher is a stromatoporoid biostrome, as at Trilobite Mountain and Cuddebackville, N.Y. (fig. 7). It was long thought that the contact between the Manlius and Coeymans represented a major disconformity, hence was a convenient break for the Silurian-Devonian systemic boundary. However, Rickard (1962, p. 47–49) demonstrated that no major break exists in New York and that local irregularities of the contact are due to the deposition of Coeymans crinoidal limestone on the undulatory upper surface of a Manlius stromatoporoid biostrome. Any depositional hiatus is therefore only of diastemic rank. The Ravena grades laterally into the Shawnee Island Member northeast of the Nearpass quarries, New Jersey. It is distinguished from the Shawnee Island Member by its slightly coarser grain size, lack of sand, and low shale content.

Reference section.—The Ravena Member is best exposed in southeasternmost New York in three small abandoned quarries on the northwest side of Lime Kiln Road, on the southeast slope of Trilobite Mountain, Port Jervis, N.Y., (section 2). This section is the same as the one measured by Shimer (1905), who included the lower 11 feet of chert-bearing limestone beds in the New Scotland. In the present report, chert-bearing beds at Trilobite Mountain are included in the Kalkberg Limestone.

STORMVILLE MEMBER

White (1882, p. 132) named the Stormville Conglomerate for "a series of alternating beds of quartz pebble rock, and pebbly limestone" lying between his Stormville Limestone below (Shawnee Island Member of the Coeymans Formation through the Mashipacong Mem-

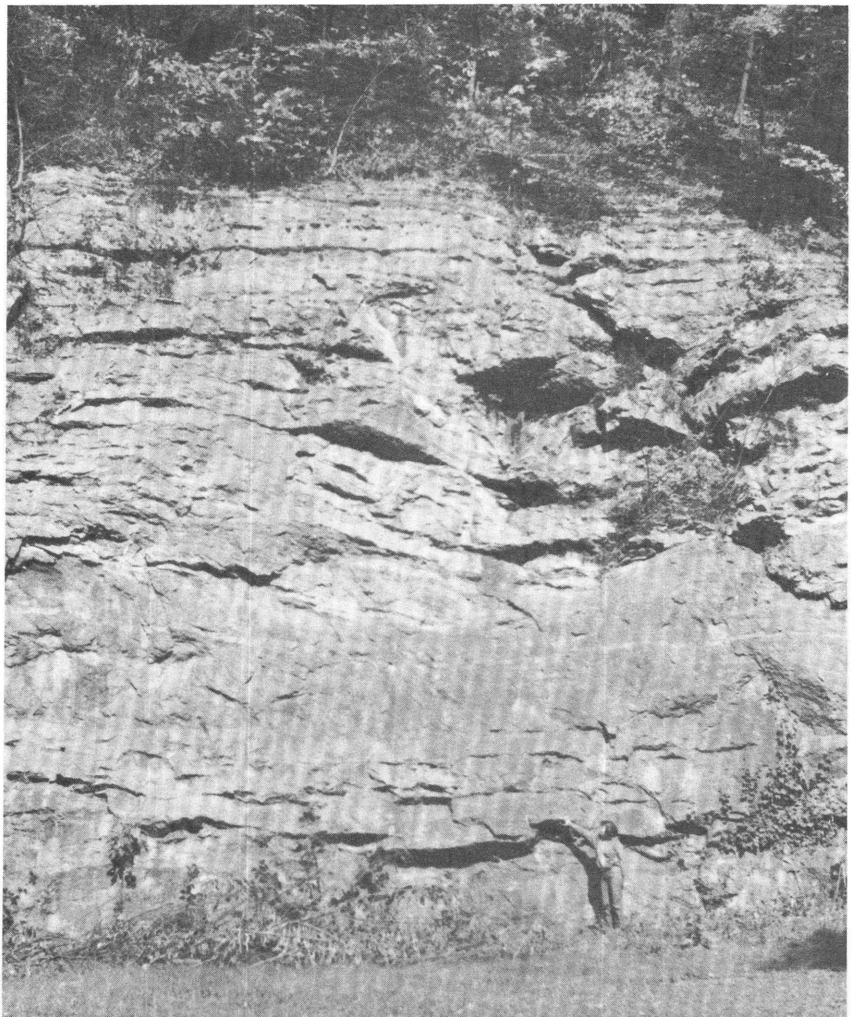

FIGURE 7.—Contact between Ravena Member (Coeymans Limestone) and Thacher Member (Manlius Limestone) on northwest side of Lime Kiln Road, southeast slope of Trilobite Mountain, near Tristates, N.Y. (section 2); hand is at undulatory contact between Thacher coral-stromatoporoid biostrome and overlying Ravena massive limestone.

ber of the Rondout Formation of this report) and Stormville Shales above (New Scotland through Port Ewen Formations). At Stormville, Pa., the type locality, White (1882, p. 278) reported the Stormville Conglomerate to be 45 feet thick; but Swartz and Swartz (1941, p. 1159), upon reexamining the section, found only 14 feet of massive gray conglomeratic sandstone attributable to the Stormville Conglomerate, which they designated a member of the Coeymans Limestone. The Stormville Conglomerate was recognized at Wallpack Bend, Pa., by White (1882, p. 132) and in New Jersey by Weller (1900, 1903).

The Stormville Member, as adopted for this report, includes all beds from the base of the first calcareous quartz-pebble conglomerate or calcareous sandstone to the shale of the New Scotland Formation. White's section at Stormville is presently overgrown and measurements are not readily obtainable. However, an excellent reference section is found near the top of Godfrey Ridge, at Hartman's Cave, less than 1 mile northeast of Stormville (section 17). The Stormville Member here is 24.7 feet thick. It has been traced to near its featheredge at Hainesville, N.J., where it is 1.5 feet thick. At Trilobite Mountain (section 2) the uppermost beds of the Kalkberg Limestone contain very thin beds and lenses of very fine to fine-grained sandstone and siltstone. It gradually thickens southwest from Hainesville and near Wallpack Center, N.J., it is 4.5 feet thick, 9 feet at Wallpack Bend, Pa., and 17 feet at Minisink Hills, Pa. The Stormville thickens by replacing Kalkberg and Shawnee Island strata below and possibly New Scotland beds above.

The Stormville Member consists of juxtaposed lenses of medium-gray fine- to coarse-grained biogenic limestone, medium-gray fine- to medium-grained arenaceous fossiliferous limestone, medium-light-gray fine- to coarse-grained calcareous limonitic sandstone having scattered rugose corals, stromatoporoids, crinoid columnals, and *Gypidula coeymanensis*, and conglomerate having subrounded to rounded milky quartz pebbles as much as 1 inch long. Many of the lenses are crossbedded (fig. 8). Nodules and lenses of dark-gray chert occur in the Stormville in the Stroudsburg quadrangle. The contact with the overlying Flatbrookville Member of the New Scotland Formation is abrupt. The Stormville disconformably overlies the Shawnee Island Member southwest of Wallpack Center, N.J., (fig. 9) and the Kalkberg Limestone northeast of Wallpack Center. Grabau (1906, p. 173) believed that the lower contact of the Stormville represents a marked break in sedimentation. However, only a slight hiatus is indicated.

Reference section.—The Stormville Member of the Coeymans Formation is well exposed at Hartman's Cave, at an elevation of 650 feet on the southeast slope of Godfrey Ridge, 0.85 mile northeast of the Stormville church in the Stroudsburg quadrangle (section 17).

KALKBERG LIMESTONE

Chadwick (1908, p. 347–348) applied the name Kalkberg Limestone to cherty limestone beds that were earlier included in either the upper

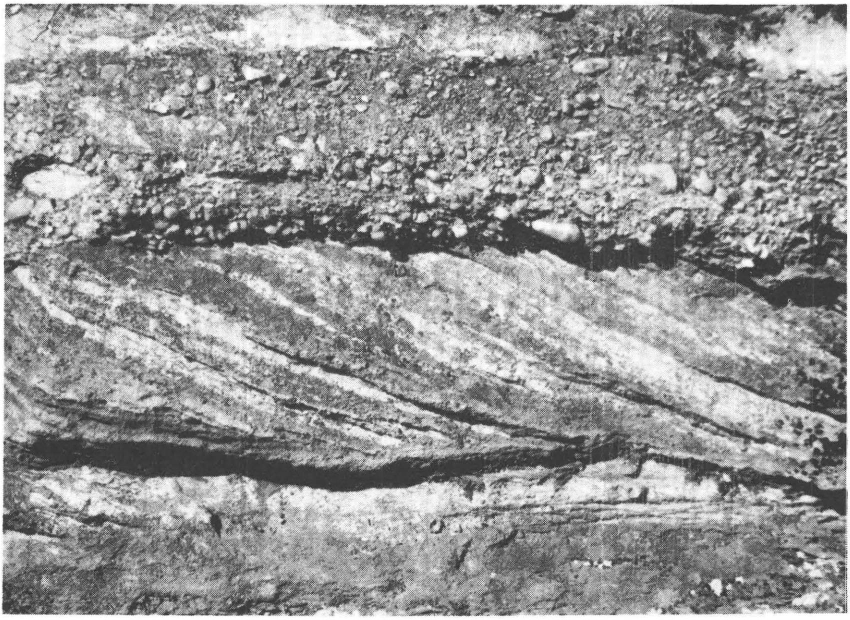

FIGURE 8.—Stormville Member of the Coeymans Formation, intersection of State Highway 90 and the Cherry Valley Road (section 16), 2.4 miles northeast of Stormville, Pa. Calcareous quartz-pebble conglomerate, pebbles as much as 1 inch long; crossbedded calcareous sandstone; and arenaceous crinoidal limestone at bottom.

part of the Coeymans Limestone (Weller, 1903, p. 81) or the lower part of the New Scotland Limestone. Later, Swartz (1939, p. 58) and Chadwick (1944, p. 44) placed these beds in the New Scotland. Rickard (1962, p. 79) following the work of Hartnagel (1912, p. 29, 60) and Goldring (1935, p. 103–114) considered the Kalkberg a distinct formation.

The Kalkberg crops out from Oriskany Falls, N.Y., eastward to Albany, then southwestward. It persists as a distinct lithic unit as far southwest as Wallpack Center, N.J. The Kalkberg of the Hudson River Valley consists largely of medium-bedded medium-dark-gray fine-grained fossiliferous limestone having bluish-black chert limited to the basal 10–15 feet and shaly intervals confined to the upper beds (Rickard, 1962, p. 78). At Trilobite Mountain (section 2), the Kalkberg consists of medium-dark-gray fine-grained argillaceous massively bedded fossiliferous limestone having nodules and lenses of dark-gray chert. These beds are more arenaceous to the southwest where the upper beds of the Kalkberg are partly replaced by the sandstone and conglomerate of the Stormville Member of the Coeymans Formation.

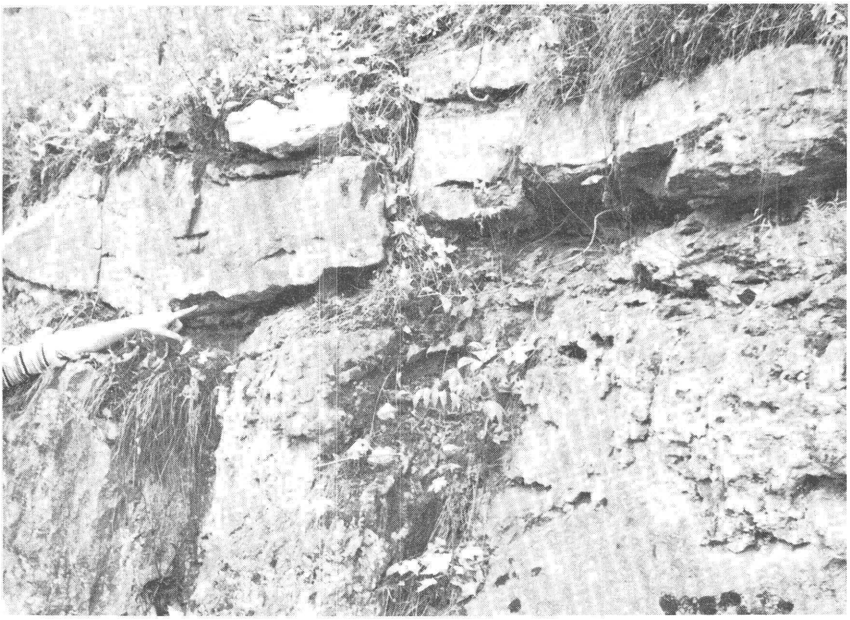

FIGURE 9.—Disconformable contact between Stormville Member (above) and Shawnee Island Member (below) of the Coeymans Formation at Shawnee on Delaware, Pa. (section 14–b).

Southwest of Wallpack Center, N.J., the Kalkberg is not a distinct lithic unit and laterally equivalent strata are included either within the Shawnee Island Member or Stormville Member of the Coeymans Formation. Swartz (1939) designated 33 feet of chert-bearing dark-gray siliceous calcareous shale above the Stormville at Minisink Hills and Wallpack Bend, Pa., as the Kalkberg Member of the New Scotland Formation. Swartz and Swartz (1941) later modified this designation by suggesting that this 33 feet of strata at Wallpack Bend might represent the Kalkberg Limestone of Chadwick. However, these beds are lithologically distinct from and stratigraphically higher than the Kalkberg and contain *Macropleura macropleura*, the guide fossil for rocks of New Scotland age in this area.

The Kalkberg grades downward into the Coeymans Limestone and is distinguished from it by its finer grain size, higher shale content, nodules and lenses of dark-gray chert, and greater faunal diversity. It grades upward into the slightly more argillaceous Flatbrookville Member of the New Scotland Formation northeast of Hainesville, N.J., and is disconformably overlain by the Stormville Member of the Coeymans Formation over a small area to the southwest. It grades laterally into the upper beds of the Shawnee Island Member of the

Coeymans Formation southwest of Wallpack Center, N.J., and is separated from these beds by an arbitrary cutoff (pl. 1). Thirty-eight feet of Kalkberg strata are exposed at Trilobite Mountain (section 2).

The Kalkberg Limestone contains an abundant and diversified fauna that includes brachiopods, trepostomatous and fenestellid bryozoans, ostracodes, and crinoid columnals. The brachiopod *Gypidula coeymanensis* was found in the basal 9 feet of the Kalkberg at Trilobite Mountain and in northwestern New Jersey.

NEW SCOTLAND FORMATION

The New Scotland Limestone was proposed by Clarke and Schuchert (1899, p. 877) for exposures in eastern New York, replacing the "Catskill" or "Delthyris" shaly limestone of earlier workers. Beds from the lower part of the New Scotland were reassigned to the Kalkberg by Chadwick (1908). So defined, the New Scotland in the Helderberg escarpment of New York consists of "massively bedded calcareous and argillaceous strata which weather into gray or brown shales. Fine-grained, thin-bedded, somewhat siliceous limestone beds are also to be found, especially near the top" (Rickard, 1962, p. 85). It grades into the underlying Kalkberg and overlying Becraft Limestones.

White (1882, p. 128, 131–132) included 160 feet of "ashen-gray, calcareous layers, often quite cherty, and * * * beds of impure limestone; fossiliferous" in his Stormville Shales north of the village of Stormville. The Stormville Shales are the New Scotland, Minisink, Port Ewen, and basal Oriskany of this report. White's measurement is somewhat low; 295 feet of this strata was measured near Minisink Hills, Pa. (section 15–c). Weller (1903, p. 86) estimated the thickness of strata containing typical New Scotland fauna to be 160 feet in New Jersey. Kümmel (1940, p. 89) likewise believed the poorly exposed New Scotland to be about 160 feet in New Jersey. Shimer (1905, p. 182) estimated the New Scotland's thickness (in which he included part of the Kalkberg) at Trilobite Mountain, N.Y., to be about 170 feet. This figure may be large. In the Lake Maskenozha quadrangle, 28 miles to the southwest, the New Scotland is about 65 feet thick (section 9). Swartz and Swartz (1941, p. 1168–1169, p. 1161) measured 79 feet of New Scotland near Wallpack Bend in Pennsylvania and 76 feet near Minisink Hills, which are the same measurements reported in the paper (section 15–c, p. 64).

The dual nature of the New Scotland was recognized by Weller (1900, p. 32; 1903, p. 86), Kümmel (1940, p. 89), Swartz (1939, p. 55–56), and Swartz and Swartz (1941, p. 1168, 1169, 1174). The lower 20–33 feet in New Jersey and northeastern Pennsylvania consists of medium-dark-gray slightly calcareous and siliceous shale with beds of medium-gray fine-grained argillaceous limestone and nodules and lenses of dark-gray chert. The upper 30–40 feet consists of slightly calcareous and siliceous dark-gray laminated shale with scattered concretions of medium-dark-gray dense limestone (fig. 10) and lenses and beds of medium-gray fine-grained argillaceous fossilferous limestone. Swartz and Swartz (1941) informally designated these the limestone member (lower) and shale member (upper). The formal names proposed in this report are the Flatbrookville and Maskenozha Members, respectively. This twofold division of the New Scotland Formation appears to persist to just southwest of Wallpack Center, N.J. The presence of abundant chert and purer limestone beds in the lower part of the New Scotland in New Jersey and eastern Pennsylvania is similar to the entire New Scotland at Broncks Lake, N.Y. (Rickard, 1962).

The New Scotland grades down into the Kalkberg Limestone northeast of Hainesville, N.J., and is in sharp contact with the Stormville Member of the Coeymans Formation southwest of Hainesville. Near Minisink Hills it is abruptly overlain by the Minisink Limestone but grades into it in the Lake Maskenozha quadrangle, New Jersey.

FLATBROOKVILLE MEMBER

The Flatbrookville Member, herein named for Flatbrookville, N.J., consists of medium-dark-gray siliceous and calcareous fossiliferous shale that weathers medium gray; beds and lenses of medium-gray fine-grained argillaceous very fossiliferous limestone that weathers medium light gray; and nodules and lenses of dark-gray chert. The shale exhibits slaty cleavage; the limestone has weak fracture cleavage. The member is generally poorly exposed. Complete exposures are unknown in New Jersey and northeastern Pennsylvania. The member is approximately 20 feet thick in the Lake Maskenozha quadrangle and 33 feet thick at Minisink Hills, Pa. Swartz and Swartz (1941, p. 1169) reported a thickness of 23 feet for the limestone member of the New Scotland at Wallpack Bend, Pa. Weller (1903, p. 86) and Kümmel (1940, p. 89) believed the lower chert-bearing purer limestone beds of the New Scotland to be about 20 feet thick. Shimer (1905, p. 182) divided the New Scotland into two faunal zones but did not distinguish them lithically. Willis (1912, p. 295) and Kümmel (1940, p. 90) erroneously reported that at Wallpack Bend the lower cherty limestone member of the New Scotland had disappeared and the Stormville Sandstone of White (1882) contains a fauna characterized by "*Spirifer macropleurus*." The lower New Scotland beds persist there and the Stormville replaces

FIGURE 10.—Dense limestone concretion in dark-gray siliceous laminated shale of the Maskenozha Member of the New Scotland Formation in a roadcut along the southeast slope of Wallpack Ridge, 2.9 miles southwest of Wallpack Center, N.J. (section 9). Note arching of bedding around concretion.

beds of the Kalkberg interval (now upper part of Shawnee Island Member of the Coeymans). *Macropleura macropleura* occurs above the Stormville Member and not within it.

The Flatbrookville Member abruptly overlies the Stormville Member of the Coeymans Formation southwest of Hainsville, N.J., and grades down into the Kalkberg Limestone northeast of Hainsville. It underlies the Maskenozha Member of the New Scotland Formation abruptly. The upper contact is placed at the highest occurrence of abundant dark-gray chert and abundant pure limestone beds and below the dark-gray laminated shales of the Maskenozha Member. The Flatbrookville persists to the southwest end of Godfrey Ridge in the Saylorsburg quadrangle.

The Flatbrookville has a more diverse fauna than the Maskenozha Member. *Macropleura macropleura*, *Leptaena* "*rhomboidalis*," and *Isorthis perelegans* are abundant. There are many other brachiopods, bryozoans, corals, crinoid columnals, trilobites, and ostracodes as well.

Type section.—The type section of the Flatbrookville Member is about 3.5 miles northeast of Flatbrookville, N.J. No complete exposure of the Flatbrookville and Maskenozha Members has been found in New Jersey or northeastern Pennsylvania, but the type section

(section 9) and a reference section (section 15–c) provide a complete description of both members. The type section is in the woods and along the northeast side of the Flatbrookville-Wallpack Center road, 3.2 miles (road distance) from the intersection with the trans-Kittatinny road joining it from the southeast, in the Lake Maskenozha quadrangle.

Reference section.—A reference section for the Flatbrookville Member of the New Scotland Formation is on the northeast bank of Brodhead Creek at Minisink Hills, Pa., in the Stroudsburg quadrangle (section 15–c).

MASKENOZHA MEMBER

The Maskenozha Member of the New Scotland Formation is herein named for Lake Maskenozha in Pennsylvania, northeast of the type section. The member consists of dark-gray siliceous laminated shale beds that weather medium gray to light medium gray. Medium-dark-gray dense limestone pods as much as 1 foot wide and 0.8 foot thick, as well as scattered beds and lenses of medium-gray fine-grained argillaceous fossiliferous limestone as much as 1 foot thick, occur 20–35 feet above the base. Small dark-gray chert nodules also occur in the limestone in places. Alternation of silty and nonsilty shale gives the rock its laminated appearance. The member is very poorly exposed; it forms covered slopes throughout New Jersey and northeastern Pennsylvania. The contact with the underlying Flatbrookville Member varies from abrupt to gradational and is placed at the highest occurrence of abundant dark-gray chert and abundant pure limestone beds characteristic of the Flatbrookville. The Maskenozha Member is darker and more thinly bedded than the Flatbrookville. The contact with the overlying Minisink Limestone is abrupt or gradational and is characterized by a change from shale having some argillaceous limestone beds in the Maskenozha to argillaceous limestone in the Minisink.

Only 23 feet of the Maskenozha Member is exposed in the Lake Maskenozha quadrangle at the type section; however, its estimated total thickness in this area is 43–48 feet. Swartz and Swartz (1941, p. 1168) report 56 feet of poorly exposed beds for the upper shale member of the New Scotland at Wallpack Bend, Pa. At Minisink Hills, the member is 43 feet thick. The 140 feet of upper New Scotland shales reported by Weller (1903, p. 86) in New Jersey and the 170 feet reported by Shimer (1905, p. 182) in New York (including part of the Kalkberg) seem disproportionately large. A thickening of the interval seems unlikely because all other formations of the Helderberg Group remain fairly constant in thickness from Port Jervis, N.Y., to Stroudsburg, Pa.

The Maskenozha Member persists to the southwest end of Godfrey Ridge in the Saylorsburg quadrangle. Complete exposures are unknown in southeastern New York. The nearest complete sections of the New Scotland are at Kingston and Broncks Lake, N.Y., where the formation is comparatively homogeneous (Rickard, 1962, p. 87).

The Maskenozha Member is abundantly fossiliferous, especially in the purer limestone beds. Brachiopods, bryozoans, corals, crinoid columnals, ostracodes, and trilobites are common. The large thick-shelled coarsely costate brachiopod *Macropleura macropleura* occurs throughout the member.

Type section.—The type section of the Maskenozha Member of the New Scotland Formation is about 3.5 miles northeast of Flatbrookville, N.J., in the woods and along the northeast side of the Flatbrookville-Wallpack Center road, 3.2 miles (road distance) from the intersection with the trans-Kittatinny road joining it from the southeast, in the Lake Maskenozha quadrangle. The member is named for Lake Maskenozha, Pa., which is 5.5 miles northwest of the type section (section 9).

Reference section.—Section 15–c on the northeast bank of Brodhead Creek at Minisink Hills, Pa., in the Stroudsburg quadrangle serves as a reference section for the Maskenozha Member.

MINISINK LIMESTONE

A thin unit of dark- to medium-gray fine-grained argillaceous limestone between the Port Ewen Shale and shale of the New Scotland Formation in eastern Pennsylvania and New Jersey has in the past been assigned, with some uncertainty, to the Becraft Limestone. However, inasmuch as the type Becraft of New York consists of "very coarse-grained, crinoidal, dark-gray or pink limestone containing such an abundance of fossils in place that it may be classified as a shellrock or coquinite" (Rickard, 1962, p. 88) and its stratigraphic relations to the limestone interval between the New Scotland and Port Ewen Formations of the Pennsylvania-New Jersey area are unknown, the name Minisink Limestone, for the village of Minisink Hills, Pa., in the Stroudsburg quadrangle, is proposed herein for these beds.

The Minisink Limestone consists of medium-gray fine-grained light-gray weathering argillaceous limestone that occurs in beds from a few inches to about 3 feet thick. Lenses of purer limestone occur in the Lake Maskenozha quadrangle (section 9). The contact with the overlying dark-gray siliceous and calcareous laminated shale of the Port Ewen is abrupt, whereas the contact with the subjacent dark-gray laminated shale of the New Scotland is gradational in the Lake Maskenozha quadrangle but is abrupt near Minisink Hills, Pa. The thickness of the Minisink does not vary much; it is 11.5 feet in the Lake

Maskenozha quadrangle and 14 feet at the type section. The Minisink persists southwest to a point near Bossardsville, Pa. It is known to continue as far northeast as Trilobite Mountain where it is 20 feet thick. It is generally not a well-exposed formation. The limestone is moderately fossiliferous and contains brachiopods, bryozoans, corals, and crinoid columnals.

White (1882, p. 131–132) included beds of impure fossiliferous limestone in his Stormville Shales. Weller (1900, p. 32) included about 20 feet of gray cherty limestone in the New Scotland, but later (1903, p. 91–92) he placed them in the Becraft Limestone. Shimer (1905, p. 183) referred 16 feet of very dark gray fine-grained limestone, lying above the New Scotland and below the Kingston Beds of former usage (Port Ewen) at Trilobite Mountain, near Port Jervis, N.Y., to the Becraft Limestone. Willis (1912, p. 295) correlated an estimated 20 feet of "hard gray cherty limestone" exposed along Wallpack Ridge with the Becraft Limestone of New York. Swartz (1939, p. 62) and Swartz and Swartz (1941, p. 1162) recognized 14 feet of impure limestone which they questionably referred to the Becraft, but Swartz and Swartz (1941, p. 1168) apparently assigned 20 feet of "medium to thick-bedded finely crystalline blue fossiliferous limestone" without reservation to the Becraft. Willard and Stevenson (1950, p. 2273) included the Becraft Limestone in the Helderberg Group in the Delaware Valley of Pennsylvania.

The position of the Minisink Limestone between the New Scotland Formation and the Port Ewen Shale suggests that the Minisink is equivalent to the Becraft and (or) Alsen Limestones of eastern New York. (See Rickard, 1962, fig. 27.) However, the Minisink may be stratigraphically lower than either the Becraft or Alsen (Rickard, 1962, p. 89); if it is, the New Scotland and Port Ewen are not exact equivalents between the two areas. Rather than introduce new names for these formations, the names New Scotland and Port Ewen are retained. Future work between Trilobite Mountain and Kingston, N.Y., may resolve this problem, although lack of sufficient exposures will be a difficulty.

Type section.—The type section of the Minisink Limestone is in a roadcut on the southwest side of U.S. Interstate Highway 80, approximately 0.4 mile southwest of Minisink Hills (section 15–d). The Minisink is completely exposed, although upper and lower contacts tend to become covered by shale float from above. The section lies along an overturned asymmetrical syncline (fig. 11).

Reference section.—Section 9, the type section for the Maskenozha and Flatbrookville Members of the New Scotland Formation, also serves as reference section for the Minisink Limestone.

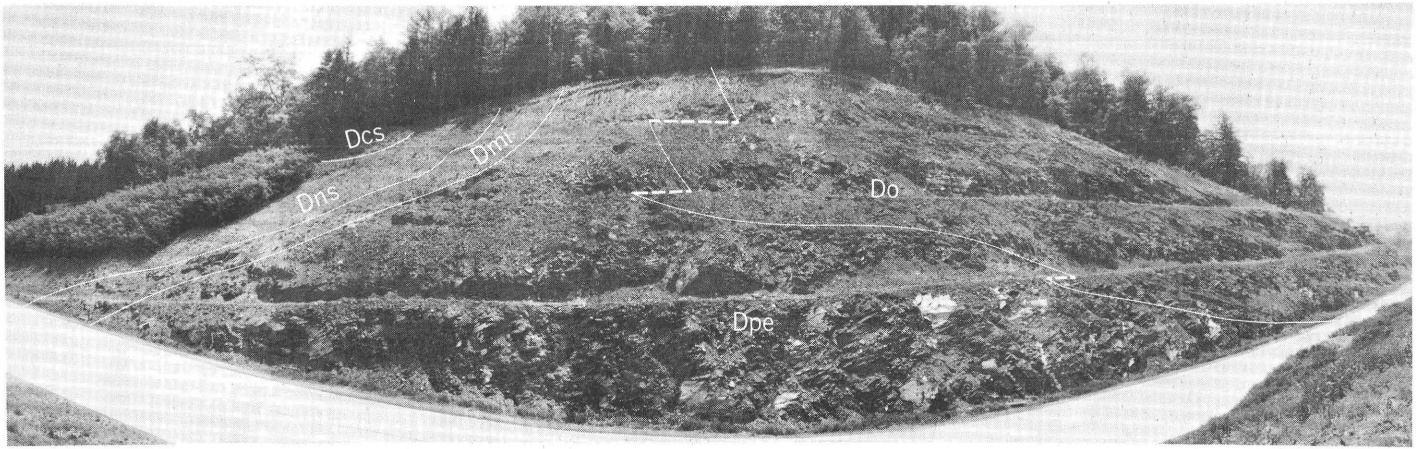

FIGURE 11.—Overturned syncline exposed in roadcut along U.S. Interstate Highway 80, approximately 0.4 mile southwest of Minisink Hills, Pa. (section 15–d). Dcs, Stormville Member of the Coeymans Formation; Dns, Flatbrookville and Maskenozha Members of the New Scotland Formation; Dmi, Minisink Limestone; Dpe, Port Ewen Shale; and Do, Oriskany Formation. Dashed lines are bedding traces. Overturning of beds seems greater because of foreshortening in photo.

PORT EWEN SHALE

Clarke (1903, p. 21) proposed the name Port Ewen Limestone to replace the earlier submitted but preoccupied, Kingston Beds—100-200 feet of shaly limestone exposed near Port Ewen, N.Y. The name Alsen Cherty Limestone was proposed by Grabau (1919, p. 468–470) for 20–50 feet of cherty limestone previously assigned to the lower part of the Port Ewen.

In southeasternmost New York, New Jersey, and eastern Pennsylvania the Port Ewen Shale, as it will be referred to in this report, is the most poorly exposed formation in the Helderberg Group, hence lateral lithic variations are incompletely known. There are no complete exposures in New Jersey and only one in eastern Pennsylvania. At the latter, in a cut through Godfrey Ridge along U.S. Interstate Highway 80, 0.4 mile southwest of Minisink Hills, Pa., the Port Ewen is 150 feet thick (fig. 11; section 15–d). The lower 60 feet of the formation consists of medium-dark-gray calcareous and siliceous silty shales that weather light gray. The beds are irregularly laminated and poorly fossiliferous. The upper 90 feet is more siliceous, calcareous, and irregularly bedded. Abundance and diversity of fossils increase upwards. Slaty cleavage is conspicuous throughout the Port Ewen and tends to obscure bedding and distort fossils.

The contact with the underlying Minisink Limestone is visible at sections 15–d and 9. It is abrupt at both localities. In eastern Pennsylvania the contact with the overlying Oriskany Formation is in a gradational sequence of interbedded siliceous and calcareous shale, dark-gray chert, and argillaceous limestone and is placed at the base of the lowest bed containing chert encountered up-section. So defined, the contact is abrupt and no significant disconformity is indicated. Where the Oriskany grades into the Port Jervis Limestone of Chadwick (1908) in northeast New Jersey, the contact is apparently gradational (Chadwick, 1908, p. 348).

The Port Ewen Shale extends to the southwest end of Godfrey Ridge in eastern Pennsylvania and persists across New Jersey into New York where it has been described by Rickard (1962, p. 90–92). The Port Ewen has an abundant ostracode and brachiopod fauna limited mainly to the upper 90 feet. Corals, bryozoans, trilobites, and crinoid columnals are also common.

Many disparities exist in thicknesses of the Port Ewen Shale as obtained by previous workers. The reasons for this may be manyfold. The Port Ewen is poorly exposed and generally forms covered slopes. In many places the rocks are complexly deformed, and hidden folds would yield exaggerated thicknesses. Cleavage tends to obscure bedding in most localities and makes measurement difficult. Finally, actual variations in thickness occur in different parts of folds. For example, beds have been observed to thin as much as 60 percent from the trough to limb in the overturned syncline exposed along U.S. Interstate Highway 80 (fig. 11).

White (1882, p. 131–132) included the Port Ewen in his Stormville Shales, which he believed were about 160 feet thick—an underestimate. Weller (1903, p. 93) believed about 80 feet of strata, covered everywhere in New Jersey, are assignable to the Kingston Beds of former usage. At Trilobite Mountain, N.Y., Shimer (1905, p. 184) placed 200 feet of dark-blue limestone and siliceous shale in the Port Ewen. This thickness may be inaccurate because most of the formation is concealed and because of difficulty in locating contacts with the similar rocks of formations above and below. Swartz (1929, p. 84) did not recognize the intervening (Minisink) limestone between the Port Ewen and New Scotland at Brodhead Creek, near Minisink Hills, Pa., so he included all the strata in the New Scotland, although he believed, as did Willard (1938, p. 13), that the upper part of the sequence is equivalent to the Port Ewen of New Jersey. Swartz (1939, p. 62, 65) later correlated these beds "with the Port Ewen of New Jersey and New York because of comparable lithology, similar stratigraphic position, and some features of the fauna." He (1939, p. 88) assigned 136 feet of dark-gray calcareous and siliceous ash-gray-weathering shale to the Port Ewen on Brodhead Creek, although the section was partly concealed, and 165 feet to the Port Ewen at Wallpack Bend, Pa. (1939, p. 90), although (p. 62) he reported the thickness as about 150 feet at the latter locality. Swartz and Swartz (1941, p. 1161–1162) reproduced the same section on Brodhead Creek as did Swartz (1939), but reported 174 feet of Port Ewen near Wallpack Bend (p. 1168). Kümmel (1940, p. 91) estimated 80 feet of Port Ewen in New Jersey.

ENVIRONMENTS OF DEPOSITION

The Upper Silurian and lowermost Devonian rock succession in northeastern Pennsylvania and New Jersey is part of a major nearly continuous depositional sequence that began in the Early Silurian and ended, at least in northeastern Pennsylvania and part of northwestern New Jersey, with the deposition of the Oriskany Formation.

After the Taconic orogeny, northeastern Pennsylvania and northwestern New Jersey were covered by a thick succession of coarse clastic deltaic deposits (Shawangunk Conglomerate). In time, slightly finer grained clastics were deposited (Bloomsburg Red Beds; High Falls of the New Jersey Geological Survey). By the end of Bloomsburg time, basin filling and sinking were more or less in balance, and the Poxono Island Formation of White (1892) was deposited on a shallow shelf, in a partly lagoonal environment. The succeeding rocks (Bossardville through part of the Port Ewen) record a steady deepening of the basin in the northeastern Pennsylvania-New Jersey area and only minor regressions. During Port Ewen time, sediment influx exceeded basin sinking and the depth of the sea steadily decreased. After Oriskany deposition and before Esopus accumulation, at least in northeastern Pennsylvania, the area was exposed to erosion.

The Bossardville Limestone, a very fine grained laminated slightly pyritic limestone and some dolomite having deep desiccation columns (fig. 2) and sporadic desiccation breccias, indicates rhythmic deposition in a supra- and intratidal highly saline and (or) brackish-water restricted lagoonal area similar to the depositional situation described by Shinn and others (1965), Gwinn and Clack (1965), and Laporte (1965). The fauna is composed solely of leperditiid ostracodes which occur in close association with desiccation cracks and interbedded dolomite. The Bossardville underlies and grades laterally into the Wallpack Center Member of the Decker Formation, a barrier-beach deposit of a type closely associated with lagoonal and tidal sediments.

At Bossardsville, Pa., the Wallpack Center Member of the Decker Formation consists of approximately 66 feet of interbedded biogenic limestone, dolomite, arenaceous limestone, calcareous siltstone, sandstone, and conglomerate. The carbonate-clastic ratio is approximately 1:1. The upper 5 feet of the Bossardville and basal 25 feet of the Wallpack Center Member represent an interfingering of Bossardville and Wallpack Center rock types (the interfingering of lagoon-barrier beach facies). Near Stroudsburg, Pa., the Wallpack Center Member consists of 83 feet of crossbedded juxtaposed lenses of quartz-pebble conglomerate, calcareous sandstone, and siltstone and a few lenses of biogenic limestone, all having marine fossils. At the William Nearpass quarry, New Jersey, the Decker consists of 43 feet of coarse-grained biogenic limestone interbedded with minor amounts of calcareous shale, siltstone, and sandstone. Thus, the Decker time interval is represented by a change from barrier-beach to biostromal-bank as it is traced from southwest to northeast.

The barrier-beach and biostromal-bank facies acted as sedimentary barriers protecting the lagoon area. According to Dunbar and Rodgers (1957, p. 69), the foreshore deposits of a beach and associated bars have strong cross-stratification (cut-and-fill crossbedding) that dips both landward and seaward, whereas the backshore beds are very irregular. Some beds show low-angle crossbedding, but cut-and-fill crossbedding is also common, and patches of sand, silt, or clay may be present. In the barrier-beach environment, alternating storm and calm produce a deposit in which adjacent laminae have different grain sizes. All the above characteristics are exhibited by the Wallpack Center Member of the Decker Formation. With increasing distance from the clastic source, these barrier-beach deposits are replaced by deposits of the shell-bank type (Clove Brook Member of the Decker Formation).

Above the Decker or Bossardville are restricted lagoonal and (or) tidal-flat deposits of the Rondout Formation (Herpers, 1951). These rocks are laminated and in places graded. Dolomite having deep desiccation cracks and limestone and calcareous shale having shallow mud cracks indicate intermittent subaerial exposure. The shale and limestone contain intervals of abundant ostracodes and rare minute algal structures. Biostromal layers of fragmented normal marine fossils occurs at some localities and are indicative of washover during high-wave activity. Sand stringers at the top of the Rondout near Stroudsburg, Pa., represent the leading edge of the barrier zone during Rondout time.

The Mashipacong Member of the Rondout Formation persists throughout the area of study and consists of lagoonal and (or) tidal-flat deposits of pyritic mud-cracked laminated and in places graded calcareous shale and argillaceous limestone; some beds exhibit cut-and-fill structure. This combination of primary sedimentary structural features is characteristic of the varying levels of physical activity in a tidal environment. The overlying Thacher Member of the Manlius Limestone northwest of Montague, N.J., represents an environment much like that described for the Thacher by Laporte (1963) and Rickard (1962, p. 94–96) in New York State. These authors interpreted the environment of deposition of the Manlius as a moderately open lagoon having scattered stromatoporoid banks and a prevalence of facies fossils such as tentaculitids, leperditiid ostracodes, and the brachiopod *Howellella vanuxemi* (Hall). However, there is an increasing abundance of more normal marine forms as the Thacher-Coeymans contact is approached. Southwest of Montague, the Thacher interval becomes more arenaceous and argillaceous, the fauna becomes more cosmopolitan, and the interval is included within the Coeymans Formation. Leperditiid ostracodes dominate in the basal beds of the Depue Limestone Member but rapidly give way to more normal marine faunas in the overlying beds.

The Coeymans Formation is characterized by deposits of a vigorous shallow-water neritic environment in which crinoidal debris and the thick-shelled brachiopod *Gypidula coeymanensis* Schuchert are dominant. Wide bands of biogenic limestone are interpreted as bank deposits. These biogenic banks, made up dominantly of sand-sized carbonate grains, occupy the same geographic locus as would an offshore bar in an area of clastic deposition.

Between Port Jervis and Stroudsburg, biogenic limestone of the Coeymans, as well as superjacent (Kalkberg) and subjacent (Thacher) rocks are gradually replaced by quartz-pebble conglomerate and sandstone (Stormville and Peters Valley Members) and arenaceous and argillaceous limestone. Within a narrow area between Montague and Tocks Island, N. J., localized coral-crinoid-bryozoan mounds formed on preexistig Thacher stromatoporoid banks or on the slightly raised cleaner sand bottom of the Peters Valley Member of the Coeymans Formation. Interbiostromal areas received clay- to sand-sized clastic and biogenic debris that washed over and between the bioherms. Stronger wave activity over these mounds kept them free of fine-grained detritus. It is not possible to determine the actual relief of these structures on the sea floor. Although no flanking beds were seen, bioherm margins grade abruptly into nonbiohermal facies. A relief of about 20 feet has been observed at the top of the Tocks Island bioherm (fig. 4) which indicates a minimum relief of 20 feet above the sea floor.

The association of clastic debris with reeflike structures is in no way peculiar. Newell (1953, p. 51) reports the intercalation of sandstone and reef material in the Permian reef complex of Texas and New Mexico and believes (p. 48) that much of the quartz sand was transported through the reefs from the back-reef area. Carbonate and quartz sand is also associated with some patch reefs in the Permian Bone Spring Limestone of Texas. Fairbridge (1950) reports that sand-sized clastics are being transported to and beyond the Great Barrier Reef of Australia in areas where sediment-bearing rivers enter the back-reef basin. Near a river mouth, biogenic debris would be mixed with and dominated by quartz sand and conglomerate.

The southwestern limit of bioherm development in Coeymans time was probably controlled by the percentage of clastic material invading the basin. Southwest of Tocks Island, the mud-silt-sand content of basin waters was probably too high for the formation of bioherms, and northeast of Montague, N. J., the Coeymans may represent a more basinward site of deposition with the reef zone lying farther east. This eastern area has been removed by erosion.

Biohermal formation ceased with the flood of mud and sand over the reefs that culminated in deposition of the Stormville Member, which is probably a barrier-beach deposit. The Stormville is crossbedded and highly irregular in rock type, and it contains quartz pebbles and fragmented marine fossils (fig. 5). The disconformable basal contact probably represents a break in deposition of only diastemic proportion.

A deeper water neritic phase followed Stormville deposition. The Flatbrookville Member of the New Scotland Formation has an abundant and diversified benthonic fauna, is for the most part regularly bedded, and contains nodules and lenses of dark-gray chert and fossiliferous argillaceous limestone. The lenses and beds of higher limestone content record times of decreased clastic influx during which there was concentration of fossil material and carbonates. The Maskenozha Member of the New Scotland records an even deeper water depositional phase. It consists of laminated silty limestone that has a few interbeds of argillaceous limestone and a fauna that is virtually identical with that of the Flatbrookville but less prolific. The Maskenozha Member grades upward into the Minisink Limestone and argillaceous fossiliferous limestone probably of deep-water neritic origin.

Gradual decrease in clastic influx as well as a shallowing of the basin with time is recorded in the Port Ewen Shale. The lower beds have a small number of fossils and contain many irregular silt laminae. The percentage of silt decreases upwards, but the carbonate content and fossil abundance and diversity increase. A gradual transition from deep-water to shallow-water neritic environment proceeded from Port Ewen to Oriskany time. Rickard (1962, p. 98–99) interprets the New Scotland and Port Ewen lithofacies as indicative of a deep-water neritic environment.

The facies relations described above are demonstrable along the very narrow outcrop belt of uppermost Silurian and lowermost Devonian strata in northeastern Pennsylvania, New Jersey, and southeasternmost New York. Eastern equivalents of these strata have been removed by erosion, and western equivalents are buried beneath the Pocono Plateau. There is lack of subsurface information concerning Upper Silurian and Lower Devonian stratigraphic units in northeastern Pennsylvania. Most wells drilled in the area penetrate only younger strata.

Figure 12 summarizes the environmental record during late Cayuga and Helderberg time in northeastern Pennsylvania, and can also be applied to New Jersey and southeasternmost New York with modification.

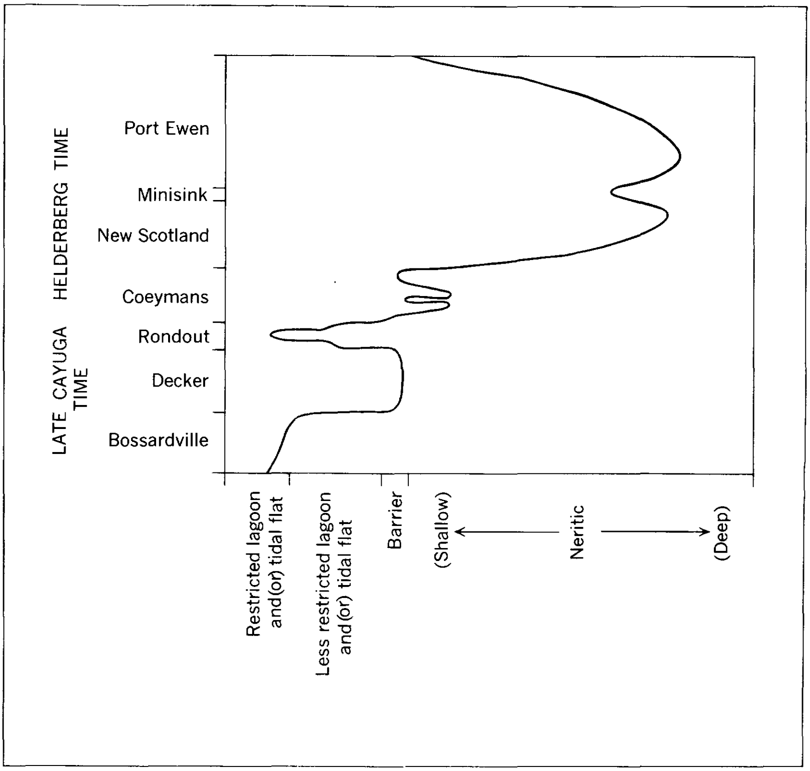

FIGURE 12.—Bathymetric changes from late Cayuga to late Helderberg time in the Stroudsburg area, Pennsylvania.

MEASURED SECTIONS

Type and reference sections are described below and the location of other sections shown on plate 1 are listed.

Section 1

Otisville quadrangle. Otisville sand and gravel quarry, 1 mile southeast of Cuddebackville, N.Y. Exposed quarry section measured by W. J. Spink. Units 1 through 15 were measured from a 2-inch core by S. G. Barnett III, A. G. Epstein, and J. B. Epstein. Beds in core dip 35°.

	Thickness (feet)
New Scotland Formation (part):	
Maskenozha Member (part):	
25. Argillaceous limestone and calcareous shale, medium-gray to medium-dark-gray; weather medium gray to medium light gray. Unit about 30 percent exposed; brachiopods; upper contact concealed; basal contact abrupt. Limestone is fine grained and flaggy to massive and comprises about 10 percent of unit	70.0
Incomplete thickness of Maskenozha Member	70.0
Incomplete thickness of New Scotland Formation	70.0

	Thickness (feet)
Kalkberg Limestone:	
24. Limestone, medium-gray to medium-dark-gray, fine-grained, argillaceous; weathers medium light gray to light gray; massive. Unit contains about 5 percent chert in continuous beds near base but becomes nodular near top, nodules arranged in layers parallel to bedding; uppermost foot silty. *Gypidula coeymanensis* and crinoid columnals abundant in places; basal contact concealed	43.0
23. Covered; approximate thickness	60.0
Coeymans Limestone:	
Ravena Member:	
22. Limestone, medium-dark-gray to dark-gray, fine- to medium-grained; weathers medium light gray to light gray; contains flecks of limonite; irregularly bedded; chert rare; biohermal; favositids, stromatoporoids, brachiopods, including *Gypidula coeymanensis*, and crinoid columnals; basal contact abrupt and irregular, placed at base of first crinoid-coral-stromatoporoid bed	8.0
Total thickness of Kalkberg and Coeymans Limestones	111.0
Manlius Limestone:	
Thacher Member:	
21. Limestone, dark-gray, fine- to medium-grained; weathers medium light gray; bedding undulatory with shaly to silty partings; about 10 percent of beds contain small crinoid columnals; brachiopods (*Howellella vanuxemi* noted) and ostracodes rare; abundant gastropods in one bed; basal contact concealed	35.0
Total thickness of Thacher Member	35.0
Total thickness of Manlius Limestone	35.0
Rondout Formation:	
Mashipacong Member:	
20. Limestone, medium-dark-gray, very fine grained to fine-grained, argillaceous; weathers yellowish gray; shaly to platy; basal contact abrupt	4.5
19. Limestone, medium-dark-gray to dark-gray, fine-grained, argillaceous; weathers yellowish gray; massive; basal contact concealed	1.0
18. Covered	2.0
Total thickness of Mashipacong Member	7.5

	Thickness (feet)
Rondout Formation—Continued	
Whiteport Dolomite Member:	
17. Dolomite, medium-dark-gray to dark-gray, very fine grained, argillaceous; weathers yellowish gray to grayish yellow; massive; disseminated euhedral pyrite (as much as 1/8 in. long); vugs as much as 2 in. in diameter lined with calcite and pyrite as much as 1/4 in. long; upper contact concealed; basal contact gradational through an interval of 2.3 ft. At top of transition zone is a 0.5-ft layer of weathered orange-brown clayey dolomite	27.0
Total thickness of Whiteport Dolomite Member	27.0
Duttonville Member:	
16. Limestone, medium-dark-gray to dark-gray, very fine grained; weathers medium light gray to light gray; platy to flaggy; much pyrite and chalcopyrite from 40 to 57 in. above base; strong odor of hydrogen sulfide when freshly broken; dolomitic near top; desiccation columns; upper contact placed at abrupt change in color from dark gray to medium dark gray	6.2
15. Limestone, medium-gray to dark-gray, very fine grained to medium-grained; weathers medium light gray to light gray; laminated to thinly bedded; most beds very fine grained to fine grained and dark gray; unit silty, crossbedded, and convolutely bedded at top; entire unit slightly pyritic; basal 4 feet described from core and consists of medium-gray to medium-dark-gray very fine grained limestone which grades up into medium-gray very fine grained slightly dolomitic thin-bedded to laminated unevenly bedded limestone with dark-gray calcareous shale partings throughout; leperditiid ostracodes scattered throughout unit; rugose coral fragment 5 ft. above base of unit; basal contact abrupt	49.8
14. Limestone, medium-gray, very fine grained, and light-olive-gray to medium-gray very fine grained dolomitic limestone; massive; basal contact abrupt	.9
Total thickness of Duttonville Member	56.9
Total thickness of Rondout Formation	91.4
Decker Formation:	
Clove Brook Member:	
13. Limestone, medium-dark-gray, very fine grained; interbedded with light-olive-gray very fine grained dolomitic limestone and medium-gray fine- to medium-grained fossiliferous limestone; irregularly bedded; leperditiid ostracodes and small brachiopods abundant; basal contact abrupt and placed at base of first olive-gray dolomitic limestone	1.2

	Thickness (feet)
Decker Formation—Continued	
Clove Brook Member—Continued	
12. Limestone, medium-dark-gray to dark-gray, very fine grained to fine-grained; irregularly bedded; scattered beds and lenses of medium-gray to medium-dark-gray fine- to medium-grained more fossiliferous limestone; dark-gray calcareous shale partings (about 1 mm thick) scattered throughout; leperditiid ostracodes and small brachiopods numerous in the medium-dark-gray fine- to medium-grained limestone; basal contact abrupt	9.1
11. Limestone, medium-gray to medium-dark-gray, fine-grained, slightly argillaceous; interbedded with medium-gray to medium-dark-gray fine- to coarse-grained limestone; dark-gray calcareous shale partings (approximately 1 mm thick) and euhedral pyrite scattered throughout; very unevenly bedded; fossils abundant and include rugose corals, brachiopods ("*Leptaena rhomboidalis*"), crinoid columnals, and bryozoa; basal contact abrupt	15.0
10. Limestone and argillaceous limestone. Medium-gray very fine grained to coarse-grained limestone. Light-olive-gray predominantly fine-grained argillaceous limestone. Unit very unevenly bedded with medium-gray coarse-grained limestone as lenticles in the olive-gray finer grained argillaceous limestone. Dark-gray calcareous shale mud crack fillings scattered throughout. Bryozoa abundant in coarser grained limestone lenticles. Limestone lenticles recrystallized so that bryozoan structure is obscured. Basal contact abrupt	8.9
9. Limestone, medium-gray to medium-dark-gray, fine- to coarse-grained; interbedded with lesser amounts of medium-dark-gray to dark-gray very fine grained to fine-grained laminated to thinly bedded (beds as much as 3 inches thick) limestone; thicker beds are unevenly bedded and lenticular; lower 0.5 ft contains dark-gray argillaceous limestone fillings (mud crack fillings), biogenic debris confined to more thickly bedded intervals and scattered throughout unit; fossils predominantly fragmented crinoid columnals and brachiopods; basal contact abrupt	.7
8. Similar to unit 9, but dark-gray fine-grained laminated limestone predominates over medium-gray coarse-grained limestone; basal contact gradational	1.6
7. Similar to unit 9. Basal contact gradational	2.9
Total thickness of Clove Brook Member	39.4
Total thickness of Decker Formation	39.4
Bossardville Limestone:	
6. Limestone, medium-gray to medium-dark-gray, very fine grained; laminated; a few scattered laminae of medium-gray to medium-light-gray very fine grained calcareous dolomite; medium-dark-gray to light-greenish-gray shale fillings about 1 mm thick, approximately perpendicular to bedding (mud crack fillings); basal contact abrupt	2.1

	Thickness (feet)
Bossardville Limestone—Continued	
5. Limestone, medium-gray to dark-gray, fine-grained; interbedded with thin beds and lenticles (as much as 5 mm thick) of medium-grained limestone containing medium-grained subrounded quartz sand; basal 0.5 in. consists of medium-gray to medium-dark-gray fine-grained limestone with a small amount of euhedral pyrite; branchiopod noted 4.3 ft above base of unit; basal contact abrupt and irregular	7.0
4. Limestone and dolomitic limestone, interlaminated. Medium-gray to medium-dark-gray very fine grained limestone. Light-gray very fine grained dolomitic limestone. Euhedral pyrite scattered throughout unit. Basal contact gradational	.9
3. Limestone, medium-gray to medium-dark-gray, very fine grained; laminated; basal contact gradational	.4
2. Dolomite and limestone, interlaminated. Medium-light-gray very fine grained calcareous dolomite; laminae as much as 15 mm. Medium-gray very fine grained dolomitic limestone; laminae as much as 1 mm. Calcareous dolomite predominates. Basal contact abrupt	.5
Total thickness of Bossardville Limestone	10.9
Poxono Island Formation of White (1882) (part):	
1. Dolomite, grayish-yellow, calcareous, leached; about 0.4 ft of core recovered; core boring bottomed within unit	7.7
Incomplete thickness of Poxono Island Formation of White (1882)	7.7

Section 2

Port Jervis South quadrangle. Three small abandoned quarries on the northwest side of Lime Kiln Road, on the southeast slope of Trilobite Mountain, Port Jervis, N.Y. Measurement begins in the middle of the three quarries near the top of the Thacher Member of the Manlius Limestone and extends up the northwest face of the quarry into the Kalkberg Limestone. Beds strike N. 50° E. and dip 30° NW. Reference section for the Ravena Member of the Coeymans Limestone. Section measured by A. G. Epstein, J. B. Epstein, and W. J. Spink.

Kalkberg Limestone (part):	
7. Limestone, medium-dark-gray, fine-grained, argillaceous and silty; weathers medium gray to medium light gray; very thin to thin beds and lenses of fine-grained sandstone; dark-gray chert nodules rare; well-formed fracture cleavage; unit approximately 60 percent exposed; upper contact concealed; basal contact gradational	8.0
6. Limestone, medium-dark-gray, fine- to medium-grained, argillaceous; weathers medium gray to medium light gray; 25–30 percent nodules and lenses of dark-gray chert; massively bedded; coralline bed from 10 to 12.5 ft above base; brachiopods, bryozoans, crinoid columnals, and ostracodes; basal contact at a slight reentrant; more argillaceous than unit below	33.0

	Thickness (feet)
Kalkberg Limestone (part)—Continued	
5. Limestone, medium-dark-gray, fine- to medium-grained, argillaceous, limonite flecked; weathers medium gray to medium light gray; about 10 percent nodules and lenses of dark-gray chert; massively bedded; brachiopods, bryozoans, crinoid columnals; *Gypidula coeymanensis* rare; transition zone between Coeymans and Kalkberg; basal contact transitional and placed at base of first chert bed	5.0
Incomplete thickness of Kalkberg Limestone	46.0
Coeymans Limestone:	
Ravena Member:	
4. Limestone, medium-dark-gray, medium- to coarse-grained, slightly argillaceous; weathers medium light gray; irregularly bedded; weak fracture cleavage; abundant biogenic debris; *Gypidula coeymanensis* and crinoid columnals abundant; scattered rugose and tabulate corals; contact with underlying unit abrupt and irregular	31.5
Total thickness of Ravena Member	31.5
Total thickness of Coeymans Limestone	31.5
Manlius Limestone (part):	
Thacher Member (part):	
3. Limestone, medium-gray to medium-dark-gray, coarse- to fine-grained, slightly limonitic; weathers medium light gray to medium gray; composed almost wholly of stromatoporoids and *Favosites* sp., colony heads as much as 1 ft in diameter; basal contact gradational	1.3
2. Limestone, medium-gray to medium-dark-gray, fine-grained with coarser grained pockets; weathers medium light gray to medium gray; fossils abundant; basal contact graditional	2.7
1. Limestone, medium-dark-gray to medium-gray, fine-grained; scattered lenses of coarser grained limestone; weathers medium light gray to medium gray; evenly bedded; alternations of massive 1-ft-thick beds of pure limestone with 1-in.-thick beds of slightly argillaceous limestone; numerous thin layers of stropheodontid brachiopods; base concealed	9.0
Incomplete thickness of Thacher Member	13.0
Incomplete thickness of Manlius Limestone	13.0

Section 3

Port Jervis South quadrangle. Abandoned William Nearpass quarry, on the southwest slope of Wallpack Ridge, 1.8 miles southwest of Duttonville, N.J. Beds strike N. 65° E. and dip 16° NW. Type locality of the Clove Brook Member of the Decker Formation and the Duttonville and Mashipacong Members of the Rondout Formation. Section measured by W. J. Spink.

	Thickness (feet)
Coeyman's Formation (part):	
Shawnee Island Member (part):	
22. Limestone, medium-gray, coarse- to fine-grained, slightly arenaceous; weathers light gray to medium light gray; flaggy to massive, irregularly bedded; fossils include *Gypidula coeymanensis*, rugose and tabulate corals, crinoid columnals, stropheodontid and spiriferid brachiopods, stromatoporoids, bryozoans, and trilobites; upper contact concealed; basal contact gradational	10.2
Incomplete thickness of Shawnee Island Member	10.2
Incomplete thickness of Coeymans Formation	10.2
Manlius Limestone:	
Thacher Member:	
21. Limestone, medium-dark-gray to dark-gray, very fine grained to fine-grained; weathers medium gray to medium light gray and dark greenish yellow; thin yellow shale partings; undulatory bedding, flaggy to massive; tentaculitids, stropheodontid and spiriferid brachiopods, ostracodes abundant; basal contact concealed	21.0
20. Covered	1.0
19. Limestone, medium-dark-gray to dark-gray, fine- to medium-grained; weathers medium gray to medium light gray; massive undulatory to knobby bedding; many stromatoporoids, stropheodontid brachiopods, ostracodes and tentaculitids; basal contact abrupt	10.3
18. Limestone, dark-gray, very fine grained to fine-grained; weathers medium gray; massive ostracodes abundant; some stromatoporiods; basal contact concealed, probably abrupt	2.5
Total thickness of Thacher Member	34.8
Total thickness of Manlius Limestone	34.8
Rondout Formation:	
Mashipacong Member:	
17. Limestone, medium-dark-gray, very fine grained to fine-grained, argillaceous; weathers yellowish gray; shaly to platy; a few beds flaggy to massive; bedding undulatory; mud cracked; basal contact abrupt	15.0
Total thickness of Mashipacong Member	15.0
Whiteport Dolomite Member:	
16. Dolomite, medium-gray, very fine grained, slightly argillaceous; weathers grayish orange; massive to platy; partly laminated; pyritic; unfossiliferous; basal contact abrupt	5.5
Total thickness of Whiteport Dolomite Member	5.5

	Thickness (feet)
Rondout Formation—Continued	
Duttonville Member:	
15. Limestone, shale, and dolomite. Limestone is dark gray, very fine grained to fine grained; weathers medium gray; thin bedded to massive; mud cracked at top of unit. Shale is medium dark gray, calcareous; weathers yellowish gray; laminated. Dolomite is medium gray, dense, argillaceous; weathers yellowish gray; laminated; flaggy to massive; pyritic. Unit is about 45 percent limestone, 42 percent shale, and 13 percent dolomite; ostracodes and stropheodontid brachiopods; basal contact abrupt	22. 5
Total thickness of Duttonville Member	22. 5
Total thickness of Rondout Formation	43. 0
Decker Formation:	
Clove Brook Member:	
14. Limestone, medium-dark-gray, coarse- to fine-grained; weathers medium gray to medium light gray; platy to massive; a few light-grayish-olive silty shale partings; rugose corals, favositids, and *Halysites* common; stromatoporoids, stropheodontid brachiopods, and ostracodes sporadic; basal contact abrupt	7. 5
13. Limestone and siltstone. Limestone is medium gray, medium grained, slightly arenaceous; weathers light to medium gray; platy to flaggy. Siltstone is olive gray, calcareous and shaly; platy; sparsely fossiliferous. Basal contact abrupt	7. 2
12. Limestone, medium-dark-gray, coarse-grained; weathers medium gray to light olive gray; basal contact abrupt	. 3
11. Sandstone, medium-gray to medium-light-gray, fine-grained, calcareous; weathers pale yellowish brown; crossbedded; basal contact abrupt	1. 0
10. Limestone, medium-dark-gray, coarse-grained; weathers medium gray to light olive gray; basal contact abrupt	. 2
9. Siltstone, light-olive-gray, calcareous; basal contact abrupt	. 1
8. Limestone and sandstone. Limestone is medium dark gray, coarse grained, arenaceous; weathers medium gray to light olive gray; some light-olive-gray silt layers; crinoidal. Sandstone is medium gray to medium light gray, fine grained, calcareous; weathers pale yellowish brown; platy. Basal contact abrupt	8. 7
7. Limestone, medium-dark-gray to moderate-reddish-brown to dark-reddish-brown, coarse-grained; weathers grayish yellow; massive; abundantly fossiliferous; basal contact abrupt	2. 5
6. Limestone and shale. Limestone is medium dark gray, medium grained; weathers medium gray. Shale is calcareous. Basal contact abrupt	. 4
5. Limestone, medium-dark-gray, medium- to coarse-grained, slightly arenaceous; weathers medium gray; massive, fossiliferous; basal contact abrupt	. 7

	Thickness (feet)
Decker Formation—Continued	
Clove Brook Member—Continued	
4. Limestone and sandstone. Limestone is medium dark gray, medium grained; weathers yellowish gray; flaggy; some calcareous shale partings. Sandstone is moderate brown, fine grained, calcareous; weathers yellowish gray. Basal contact abrupt	4.9
3. Limestone, medium-dark-gray, medium- to coarse-grained; weathers medium gray to grayish orange; flaggy to massive; some light-olive-gray silty shale partings; fossiliferous; basal contact abrupt	15.0
2. Limestone, medium-gray to medium-dark gray, medium- to coarse-grained, arenaceous; weathers medium orange to grayish orange; fossiliferous; basal contact abrupt and disconformable	1.7
Total thickness of Clove Brook Member	50.2
Total thickness of Decker Formation	50.2
Bossardville Limestone (part):	
1. Limestone, medium-dark-gray, very fine grained to fine-grained; weathers light gray to medium light gray; laminated and flaggy; some light-olive-gray silt layers; sporadic occurrence of leperditiid ostracodes; basal contact concealed	9.0
Incomplete thickness of Bossardville Limestone	9.0

Section 4

Milford quadrangle. Section on southwest side of county road and in woods on northeast side of road, approximately 1 mile southeast of Montague, N.J. Beds strike N. 20° E. and dip 14° SW. Section measured by A. G. Epstein and J. B. Epstein.

Section 5

Culvers Gap quadrangle. A series of ledges which crop out along the hillside above a small abandoned quarry at an elevation of approximately 600 ft, 0.7 mile northeast of Peters Valley, N.J. Weller's 1903 locality 37A. Beds strike N. 50° E. and dip 10° NW. Section measured by A. G. Epstein and J. B. Epstein.

Section 6

Culvers Gap quadrangle. Section on steep southeast slope of Wallpack Ridge at an elevation of approximately 620 ft, 1.7 miles (road distance) southwest of Peters Valley, N.J. Beds dip 15° NW. Section measured by A. G. Epstein and J. B. Epstein.

Section 7

Culvers Gap quadrangle. Southeast slope of Wallpack Ridge, 1 mile northeast of Wallpack Center, N.J. Beds strike N. 40° E. and dip 30° NW. Type section of the Wallpack Center Member of the Decker Formation. Section measured by W. J. Spink.

	Thickness (feet)
Coeymans Formation (part):	
Stormville Member (part):	
29. Sandstone, medium-gray to medium-light-gray, fine- to coarse-grained, calcareous; weathers light gray to medium light gray; scattered lenses of arenaceous limestone; abrupt vertical and lateral changes in rock type; upper contact concealed; basal contact gradational	5.0
Incomplete thickness of Stormville Member	5.0
Kalkberg Limestone:	
28. Limestone, medium-gray to medium-dark-gray, medium-grained, silty; weathers medium light gray; flaggy to massive; about 5 percent dark-gray chert occurs as beds near base of formation and as nodules toward top, amount of chert decreases from base to top; basal contact abrupt and drawn at base of lowest chert bed	23.0
Total thickness of Kalkberg Limestone	23.0
Coeymans Formation (part):	
Shawnee Island Member:	
27. Limestone, medium-gray to medium-dark-gray, medium- to coarse-grained, silty and arenaceous; weathers medium gray to medium light gray; flaggy to massive; well-formed fracture cleavage; *Gypidula coeymanensis* and crinoid columnals rare to abundant; basal contact gradational	36.0
Total thickness of Shawnee Island Member	36.0
Depue Limestone Member:	
26. Limestone, medium-dark-gray, very fine grained to fine-grained, silty; weathers medium gray to medium light gray; flaggy to massive. One bed of medium-dark-gray coarse-grained medium-gray- to medium-light-gray-weathering crinoidal limestone containing *Gypidula coeymanensis* is 7–10 ft below top. Basal contact concealed	29.0
Total thickness of Depue Limestone Member	29.0
Incomplete thickness of Coeymans Formation	70.0
Rondout Formation:	
Mashipacong Member:	
25. Limestone, medium-dark-gray, very fine grained to fine-grained, argillaceous and silty; weathers yellowish gray; platy; bedding undulatory to crumpled; "ribbon" limestone; poorly exposed; basal contact concealed	13.0
Total thickness of Mashipacong Member	13.0

Rondout Formation—Continued	Thickness (feet)
Whiteport Dolomite Member:	
24. Dolomite, medium-gray, very fine grained, argillaceous; weathers characteristic grayish orange; massive; laminated; basal contact abrupt	7.0
Total thickness of Whiteport Dolomite Member	7.0
Duttonville Member:	
23. Shale, medium-dark-gray, calcareous, weathered; weathers medium light gray; basal contact abrupt	3.5
22. Limestone, dark-gray, very fine grained to medium-grained; weathers medium gray to medium light gray; massive; basal contact abrupt	4.8
21. Limestone, dark-gray to medium-dark-gray, very fine grained, argillaceous; weathers medium light gray to yellowish gray; silty laminae weather yellowish gray and give unit a ribbony appearance; large smooth-shelled ostracodes common; basal contact abrupt	2.0
20. Dolomite, medium-gray, very fine grained, argillaceous; weathers grayish orange; massive	1.0
19. Limestone, dark-gray to medium-dark-gray, medium-grained; weathers medium gray to medium light gray	.2
18. Limestone, medium-dark-gray, very fine grained, silty; weathers medium light gray; massive; fracture cleavage; basal contact abrupt	1.5
Total thickness of Duttonville Member	13.0
Total thickness of Rondout Formation	33.0
Decker Formation:	
Wallpack Center Member:	
17. Sandstone, medium-gray, fine-grained, calcareous; weathers yellowish gray to grayish orange; flaggy to massive; crossbedded; about 40 percent exposed; basal contact concealed	33.0
16. Sandstone and siltstone. Sandstone is medium gray, fine grained, calcareous; weathers yellowish gray to grayish orange; platy to flaggy. Light-olive-gray calcareous siltstone. Basal contact abrupt	15.0
15. Limestone, medium-dark-gray, coarse-grained, slightly arenaceous; weathers medium gray to medium light gray; massive; basal contact abrupt	2.7
14. Siltstone and limestone. Siltstone is medium gray; weathers medium light gray; platy to flaggy. Limestone is medium to coarse grained, slightly limonitic. Basal contact concealed	2.5
13. Sandstone, medium-gray, fine-grained, calcareous; weathers yellowish gray to grayish orange; platy to flaggy; basal contact abrupt	2.1

	Thickness (feet)
Decker Formation—Continued	
Wallpack Center Member—Continued	
12. Limestone, medium-dark-gray and moderate- to dark-reddish-brown, coarse-grained; weathers grayish yellow; interbedded with platy siltstone layers; fossiliferous, crinoidal; basal contact abrupt	2.5
11. Sandstone and limestone. Sandstone is medium gray, fine grained, calcareous; weathers light gray to yellowish gray; flaggy to massive. Limestone is medium gray, medium to coarse grained, arenaceous; weathers medium light gray; platy to flaggy; fossiliferous with coral fragments. Unit about 70 percent sandstone; basal contact abrupt	7.7
10. Limestone, medium-dark-gray, medium- to coarse-grained, arenaceous; light-olive-gray silt partings as much as ½ in. thick; top bed has load markings; fossiliferous; basal contact abrupt	.7
9. Sandstone, medium-gray to medium-light-gray, calcareous; weathers yellowish gray; platy to flaggy; some light-olive-gray silt partings; basal contact abrupt	3.3
8. Limestone, medium-dark-gray, very coarse grained; weathers medium gray to medium light gray; crinoidal; basal contact abrupt	.5
7. Sandstone, medium-gray to medium-light-gray, fine-grained, calcareous; weathers grayish orange to light gray; flaggy to massive; argillaceous light-olive-gray silt partings; basal contact abrupt	7.3
6. Siltstone, medium-gray to medium-light-gray, calcareous; weathers light gray to very light gray; laminated; basal contact abrupt	.1
5. Limestone, medium-gray to medium-dark-gray, medium- to coarse-grained, arenaceous; weathers medium gray to medium light gray; some silty beds; fossiliferous; basal contact abrupt	.8
4. Siltstone and limestone. Calcareous siltstone interbedded with medium-light-gray yellowish-gray-weathering fine- to medium-grained silty limestone. Basal contact abrupt	.6
3. Limestone, medium-dark-gray, medium-grained, limonitic; weathers medium light gray; massive; scattered siltstone layers; unfossiliferous; basal contact abrupt	1.0
2. Limestone, medium-gray, fine- to medium-grained, arenaceous and argillaceous; weathers medium light gray; limonitic; well-formed fracture cleavage; fossiliferous, many coral fragments; basal contact abrupt	2.0
Total thickness of Wallpack Center Member	81.8
Total thickness of Decker Formation	81.8

	Thickness (feet)
Bossardville Limestone (part):	
1. Limestone, medium-dark-gray, very fine grained to fine-grained; weathers light gray except for upper 2 ft which weather grayish orange to dark yellowish orange; partially dolomitic; massive; laminated; some laminae consist of light-olive-gray irregular silt lenses; 2-ft fine-grained limestone 37 ft below upper contact; unfossiliferous; basal contact concealed	47.9
Incomplete thickness of Bossardville Limestone	47.9

Section 8

Lake Maskenozha quadrangle. Section on west side of road which crosses Wallpack Ridge, 0.1 mile northwest of Wallpack Center, N.J. Beds strike N. 45° E. and dip 15° NW. Section measured by A. G. Epstein and J. B. Epstein.

Section 9

Lake Maskenozha quadrangle. On the northeast side of the Flatbrookville-Wallpack Center road, 3.2 miles (road distance) from the intersection with the trans-Kittatinny road joining it from the southeast. Measurement begins in the woods in biohermal facies of the Shawnee Island Member of the Coeymans Formation (beds strike N. 40° W. and dip 12° SW.) and continues uphill to the top of the Stormville Member (unit 4), where, at elevation 550 ft, beds strike N. 48° E. and dip 14° NW. Measurement offset 100 feet to the northeast and continues uphill to a topographic bench on the hillside (probably the top of the Flatbrookville Member of the New Scotland Formation). Measurement offset approximately 1,000 ft southwest and continues on northwest side of roadcut. Upper 14 ft of Flatbrookville reoccurs here, and beds strike N. 60° E. and dip 16° SE. The lower beds of the Maskenozha Member are concealed, and exposures are lacking for 485 ft along the road. The upper 23 ft of the Maskenozha Member is exposed; beds strike N. 50° E. and dip 24° NW. Type section for the Flatbrookville and Maskenozha Members of the New Scotland Formation and reference section for the Minisink Limestone. Section measured by A. G. Epstein and J. B. Epstein.

	Thickness (feet)
Minisink Limestone:	
8. Limestone, medium-gray, fine-grained, argillaceous; weathers medium light gray; massively bedded; beds as much as 3 ft thick; nodules and lenses of purer limestone; fossils abundant and include brachiopods, corals, bryozoans, and crinoid columnals; upper contact with Port Ewen abrupt; basal contact gradational	11.5
Total thickness of Minisink Limestone	11.5

	Thickness (feet)
New Scotland Formation:	
Maskenozha Member:	
7. Shale, dark-gray, calcareous and siliceous; weathers medium gray; laminated; scattered concretions, as much as 2 ft in diameter, of medium-dark-gray dense limestone, from 12 to 22 ft below top; bedding bends around concretions (fig. 10); unit consists of about 10 percent medium-gray fine-grained argillaceous fossiliferous limestone beds having scattered nodules of dark-gray chert; conspicuous slaty cleavage; fossils rare in shale and abundant in limestone; brachiopods, bryozoans, horn corals; fossils generally broken; basal contact concealed	23.0
6. Covered. Computed maximum thickness	25.0
Total thickness of Maskenozha Member	48.0
Flatbrookville Member:	
5. Shale, medium-dark-gray, calcareous and siliceous; weathers medium gray; irregularly bedded; conspicuous cleavage; contains 25–30 percent beds and lenses of medium-gray fine-grained argillaceous fossiliferous limestone and 5–10 percent nodules and lenses of dark-gray chert; fossils abundant; *Macropleura macropleura, Leptaena "rhomboidalis,"* other brachiopods, bryozoans, trilobites, and ostracodes common; basal contact concealed	17.5
Total thickness of Flatbrookville Member	17.5
Total thickness of New Scotland Formation	65.5
Coeymans Formation (part):	
Stormville Member:	
4. Sandstone, medium-light-gray, medium- to fine-grained, calcareous; weathers light tannish gray; slightly limonitic; massively bedded; scattered lenses of medium-grained biogenic limestone; nodules of dark-gray chert of 1.2 ft above base; sporadic crinoid columnals and *Gypidula coeymanensis;* basal contact disconformable	7.0
Total thickness of Stormville Member	7.0
Shawnee Island Member (part):	
3. Limestone, medium-gray, fine- to medium-grained, argillaceous and arenaceous; weathers medium light gray; irregularly bedded; weak fracture cleavage; unit contains about 10 percent nodules and lenses of dark-gray chert; crinoid columnals and *Gypidula coeymanensis;* basal contact abrupt	10.5
2. Limestone; similar to unit 3 but without chert; basal contact abrupt and undulatory	3.0

	Thickness (feet)
Coeymans Formation (part)—Continued	
Shawnee Island Member (part)—Continued	
1. Biohermal facies. Limestone, medium-light-gray, coarse-grained with scattered pockets of finer grain size; weathers light gray; slightly limonitic; unbedded to crudely bedded; massive; biogenic; unit composed entirely of crinoid columnals, *Favosites* sp. fragments (some as much as 0.8 ft in diameter), rugose corals, trepostomatous bryozoans, and scattered brachiopods; basal contact concealed	30.0
Incomplete thickness of Shawnee Island Member	43.5
Incomplete thickness of Coeymans Formation	50.5

Section 10

Flatbrookville quadrangle. Cut on northwest side of County road which extends along the southwest side of Wallpack Ridge, 1.5 miles northwest of Flatbrookville, N.J., and 0.1 mile southwest of a V-shaped bend in the road. Beds strike N. 65° E. and dip 50° SE., overturned. Type section of the Peters Valley Member of the Coeymans Formation. Section measured by A. G. Epstein and J. B. Epstein.

	Thickness (feet)
Coeymans Formation (part):	
Shawnee Island Member (part):	
4. Limestone, medium-dark-gray to medium-gray, fine-grained with coarser grained pockets, argillaceous and arenaceous; weathers medium light gray; small flecks of limonite throughout; irregularly bedded; about 10 percent nodules and lenses of dark-gray chert; crinoid debris, coral fragments, brachiopods, and bryozoans abundant; basal contact abrupt; upper contact concealed	7.0
3. Limestone; similar to unit 1 but without chert; *Gypidula coeymanensis* and crinoid columnals abundant; a few bryozoans, brachiopods, and coral fragments; unit about 85 percent carbonate; basal contact gradational	32.3
Incomplete thickness of Shawnee Island Member	39.3
Peters Valley Member:	
2. Limestone, medium-gray, fine- to medium-grained, arenaceous; weathers light tannish gray; contains about 40 percent quartz sand and silt; abundant stromatoporoid fragments (1–3 in. in diameter), coral fragments, brachiopods, and crinoid columnals; basal contact varies from abrupt to gradational	1.5
Total thickness of Peters Valley Member	1.5

Coeymans Formation (part)—Continued *Thickness (feet)*

Depue Limestone Member (part):

1. Limestone, medium-dark-gray; fine grained with coarser grained lenses; slightly arenaceous and argillaceous; uppermost foot limonitic; numerous layers of stropheodontid brachiopods; basal contact concealed ---------- 7.0

Incomplete thickness of Depue Limestone Member -- 7.0

Incomplete thickness of Coeymans Formation ------ 47.8

Section 11

Flatbrookville quadrangle. Section is in the woods on the northeast side of a secondary road along the ascent of Wallpack Ridge in Pennsylvania, immediately southwest of where the Delaware River cuts through the ridge. The section begins at the top of the Decker Formation on the northeast side of the road and continues uphill into the woods. Bedding strikes N. 30° W. and dips 20° NW. Near the top of unit 10, measurement is offset southwest to the roadcut. Seven ft. of nonbiohermal facies is exposed on the southwest side of the roadcut. These same beds are exposed along the bank of the Delaware River, at the foot of the back slope of Wallpack Ridge, where measurement can be continued. Beds along the river dip gently northwest. Reference section for the Peters Valley Member of the Coeymans Formation. Section measured by A. G. Epstein and J. B. Epstein.

New Scotland Formation (part):

Flatbrookville Member (part):

16. Shale, dark-gray, calcareous and siliceous; weathers medium to light gray; about 10 percent lenses and nodules of dark-gray chert; about 10 percent lenses and beds of medium-gray fine-grained argillaceous fossiliferous limestone; fossils more abundant in limestone than in shale; *Macropleura macropleura*, *Leptaena* sp., other brachiopods, bryozoans, trilobites, and ostracodes abundant; basal contact abrupt; upper contact concealed ---------- 7.0

Incomplete thickness of Flatbrookville Member ------ 7.0

Incomplete thickness of New Scotland Formation ---- 7.0

Coeymans Formation:

Stormville Member:

15. Sandstone, medium-light-gray, fine- to coarse-grained; grains rounded to subangular, calcareous; weathers light tannish gray; thin lenses of medium-gray fine- to medium-grained fossiliferous limestone; crossbedded; abrupt lateral and vertical changes in rock type; sporadic crinoid columnals and *Gypidula coeymanensis;* basal contact abrupt --------- 8.0

	Thickness (feet)
Coeymans Formation—Continued	
Stormville Member—Continued	
14. Conglomerate, medium-light-gray; rounded to subrounded milky quartz pebbles; calcareous and arenaceous; weathers light tannish gray; scattered crinoid columnals and *Gypidula coeymanensis;* basal contact disconformable; relief on surface ½–1 ft	1.2
Total thickness of Stormville Member	9.2
Shawnee Island Member:	
13. Limestone, medium-gray, fine-grained, arenaceous and argillaceous; weathers light tannish gray; slighty limonitic; irregularly bedded; weak fracture cleavage; unit about 60 percent limestone; abundant *Gypidula coeymanensis* and crinoid columnals; basal contact abrupt	2.7
12. Limestone; similar to unit 13; 3–5 percent dark-gray chert nodules; basal contact abrupt	4.0
11. Limestone; similar to unit 13; contact with underlying bioherm abrupt and irregular; relief 2–3 ft	7.0
10. Biohermal facies: Medium-light-gray to light-pinkish-gray coarse-grained limestone containing pockets of finer grained limestone; weathers light gray; forms massive rounded blocks (averaging 10 ft in diameter) on weathering; scattered flecks of limonite throughout; unbedded; composed entirely of biogenic limestone; tabulate and rugose corals, trepostomatous bryozoans, and crinoid columnals are major components; brachiopods and other invertebrates rare and in pockets; fossils mostly fragmental; *Favosites* sp. fragments as much as 6 in. in diameter; crinoid columnals as much as 5 in. long and 0.5 in. in diameter; basal 2 ft contains about 20 percent quartz sand; basal contact gradational	29.0
Total thickness of Shawnee Island Member	42.7
Peters Valley Member:	
9. Limestone, medium-gray, fine- to medium-grained, arenaceous (about 25 percent quartz sand); weathers medium light gray; slightly limonitic; faintly crossbedded; abundant biogenic debris; basal contact irregular and gradational	3.0
Total thickness of Peters Valley Member	3.0
Depue Limestone Member:	
8. Limestone medium-dark-gray, fine-grained; has pockets of coaser grain size, slightly argillaceous and arenaceous; weathers medium light gray and knobby; evenly bedded; many thin layers of stropheodontid brachiopods; other brachiopods and tentaculitids; basal contact concealed	8.0

	Thickness (feet)
Coeymans Formation—Continued	
Depue Limestone Member—Continued	
7. Covered; approximate thickness of strata concealed	9.0
Total thickness of Depue Limestone Member	17.0
Total thickness of Coeymans Formation	71.9
Rondout Formation:	
Mashipacong Member:	
6. Limestone, medium-dark-gray, very fine grained, slightly argillaceous; weathers light medium gray; laminated; basal contact concealed	3.0
5. Covered; approximate thickness of strata concealed	11.0
Total thickness of Mashipacong Member	14.0
Whiteport Dolomite Member:	
4. Dolomite, medium-gray, very fine grained; weathers light yellowish gray ("peth-stone" of early workers); laminated; unfossiliferous; basal contact abrupt	7.9
Total thickness of Whiteport Dolomite Member	7.9
Duttonville Member:	
3. Limestone, medium-gray, fine-grained, slightly argillaceous; weathers medium gray to light yellowish gray; laminated; laminae of pure limestone and argillaceous limestone; leperditiid ostracodes and stromatoporoids rare to abundant; base of unit concealed	5.3
2. Covered	3.0
Total thickness of Duttonville Member	8.3
Total thickness of Rondout Formation	30.2
Decker Formation (part):	
Wallpack Center Member (part):	
1. Sandstone, medium-light-gray, fine- to medium-grained, calcareous, which weathers light tannish gray and forms ledge; and medium-light-gray calcareous siltstone that weathers to orange soil; base of unit concealed	1.5
Incomplete thickness of Wallpack Center Member	1.5
Incomplete thickness of Decker Formation	1.5

Section 12

Bushkill quadrangle. Section on southeast side of State Highway Legislative Route 45012 in the backyard of a private residence 0.1 mile northwest of Depew Island. Section measured by A. G. Epstein.

Section 13

Bushkill quadrangle. Section including the Depue Limestone Member of the Coeymans Formation through part of the Flatbrookville Member of the New Scotland Formation measured along cliff on southeast side of Godfrey Ridge, opposite Tocks Island, N.J., at an elevation of approximately 750 ft (fig. 6). The section can best be reached by ascending the ridge along a cleared powerline area. Section including part of the Poxono Island Formation of White (1882) through the Mashipacong Member of the Rondout Formation measured from core DTB–157 drilled by the Army Corps of Engineers in connection with the Tocks Island Dam project. Drill hole at an elevation of 425 ft and approximately 150 ft east of the powerline. Section measured by A. G. Epstein and J. B. Epstein.

Section 14–a

Bushkill quadrangle. Section in creekbed and along northeast side of road which trends northeast from Shawnee on Delaware, Pa., in the village of Shawnee on Delaware. Beds along road strike N. 61° E. and dip 82° NW. Section measured by A. G. Epstein and J. B. Epstein.

Section 14–b

Bushkill quadrangle. Cut along the northwest side of the road, 0.6 mile southwest of Shawnee on Delaware, Pa. Beds dip gently northwest. Type section of Shawnee Island and Depue Limestone Members of the Coeymans Formation. Section measured by A. G. Epstein and J. B. Epstein.

	Thickness (feet)
New Scotland Formation (part):	
Flatbrookville Member (part):	
12. Shale, dark-gray, siliceous; weathers medium gray to light gray; about 10 percent nodules and lenses of dark-gray chert; about 10 percent beds and lenses of medium-gray fine-grained argillaceous fossiliferous limestone; fossils include coral fragments, brachiopods, bryozoans, trilobites, and ostracodes; basal contact concealed	5.2
11. Covered	3.5
Incomplete thickness of Flatbrookville Member	8.7
Incomplete thickness of New Scotland Formation	8.7
Coeymans Formation:	
Stormville Member:	
10. Conglomerate and sandstone, medium-light-gray, calcareous and limonitic; weathers light gray to medium light gray; rounded to subangular quartz sand and pebbles, milky quartz pebbles as much as 0.5 of an in. long; subordinate lenses of arenaceous and argillaceous limestone; calcareous cement leached on surface; crossbedded; abrupt vertical and lateral lithic changes; *Gypidula coeymanensis* and crinoid columnals rare to abundant; basal contact disconformable; relief on surface as much as 2 ft	15.0
Total thickness of Stormville Member	15.0

	Thickness (feet)
Coeymans Formation——Continued	
Shawnee Island Member:	
9. Limestone, medium-gray, fine- to medium-grained, arenaceous and argillaceous; weathers medium light gray; slightly limonitic; irregularly bedded; weak fracture cleavage; unit about 75 percent carbonate; some horn corals, abundant *Gypidula coeymanensis* and crinoid columnals; basal contact abrupt and irregular	13.6
8. Chert, dark-gray; slightly irregular in thickness; basal contact abrupt	1.0
7. Limestone; similar to unit 9, but contains scattered nodules of dark-gray chert; basal contact at base of lowest occurrence of chert	10.5
6. Limestone; similar to unit 9, but has a very sandy 1- to 2-ft crossbedded limestone bed 20 ft below top; basal contact transitional through 1-ft interval, marked by change from sandy limestone to very sandy limestone and calcareous sandstone	31.0
Total thickness of Shawnee Island Member	56.1
Peters Valley Member:	
5. Limestone, medium-gray, fine-grained, very arenaceous; and interbedded medium-gray fine- to medium-grained calcareous sandstone. Unit weathers medium light gray; limonitic; massively bedded; scattered crinoid columnals, brachiopods, and corals; basal contact transitional through 1-ft interval	9.0
Total thickness of Peters Valley Member	9.0
Depue Limestone Member:	
4. Limestone, medium-dark-gray, fine-grained with coarser grained pockets, slightly arenaceous and argillaceous; weathers medium light gray; limonitic to hematitic; fairly evenly bedded; numerous thin layers of stropheodontid brachiopods; scattered coral fragments and brachiopods; basal 1 ft very fossiliferous medium-grained limestone ledge; basal contact abrupt	13.0
Total thickness of Depue Limestone Member	13.0
Total thickness of Coeymans Formation	93.1
Rondout Formation:	
Mashipacong Member:	
3. Limestone, medium-dark-gray, fine-grained, slightly argillaceous; weathers medium gray; very evenly bedded; beds from 0.5 ft thick to thin laminae decreasing in thickness downward; basal contact abrupt	8.3
Total thickness of Mashipacong Member	8.3

	Thickness (feet)
Rondout Formation—Continued	
Whiteport Dolomite Member:	
2. Dolomite, medium-gray, very fine grained, slightly argillaceous; weathers yellowish gray; laminated; desiccation columns; "peth-stone" of early workers; basal contact concealed	7.0
Total thickness of Whiteport Dolomite Member	7.0
Duttonville Member:	
1. Shale, medium-gray, calcareous; weathers yellowish gray; laminated and mud cracked; poorly exposed; contains purer limestone beds; leperditiid ostracodes abundant; basal contact concealed	17.0
Total thickness of Duttonville Member	17.0
Total thickness of Rondout Formation	32.3
Decker Formation (thickness not measured):	
Wallpack Center Member (thickness not measured):	
Limestone, medium-gray, medium-grained, arenaceous and argillaceous; weathers medium light gray; crossbedded; poorly exposed.	

Section 15–a

Stroudsburg quadrangle. Section at North Croasdale quarry, approximately 0.5 mile southwest of Minisink Hills, Pa. Section measured by A. G. Epstein and J. B. Epstein.

Section 15–b

Stroudsburg quadrangle. Section along southeast bank of Brodhead Creek, approximately 0.1 mile above dam. Beds vertical. Section measured by A. G. Epstein and J. B. Epstein.

Section 15–c

Stroudsburg quadrangle. On the northeast bank of Brodhead Creek at Minisink Hills, Pa. Section begins just southeast of the collapsed bridge. Bedding dips 40° NW., on the average. Reference section for the Flatbrookville and Maskenozha Members of the New Scotland Formation. Section measured by A. G. Epstein and J. B. Epstein.

	Thickness (feet)
Minisink Limestone (part):	
13. Limestone, medium-gray, fine- to medium-grained, argillaceous; weathers medium light gray; irregularly bedded; weak fracture cleavage; fossils abundant and include brachiopods, bryozoans, and coral fragments; basal and upper contacts concealed	7.0
Incomplete thickness Minisink Limestone	7.0

	Thickness (feet)
New Scotland Formation:	
Maskenozha Member:	
12. Covered	10.0
11. Shale, dark-gray, slightly calcareous and siliceous; weathers medium gray; scattered pods of medium-dark-gray dense argillaceous limestone in upper 10 ft; a few beds of purer limestone in upper 10 ft; laminated: conspicuous fracture cleavage; basal 12 ft contain about 10 percent beds and lenses of medium-gray fine-grained argillaceous fossiliferous limestone; fossils abundant and include *Macropleura macropleura*, *Leptaena "rhomboidalis"* and other brachiopods, trilobites, bryozoans, corals, ostracodes, and crinoid columnals; basal contact abrupt and placed at top of first downward appearance of dark-gray chert	33.0
Total thickness of Maskenozha Member	43.0
Flatbrookville Member:	
10. Shale, dark-gray, slightly calcareous and siliceous; weathers medium gray to medium light gray; about 10–15 percent lenses and nodules of dark-gray chert; about 10 percent lenses, nodules, and beds of medium-dark-gray fine-grained argillaceous fossiliferous limestone; unit abundantly fossiliferous, having *Macropleura macropleura*, *Leptaena "rhomboidalis,"* and other brachiopods, bryozoans, trilobites, ostracodes, and crinoid columnals; lenses of fine quartz sand as much as 0.5 ft wide and 1–2 in. thick at upper contact; basal contact concealed	17.0
9. Covered	7.5
8. Shale; similar to unit 10; basal contact concealed	5.5
7. Covered	3.0
Total thickness of Flatbrookville Member	33.0
Total thickness of New Scotland Formation	76.0
Coeymans Formation (part):	
Stormville Member:	
6. Sandstone, medium-light-gray, fine- to coarse-grained, calcareous; weathers light tannish gray to orange gray; crossbedded; massive; basal contact concealed	1.9
5. Covered	11.0
4. Sandstone, conglomerate, and arenaceous limestone lenses juxtaposed, medium-light-gray to medium-gray; weathers light tannish gray; crossbedded; sand and conglomerate stand out in relief upon weathering; scattered crinoid columnals and *Gypidula coeymanensis*; basal contact disconformable	3.8
Total thickness of Stormville Member	16.7

Shawnee Island Member (part):	Thickness (feet)
3. Limestone, medium-gray, fine-grained, arenaceous and argillaceous; weathers medium light gray; irregularly bedded; unit consists of about 20 percent quartz sand; fossils abundant; crinoid columnals and *Gypidula coeymanensis;* basal contact abrupt	2.0
2. Limestone; similar to unit 3, but scattered nodules of dark-gray chert make up about 5 percent of unit; basal contact abrupt	2.0
1. Chert, dark-gray, 0.5–1 ft thick	1.0
Incomplete thickness of Shawnee Island Member	5.0
Incomplete thickness of Coeymans Formation	21.7

Section 15–d

Stroudsburg quadrangle. Roadcut on the southwest side of U.S. Interstate Highway 80, approximately 0.4 mile southwest of Minisink Hills, Pa. Section begins at road level in the upper beds of the Maskenozha Member of the New Scotland Formation and continues uphill along a construction bench to the top of the Oriskany Formation. Section lies along an overturned syncline (fig. 11). Type section of the Minisink Limestone. Section measured by A. G. Epstein and J. B. Epstein.

Oriskany Formation:	Thickness (feet)
28. Sandstone, light-gray, fine- to medium-grained, calcareous; weathers brownish orange; grains well rounded to subrounded; leached; brachiopods abundant; basal contact disconformable	7.0
27. Conglomerate and sandstone, light-gray, calcareous; weathers orange gray; grains subangular to rounded; milky quartz pebbles as much as 0.5 in. long; unit coarser toward top; massively bedded; forms ledge at top of roadcut and weathers into large blocks; scattered brachiopod fragments; basal contact gradational	3.6
26. Sandstone, medium- to light-gray, fine- to coarse-grained, calcareous; weathers orange gray; basal contact abrupt	1.5
25. Sandstone, light-gray, coarse-grained, calcareous; weathers orange gray; grains subangular to rounded; limonitic; scattered dark-gray chert nodules; brachiopod fragments; basal contact disconformable	1.9
24. Sandstone, medium-gray, fine-grained, silty, calcareous; weathers light tannish gray to orange gray; massive; sparingly fossiliferous; basal contact gradational	1.3
23. Conglomerate, light-gray, fine-grained, calcareous; weathers orange gray; basal contact disconformable	.6
22. Limestone, medium-gray, fine-grained, arenaceous and argillaceous; weathers tannish gray; nodules and lenses of dark-gray chert; sparingly fossiliferous; basal contact disconformable	1.3
21. Conglomerate and sandstone; similar to unit 27; basal contact disconformable	.3
20. Chert, dark-gray; scattered lenses of medium-gray fine-grained argillaceous limestone; basal contact disconformable	.6

	Thickness (feet)
Oriskany Formation—Continued	
19. Conglomerate and sandstone; similar to unit 27; basal contact disconformable	.3
18. Chert, dark-gray; lenses of medium-gray fine-grained argillaceous fossiliferous limestone; basal contact disconformable	6.3
17. Conglomerate and sandstone; similar to unit 27; milky quartz pebbles as much as 0.5 in. long; basal contact disconformable	.5
16. Chert, dark-gray; brachiopod shell hashes, dominantly spiriferid brachiopods, shell material composed of calcite which leaches upon weathering leaving numerous molds; coarse-grained calcareous sandstone as much as 0.6 ft thick; basal contact disconformable	5.6
15. Chert, dark-gray; basal contact disconformable	.8
14. Sandstone and conglomerate. Sandstone coarse grained; conglomerate calcareous. Unit becomes finer grained toward top; basal contact disconformable	.5-.0
13. Chert, dark-gray, massive; nodules and lenses of medium-dark-gray fine-grained siliceous limestone; unit poorly fossiliferous; basal contact disconformable	12.7
12. Sandstone and conglomerate. Sandstone coarse grained; conglomerate fine grained, calcareous. Grains subangular to rounded. Unit variable in thickness; fossils rare; basal contact disconformable	1.7
11. Chert and limestone. Chert is dark gray; spiriferid brachiopod hashes. Limestone is medium dark gray, fine grained, siliceous. Basal contact of unit at base of fossil hash	10.6
10. Limestone, medium-dark-gray, fine-grained, silty, siliceous; weathers light gray to medium gray; massively bedded; nodules and lenses of dark-gray chert; sparingly fossiliferous; basal contact placed at top of brachiopod hash	23.7
9. Limestone, medium-dark-gray, fine-grained, argillaceous, silty, siliceous; weathers light tannish gray; irregularly bedded; many spiriferid brachiopods; basal contact placed at base of brachiopod hash	10.7
8. Chert, dark-gray; about 40 percent dark-gray siliceous shale with pockets of dark-gray fine-grained poorly fossiliferous limestone; basal contact gradational	6.8
7. Chert, dark-gray; nodules and lenses of medium-dark-gray fine-grained siliceous and argillaceous limestone and calcareous shale; poorly fossiliferous; basal contact sharp, placed at first appearance of dark-gray chert	2.3
Total thickness of Oriskany Formation	100.6
Port Ewen Shale:	
6. Shale, calcareous, silty, siliceous, medium-dark-gray; weathers light tannish gray; slightly pyritic; irregularly bedded; conspicuous cleavage; fossilferous, having corals, brachiopods, ostracodes, trilobites, and crinoid columnals; basal contact gradational and marked by increase in silt	44.5

	Thickness (feet)
Port Ewen Shale—Continued	
5. Shale, medium-dark-gray, silty, calcareous; weathers light tannish gray; pyritic; conspicuous cleavage; massively bedded; scattered brachiopods and corals; unit contains fewer silty laminae than underlying unit; basal contact gradational	44.7
4. Shale, medium-dark-gray, silty, calcareous; weathers light tannish gray; slightly pyritic; irregularly laminated, because of alternations of silty and less silty beds; poorly fossiliferous; fossils disrupted by cleavage; basal contact at 1-ft-wide calcite-filled fault zone, displacement probably not more than a few feet	43.5
3. Shale, medium-dark-gray, silty, calcareous; weathers light tannish gray; irregularly laminated, owing to alternations of silty and less silty beds; poorly fossiliferous; basal contact abrupt	18.0
Total thickness of Port Ewen Shale	150.7
Minisink Limestone:	
2. Limestone, medium-gray, fine-grained, argillaceous; weathers light tannish gray; irregularly bedded; beds as much as 3 ft thick; thin interbeds of calcareous shale; fracture cleavage; fossils mostly fragmental and include corals, bryozoans, brachiopods, and crinoid columnals; basal contact sharp	14.0
Total thickness of Minisink Limestone	14.0
New Scotland Formation (thickness not measured):	
Maskenozha Member (thickness not measured):	
1. Shale, dark-gray, calcareous and siliceous; weathers medium light tannish gray; laminated; poorly exposed.	

Section 16

Stroudsburg quadrangle. Section on south side of Pennsylvania State Highway 90, at intersection with the Cherry Valley Road (State Highway Legislative Route 45010). Beds strike N. 7°5 W. and dip 6° NE. Section measured by A. G. Epstein and J. B. Epstein.

Section 17

Stroudsburg quadrangle. Hartman's Cave, at an elevation of 650 ft on the southeast slope of Godfrey Ridge, 0.85 mile northeast of the Stormville Church. Section at crest of overturned anticline. Reference section for the Stormville Member of the Coeymans Formation. Section measured by A. G. Epstein and J. B. Epstein.

	Thickness (feet)
Coeymans Formation (part):	
Stormville Member:	
11. Conglomerate, medium-light-gray, calcareous, slightly limonitic; well-rounded to subrounded milky quartz pebbles; weathers light tannish gray; scattered crinoid columnals and *Gypidula coeymanensis*; basal contact disconformable	0.5
10. Sandstone, medium-light-gray, calcareous, medium-grained; weathers light tannish gray; juxtaposed with medium-gray fine-grained arenaceous and argillaceous limestone which weathers medium light gray; abundant crinoid columnals; basal contact abrupt	1.7

	Thickness (feet)
Coeymans Formation (part)—Continued	
Stormville Member—Continued	
9. Sandstone, medium-light-gray, coarse-grained, calcareous; weathers light tannish gray; thin quartz-pebble conglomerate at base; crossbedded; abundant crinoid columnals as much as ⅛ in. in diameter; basal contact disconformable	1.0
8. Sandstone and limestone. Sandstone is medium-light-gray, medium-grained, argillaceous, calcareous; weathers tannish gray. Limestone is medium-gray, fine-grained, arenaceous and argillaceous; weathers medium light gray; 30–40 percent quartz sand. Basal 1.5 ft medium- to coarse-grained sandstone; basal contact disconformable	5.7
7. Limestone, medium-gray, fine-grained, arenaceous and argillaceous; weathers medium light gray; abundant crinoid columnals; basal contact abrupt	2.8
6. Chert, dark-gray, bedded; basal contact abrupt	.2
5. Limestone; similar to unit 7; about 20 percent quartz sand; weak fracture cleavage; irregularly bedded; basal foot contains nodules of dark-gray chert; brachiopods and crinoid columnals abundant; basal contact disconformable	8.1
4. Conglomerate, meduim-light-gray; rounded to subrounded milky quartz pebbles, calcareous; weathers light tannish gray; basal contact disconformable	.4
3. Limestone; similar to unit 7; about 30 percent quartz sand; weak fracture cleavage; irregularly bedded; 3-in. siltstone bed 2 ft above base; upper 0.4 ft dark-gray chert band; basal contact disconformable	4.0
2. Conglomerate; similar to unit 4; basal contact disconformable	.3
Total thickness of Stormville Member	24.7
Shawnee Island Member (part):	
1. Limestone, medium-gray, fine- to medium-grained, argillaceous and arenaceous; weathers medium light tannish gray; irregularly bedded; weak fracture cleavage; slightly limonitic; abundant valves of *Gypidula coeymanensis*; basal contact concealed	13.5
Incomplete thickness of Shawnee Island Member	13.5
Incomplete thickness of Coeymans Formation	38.2

Section 18

Saylorsburg quadrangle. Quarry of Hamilton Stone Co., Inc., at Bossardsville, Pa. Section measured by A. G. Epstein and J. B. Epstein.

Decker Formation (part):

Wallpack Center Member (part):

	Thickness (feet)
36. Limestone, medium-gray to medium-light-gray, fine- to medium-grained, arenaceous; weathers grayish orange at base; unit grades upward into medium-light-gray very fine grained calcareous sandstone and siltstone that weathers grayish orange and contains many calcareous shale partings; quartz pebbles as much as ¼ in. in diameter scattered throughout; beds 1 in. to 1 ft thick; coarser grained sandy limestone beds contain flecks of limonite; no fossils noted; unit forms upper quarry wall and is partly inaccessible for close examination; uppermost beds deeply weathered dark-yellowish-orange shale; unit overlain by till of Wisconsin age	14.6
35. Limestone, pale-purplish-gray and pale-greenish-gray, very fine grained to fine-grained, arenaceous; weathers pale yellowish gray to dark yellowish orange; pyrite scattered throughout; beds 1 in. to 1 ft thick; brachiopods and coral fragments; contact with overlying unit gradational	4.1
34. Conglomerate, medium-light-gray, calcareous; weathers pale yellowish gray; quartz pebbles are white and pink; a few pale-greenish-gray shale partings; forms one massive bed; upper contact gradational	.7
33. Arenaceous limestone and calcareous sandstone; medium-gray, fine- to medium-grained; unit weathers pale yellowish orange; uppermost beds are medium greenish gray; beds 1 in. to 1 ft thick; unit varies laterally; upper contact abrupt	6.1
32. Argillaceous limestone and calcareous shale, medium dark gray at base; unit grades upward into medium-gray fine-grained arenaceous limestone which in turn grades into medium-greenish-gray and pale-purplish-gray conglomeratic calcareous sandstone; beds from 1 in. to 1.5 ft thick; upper contact abrupt	13.7
31. Sandstone, medium-gray; scattered specks of limonite; calcareous and conglomeratic; weathers pale yellowish gray; quartz pebbles as much as ⅜ in. long; unit crossbedded; upper contact abrupt	1.7
30. Sandstone, medium-gray, fine-grained; beds 1 in. to 1 ft thick at base; grades upward into medium-gray slightly calcareous shale which weathers pale yellowish gray; beds ½–3 in. thick; upper contact gradational	3.0
29. Sandstone, medium-gray, fine-grained, calcareous; beds 1 in. to 1 ft. thick; upper contact gradational	2.5
28. Limestone, medium-dark-gray; scattered flecks of limonite; fine grained, arenaceous; some rounded quartz pebbles as much as ½ in. long; dark-gray calcareous shale partings occur throughout unit; beds 2 ft thick with thin shale partings; brachiopods and coral fragments; upper contact gradational	5.6

	Thickness (feet)
Decker Formation (part)—Continued	
Wallpack Center Member (part)—Continued	
27. Limestone, medium-dark-gray, fine-grained, arenaceous; weathers grayish orange; brachiopod and coral fragments; upper contact gradational	2.9
26. Dolomite, medium-gray to greenish-gray, very fine grained, calcareous; weathers pale yellowish orange; contains edgewise conglomerate; mud cracked in places; unfossiliferous	2.0
25. Limestone, medium-gray, fine-grained, slightly arenaceous; weathers grayish orange; lenses of fossil hash consisting of brachiopod and rugose coral fragments	1.5
24. Limestone, light-greenish-gray and pale-purplish-medium-gray, dolomitic and slightly arenaceous; weathers dark yellowish orange to pale yellowish orange; green beds more dolomitic; uppermost beds consist of medium-greenish-gray dolomitic limestone; mud cracked in places; ostracodes, brachiopods, and coral fragments in pale-purplish-gray beds; unit transitional with Bossardville below	8.5
Incomplete thickness of Wallpack Center Member	66.9
Incomplete thickness of Decker Formation	66.9
Bossardville Limestone:	
23. Limestone, medium-dark-gray to pinkish-gray and greenish-gray, sublithographic, slightly dolomitic and slightly arenaceous, very finely laminated; laminae coarser toward top of unit and alternating with reddish-gray fine-grained arenaceous fossiliferous limestone; mud cracked in places; contact with Decker placed at top of upper most laminated bed	4.9
22. Limestone, dark-gray, very fine grained, slightly shaly; weathers medium light gray; laminated, pyritiferous; numerous shale partings; ostracodes and numerous pyrite euhedra occur in the coarser grained laminae	19.2
21. Limestone, dark-gray, very fine grained, slightly shaly; weathers medium light gray to light gray; thin-bedded; upper contact gradational	2.5
20. Limestone, dark-gray, very fine grained, very slightly shaly; weathers medium light gray; laminated; unit contains numerous calcite seams as much as a few inches thick and many feet long	15.0
19. Limestone, dark-gray, very fine grained, slightly shaly; weathers medium light gray; laminated; laminae best displayed on weathered surface; small number of calcareous shale partings	4.4
18. Weathered zone; pale-yellowish-orange to moderate-orange-brown weathered dolomite with calcareous shale partings and small calcite vugs; many black shale partings are smeared out along cleavage	6.1
17. Similar to unit 19	15.2

	Thickness (feet)
Bossardville Limestone—Continued	
16. Limestone, dark-gray, very fine grained; dark-shale partings and scattered pyrite euhedra; laminated; desiccation polygons throughout; polygons average about 3 in. in width; polygon columns are broken at several bedding planes and are as much as 2 ft thick	10. 8
15. Limestone, medium-gray to medium-dark-gray, sublithographic; weathers light gray; laminated; beds range from laminae to about 1.5 in. thick; 3-in. to 1.7-ft thick calcite zone at top of unit; pyritiferous; poorly formed desiccation cracks at a few levels; ostracodes rare	16. 0
Total thickness of Bossardville Limestone	94. 1
Poxono Island Formation of White (1882) (part):	
14. Desiccation breccia, angular clasts of medium-gray calcareous dolomite which weathers pale grayish orange; clasts as much as 1.5 in. in length and surrounded by pyrite euhedra in a matrix of medium-gray sublithographic limestone which weathers light gray; upper contact abrupt	. 5
13. Dolomite, mottled pinkish-green-gray to medium-greenish-gray very fine grained to sublithographic; greenish-gray shale partings; poorly formed desiccation polygons; upper 2 inches consists of grayish-red limestone which weathers reddish gray; upper contact abrupt	1. 1
12. Similar to unit 18 but does not contain as many dark-gray calcareous shale partings; upper contact abrupt	1. 7
11. Dolomite, medium-gray to greenish-gray, very fine grained to sublithographic; weathers pale yellowish orange; scattered calcareous shale partings; poorly formed desiccation polygons throughout unit; upper contact abrupt	1. 5
10. Limestone, dark-yellowish-orange; has small calcite-filled vugs; weathered; upper contact gradational	. 7
9. Limestone, pinkish-medium-gray, sublithographic, dolomitic; laminated with greenish-gray calcareous dolomite; weathers yellowish gray to pale yellowish orange; beds range from fine laminae to 0.5 in. thick; entire unit mud cracked and has medium-greenish-gray calcareous shale partings between polygons; polygons from 1 to 6 in. wide; mud cracks are shortened by approximately 50 percent in the direction of tectonic transport; raindrop impressions and ostracodes occur on some bedding planes	3. 8

	Thickness (feet)
Poxono Island Formation of White (1882) (part)—Continued	
8. Limestone, dark-gray, very fine grained to sublithographic; weathers light gray; massive beds as much as 5 in. thick alternating with laminae of dark-gray sublithographic limestone as much as 0.5 in. thick and greenish-gray more dolomitic limestone as much as 1/16 in. thick; weathers yellowish gray; laminae continuous and show small folds having amplitudes of as much as 3 in.; cleavage conspicuous; numerous minute pyrite euhedra; scattered medium-dark-gray argillaceous limestone beds, several of which are mud cracked and having polygons averaging about 6 in. across and as much as 5 in. deep; has greenish-gray shale between columns and several thin (about 0.25 in. thick) greenish-gray calcareous shale beds	9.5
7. Weathered dolomite interbedded with weathered shale; grayish orange to dark yellowish orange; laminated with laminae as much as 0.5 in. thick; unit in core of anticline; small drag folds average about 1 in. across; upper contact gradational	8.5
6. Shale, light-grayish-yellow-green; faintly laminated; upper contact gradational	3.1
5. Limestone and shale. Limestone is silty, pale yellowish orange to medium yellowish orange. Shale is pale greenish yellow, calcareous; weathered. Most beds laminated; upper contact abrupt	7.7
4. Dolomite, light-bluish-green-gray, very fine grained, calcareous; weathers very pale orange; laminated; desiccation cracks about 3 in. across	2.2
3. Limestone, argillaceous; weathered; laminated; similar to unit 5	1.7
2. Limestone and shale. Limestone is medium gray, very fine grained; weathers grayish orange. Shale is light medium gray, weathers light gray. Upper contact of unit abrupt	.67
1. Limestone, weathered; weathers moderate yellowish orange; laminated; base of unit concealed	1.0
Incomplete thickness of Poxono Island Formation of White (1882)	43.6

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