1-1-1975

A stratigraphy and paleontology of the Onesquethaw stage in Pennsylvania and adjacent states

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THE STRATIGRAPHY AND PALEONTOLOGY OF THE ONESQUETHAW STAGE IN PENNSYLVANIA AND ADJACENT STATES

A Dissertation Presented

by

Jon David Inners

Submitted to the Graduate School of the

University of Massachusetts in

partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 1975

Geology

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May 1975

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ABSTRACT

The Onesquethaw Stage (Lower/Middle Devonian) in Pennsylvania and adjacent states consists of seven lithologically-defined formations and one named marker bed that are composed predominantly of limestone, chert, calcareous shale, mudstone, siltstone, sandstone, and metabentonite. Outcropping and subsurface Onesquethawan formations are areally restricted as follows:

<u>Eastern Pennsylvania and adjacent areas</u>

Onondaga Limestone
Schoharie Formation
Esopus Formation

<u>Lehigh-Schuylkill region, Pennsylvania</u>

Onondaga Limestone
Palmerton Sandstone
Schoharie-Esopus formations, undivided

<u>Central Pennsylvania and areas to the south</u>

Needmore Formation (Selinsgrove Limestone Member at top)

<u>Western Pennsylvania and adjacent areas</u>

Onondaga Limestone
Bois Blanc Formation/Huntersville Chert

The Tioga Metabentonite (middle coarse mica zone), the top of which marks the top of the Onesquethaw Stage, is probably present throughout the entire area.

Onesquethawan rocks in Pennsylvania and nearby states generally overlie the Ridgeley (Oriskany) Sandstone and Shriver (Glenerie) Chert of Deerparkian age. The contact is nearly always abrupt and is disconformable over wide areas. Locally Onesquethawan strata disconformably overlie Helderbergian (Lower Devonian) and Cayugan (Upper Silurian) rocks. The Onesquethaw gradationally underlies black shales of the Marcellus Formation (Cazenovia Stage), except in central and western New York and parts of western Pennsylvania where the uppermost member (Seneca or equivalent) of the Onondaga Limestone occurs above the Tioga.

The Onesquethaw Stage is prominently developed throughout the study area and is disconformably absent only in the Susquehanna Gap area, north of Harrisburg, Pa.

Detailed study of outcrops and published well sample descriptions and radio-activity logs has revealed the relationship between the various Onesquethawan formations in Pennsylvania and adjacent states. The Esopus Formation is represented in eastern Pennsylvania and southeasternmost New York by dark gray, silty mudstone, with abundant Taonurus-markings. The unit thins greatly to the southwest (lower part of the Schoharie-Esopus formations, undivided) and to the west (part of Beaverdam Shale Member of Needmore Formation). In the Delaware Valley, the Schoharie

Formation is composed of fossiliferous, sandy and silty mudstones. Southwestward into the Lehigh-Schuylkill region, the Schoharie is represented by the highly fossiliferous, upper part of the Schoharie-Esopus formations, undivided, and by the Palmerton Sandstone. Westward the Schoharie can be recognized in the subsurface as far as Sullivan and Columbia counties, where it grades into the calcareous shale member of the Needmore Formation. In the subsurface of western Pennsylvania rocks equivalent to the Schoharie Formation are included in the Bois Blanc Formation and Huntersville Chert (lower part). The Onondaga Limestone is the most widespread formation in the Onesquethaw Stage, being everywhere present at outcrops and in the subsurface. The Selinsgrove Limestone Member in central Pennsylvania is correlative with the Onondaga, as is the upper part of the Huntersville Chert in southwestern Pennsylvania. The Tioga Metabentonite generally lies at or near the contact between the Onondaga (or Selinsgrove) Limestone and the Marcellus Formation and marks a time of lower Middle Devonian volcanism.

All Onesquethawan formations in Pennsylvania and adjacent states contain marine faunas of Lower and Middle Devonian aspect. Corals, brachiopods, gastropods, trilobites and cricoconarids are the most abundant invertebrate megafossils.

Rocks of the Onesquethaw Stage in Pennsylvania and adjacent states were deposited during a major marine transgression that followed withdrawal of the epicontinental sea over large areas in latest Deerparkian and earliest Onesquethawan time. The Onesquethawan sea attained its maximum extent in the study area during the later portion of the stage.

Large quantities of natural gas are produced from the Huntersville Chert in western Pennsylvania and from subsurface Onondaga reefs in south-central New York. Trapping is structural in the former and stratigraphic in the latter.

GENERAL STATEMENT

Purpose and Scope

Rocks of the Onesquethaw Stage (Lower/Middle Devonian) in Pennsylvania and adjoining states consist of a lithologically and faunally varied sequence of marine limestone, chert, sandstone, siltstone, mudstone, shale, and metabentonite. Complex facies changes occur both at the surface and in the subsurface across the area, and several distinct lithologic facies regions can be recognized. Considerable lateral and vertical faunal variation also exists, reflecting both age and facies control.

The present stratigraphic and paleontologic study was undertaken to: (1) decipher the stratigraphic relationships within the Onesquethaw Stage, particularly in Pennsylvania; (2) describe the fauna and its relationship to the various lithologies; (3) reconstruct the depositional environments of the Onesquethaw sea; and (4) correlate the rock units in the Onesquethaw Stage in Pennsylvania with those in adjacent states.

During the course of this investigation, numerous stratigraphic sections in Pennsylvania were measured and described. Important sections were also measured in New York, Maryland, and

Virginia. In addition, field reconnaissance and fossil collection were conducted at many other localities in the above-mentioned states, as well as in New Jersey, West Virginia, and Kentucky. (See Plate 1.) Laboratory research included identification and systematic descriptions of fossils, study of petrographic thin sections, and examination of insoluble residues from the limestones. The information gained from field and laboratory studies was then combined with subsurface data gleaned from published sources to prepare lithofacies, biofacies, and isopachous maps.

Geographic and Stratigraphic Setting

Fig. 1 shows the outcrop and subsurface distribution of Onesquethawan rocks in Pennsylvania and nearby states.

The stratigraphic position of Onesquethaw Stage formational units within the Middle Paleozoic rock sequence in Pennsylvania and adjacent states is illustrated in Fig. 2.

Definition of Onesquethaw Stage

The Onesquethaw Stage was originally defined by Cooper and others (1942); but the definition was subsequently modified by Dennison (1961), and the stage was subdivided by Rickard (1964). As defined by Cooper and others (1942, p. 1733), the Onesquethaw includes the Onondaga Limestone, Schoharie Grit, and Esopus Formation of the

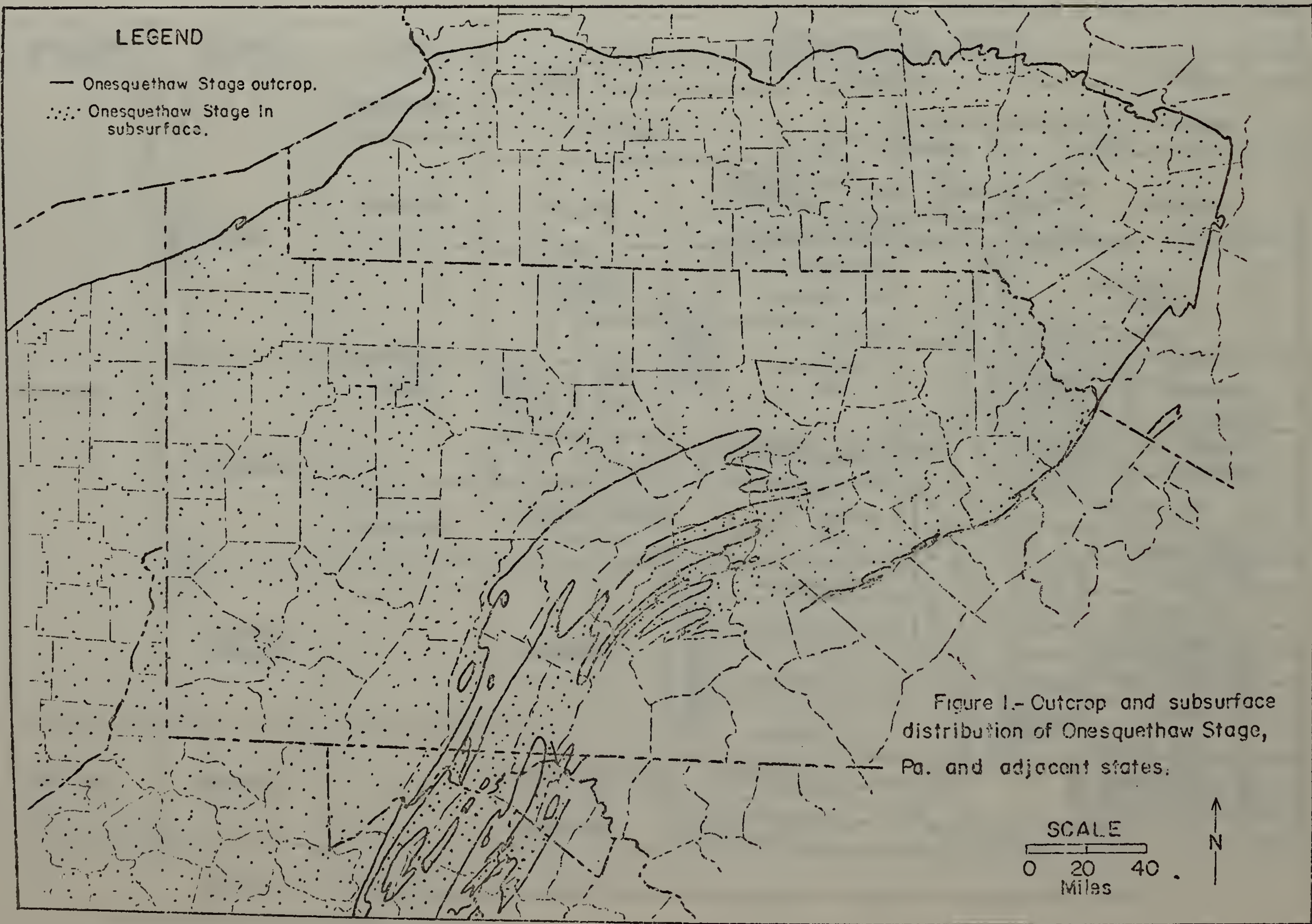

Figure I.– Outcrop and subsurface distribution of Onesquethaw Stage, Pa. and adjacent states.

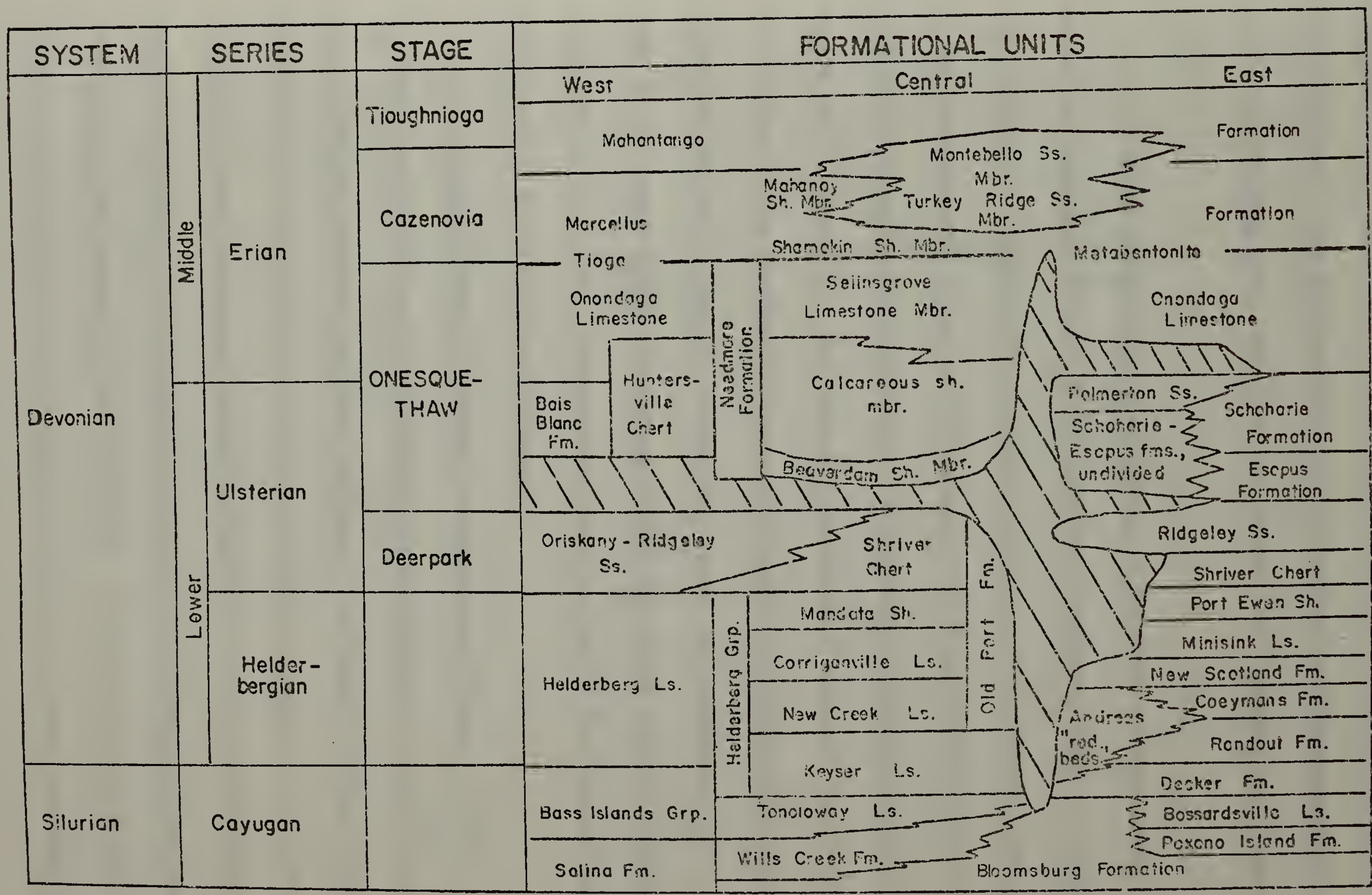

Figure 2.—Stratigraphic position of Onesquethaw Stage formational units, Pennsylvania and adjacent states.

classic New York State succession, and their correlates elsewhere on the continent. The type section is in the valley of Onesquethaw Creek in the Helderberg Mountains, in the vicinity of Clarksville, Albany Co., N.Y.

Following Oliver's elucidation of the time-transgressive nature of the upper contact of the Onondaga (Oliver, 1954, pp. 629-630; 1956, pp. 1465-1466), Dennison (1961, p. 10) redefined the top of the Onesquethaw Stage to be the top of the Tioga Metabentonite, a unit which forms a true time-line. Thus, any limestone occurring above the Tioga (e.g., the Seneca Limestone of western New York) is included in the overlying Cazenovia Stage. Likewise, any black shale of Marcellus lithology occurring below the metabentonite is part of the lower stage. Dennison (1969) has since refined his definition of the top of the Onesquethaw to be the top of the middle coarse mica zone of the Tioga Metabentonite.

Rickard (1964), following a suggestion of Boucot (1959, p. 738), subdivided the Onesquethaw into the Sawkill (Lower Devonian) and Southwood (Middle Devonian) stages. The Sawkill Stage includes the Esopus and Schoharie formations and their correlates, and the Southwood, the Onondaga Limestone (below the Tioga Metabentonite) and its correlates. The boundary between the two stages is the base of the Edgecliff Member of the Onondaga. The type section of the Sawkill is at Glenarie Falls on Esopus Creek, 4.0 miles southwest of

Saugerties, Ulster Co., N.Y. The type section of the Southwood Stage is in the Onondaga County Prison quarry, 0.5 miles south of the County Penitentiary at Jamesville, N.Y. Rickard's terminology has not been widely adopted; in this report his substages are referred to as lower and upper Onesquethaw, respectively.

Underlying the Onesquethaw is the Deerpark Stage of Lower Devonian age, defined by Cooper and others (1942, p. 1733) as consisting of the Oriskany Sandstone and its correlates. The type section is on the west slope of Shawangunk Mountain, Deerpark Township, near Port Jervis, Orange Co., N.Y.

Overlying the Onesquethaw Stage is the Cazenovia Stage. Cooper and others (1942, p. 1733) originally defined this stage as including rocks between the top of the Onondaga Limestone and the base of the Centerfield Limestone, i.e., the Marcellus and Skaneateles formations of the Hamilton Group. As modified by Dennison (1961) and Rickard (1964), the base of the Cazenovia is the top of the Tioga Metabentonite. Therefore, the stage includes the Seneca Member of the Onondaga Limestone.

<u>Acknowledgements</u>

I am indebted to many individuals for their assistance in this project. Charles W. Pitrat, chairman of the dissertation committee, supervised the research. Gregory W. Webb and William B. Nutting critically read the manuscript and offered many helpful suggestions. William D. Sevon, Rodger T. Faill, John H. Way, Jr., and Richard B. Wells, Pennsylvania Geological Survey; Frank W. Fletcher, Susquehanna University; John M. Dennison, University of North Carolina; and Peter G. Waldo, U.S.D.A. Soil Conservation Service, generously offered information concerning their own research on Lower and Middle Devonian rocks in Pennsylvania and New York. Consultations in the field with Robert Swanson, William Traeder, Gerald Scott, and James Meachum, all of Shell Oil Company, were very helpful. Roger Smith assisted in the field in the summer of 1967. My wife Martha served as field assistant through several summers and has been a constant source of encouragement. Joseph Chilek, Pennsylvania Department of Transportation, did much of the drafting; Mark A. Sholes, Pennsylvania Geological Survey, and Steve Grady, University of Massachusetts, assisted in preparation of the fossil plates; and (Mrs.) Patricia Harsch, West Chester, Pa., typed the manuscript.

Financial aid was provided by the Society of Sigma Xi, the National Science Foundation, and by my father, Lamar D. Inners.

Finally, I am extremely grateful for being permitted free access to the library facilities at Smith College, Bryn Mawr College, and the Pennsylvania Geological Survey.

STRATIGRAPHY

Introduction

Strata of Onesquethaw age in Pennsylvania and adjacent states exhibit great vertical and lateral lithologic variation. Gross regional lithofacies in the entire Onesquethaw interval are shown in Fig. 3. Cherty limestone, calcareous mudstone, and silty mudstone predominate in eastern Pennsylvania and southeastern New York; argillaceous limestone, calcareous shale, and black shale in central Pennsylvania and areas to the south; and cherty limestone and chert in the western counties of Pennsylvania, New York, and West Virginia. In the Lehigh Gap region of Pennsylvania, quartz sandstone and siliceous siltstone compose a significant portion of the Onesquethaw interval. Quartz sandstone is also present in the Green Pond-Schunemunk Mountain outlier, Orange Co., N.Y.

Outcropping Onesquethaw Stage rocks in the study area can be conveniently divided into five formations. These units are areally restricted as follows:

<u>Eastern Pennsylvania and adjacent areas</u>

Onondaga Limestone
Schoharie Formation
Esopus Formation

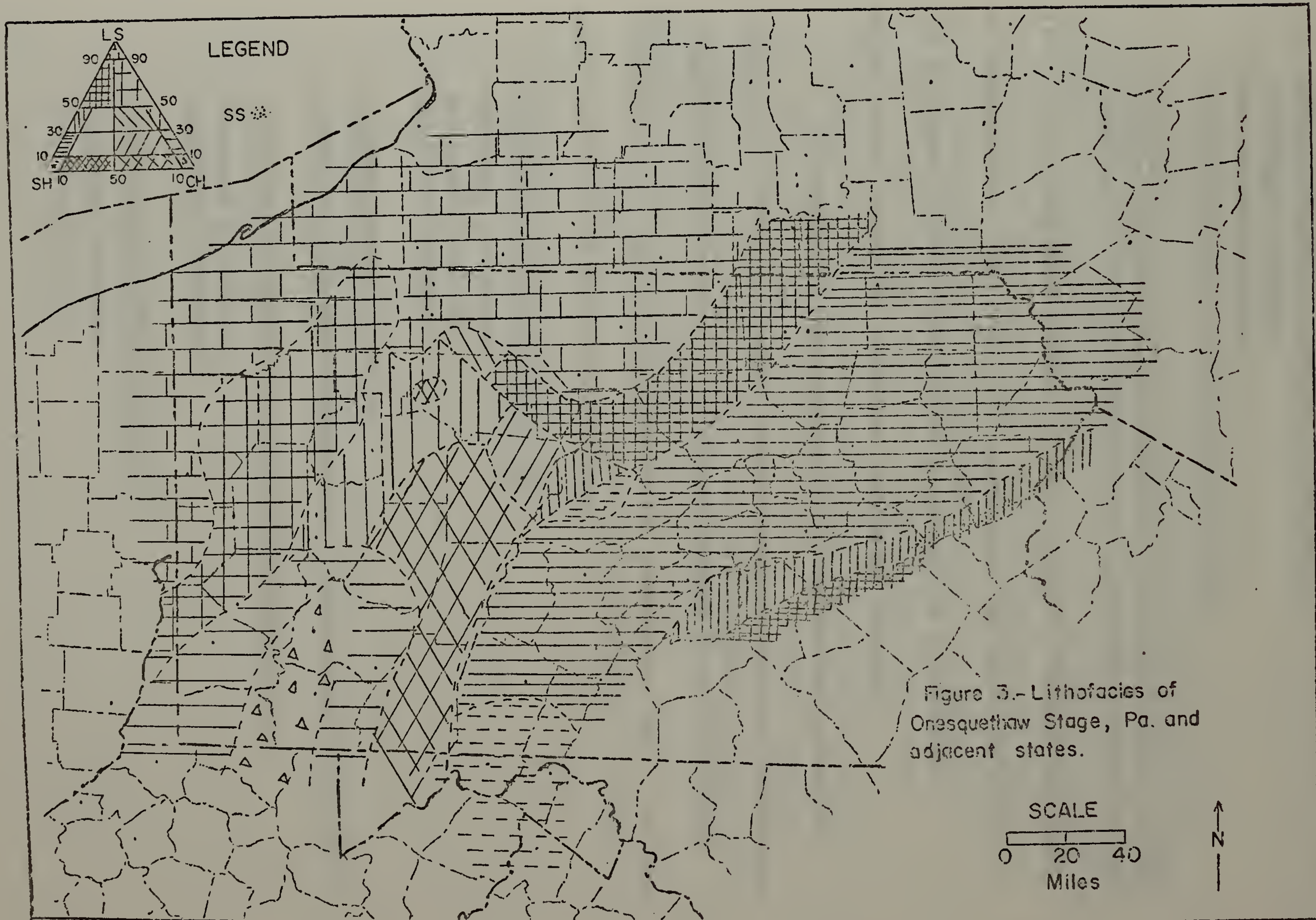

Figure 3.- Lithofacies of Onesquethaw Stage, Pa. and adjacent states.

Lehigh-Schuylkill Region, Pennsylvania

Onondaga Limestone
Palmerton Sandstone
Schoharie-Esopus formations, undivided

Central Pennsylvania and adjacent Maryland and West Virginia

Needmore Formation (Selingsgrove Limestone Member at top)

The Tioga Metabentonite occurs at the top of the Onesquethaw Stage at outcrops from the Lehigh Valley westward and northwestward to the Allegheny Front in Pennsylvania, as well as at numerous exposures in New York, Maryland, and West Virginia.

Subsurface Onesquethawan rocks are treated somewhat informally in this report since rigorous discrimination of formations recognized at the surface is not always possible from information provided by well sample descriptions and gamma-ray logs. For most wells the following terminology is used:

Northeastern Pennsylvania, etc.

Onondaga Limestone
Schoharie Formation
Esopus Formation

Western Anthracite region

Needmore Formation (Selinsgrove Limestone Member at top)

North-central and northwestern Pennsylvania, etc.

Onondaga Limestone
Bois Blanc Formation

Southwestern Pennsylvania, etc.

Onondaga Limestone
Huntersville Chert

The Tioga Metabentonite can be recognized at the top of the Onesquethaw Stage in deep wells throughout the area.

In Pennsylvania, Onesquethawan rocks have the thickest development in the subsurface of the Pocono Plateau (Fig. 4). Abrupt thinning from this thick basinal area occurs to the west and toward the sedimentary margin on the south. A trough extends southwestward into central Pennsylvania. Other areas of the thick Onesquethawan sediments are in northwestern and southwestern Pennsylvania. A broad region in north-central Pennsylvania and south-central New York received little sediment accumulation, acting as a partially emergent platform area in early Onesquethaw time and a deep, hydrographic basin in late Onesquethaw time.

As shown in Fig. 5, Onesquethaw Stage rocks in Pennsylvania and narby states generally overlie the Ridgeley (Oriskany) Sandstone and Shriver (Glenerie) Chert of Deerpark age. The contact is always abrupt and is probably disconformable in central Pennsylvania. In four areas in Pennsylvania, Onesquethaw rocks rest on pre-Deerpark strata: (1) In eastern Schuylkill County, the Schoharie-Esopus formation, undivided, lies directly on the Helderbergian New Scotland Formation. (2) From central Schuylkill County westward to Lebanon County, the Onondaga Limestone lies with marked disconformity on the Bloomsburg Formation of Cayugan (Upper Silurian) age. (3) Over a broad northeast-southwest trending belt in the

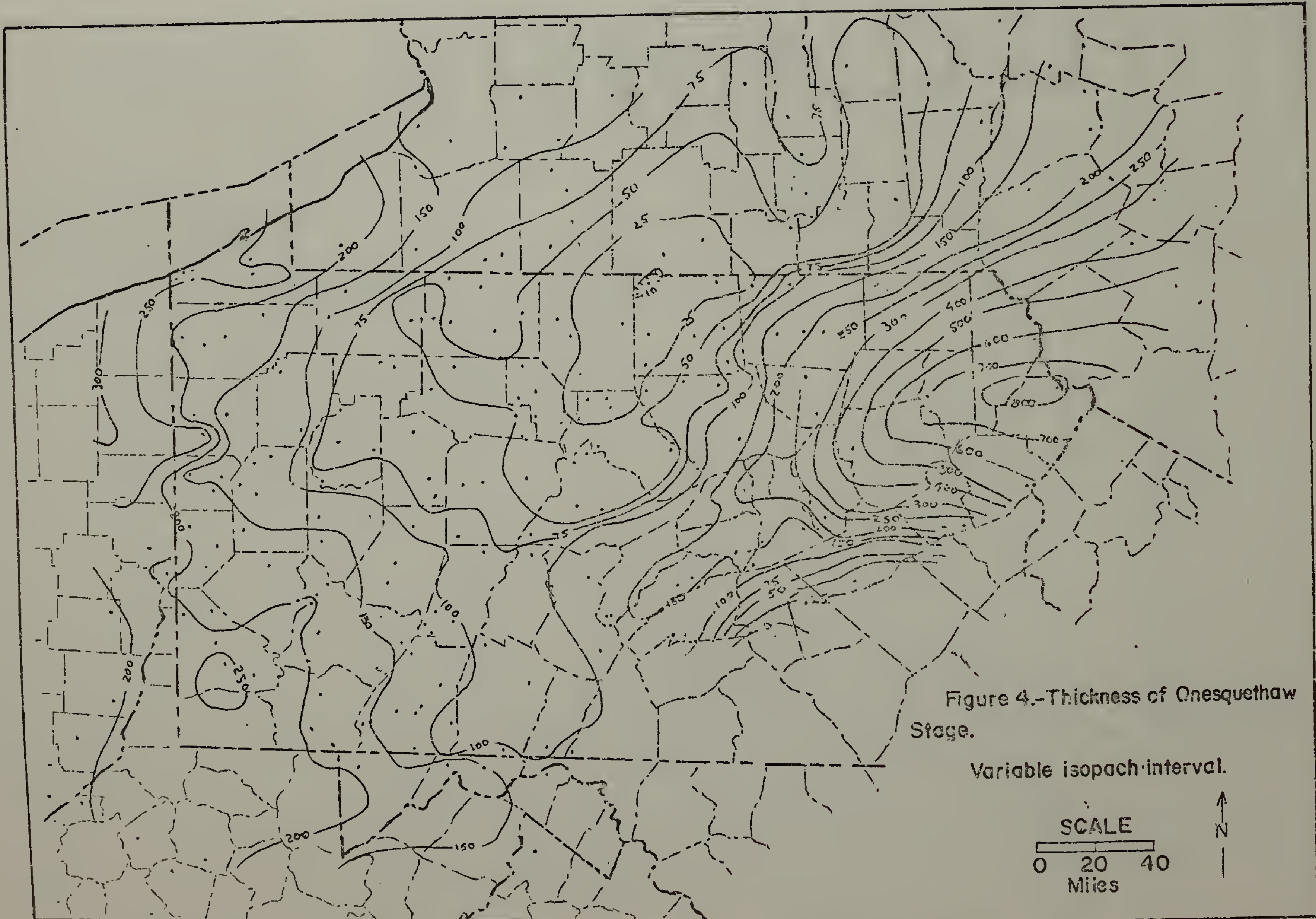

Figure 4.-Thickness of Onesquethaw Stage.

Variable isopach interval.

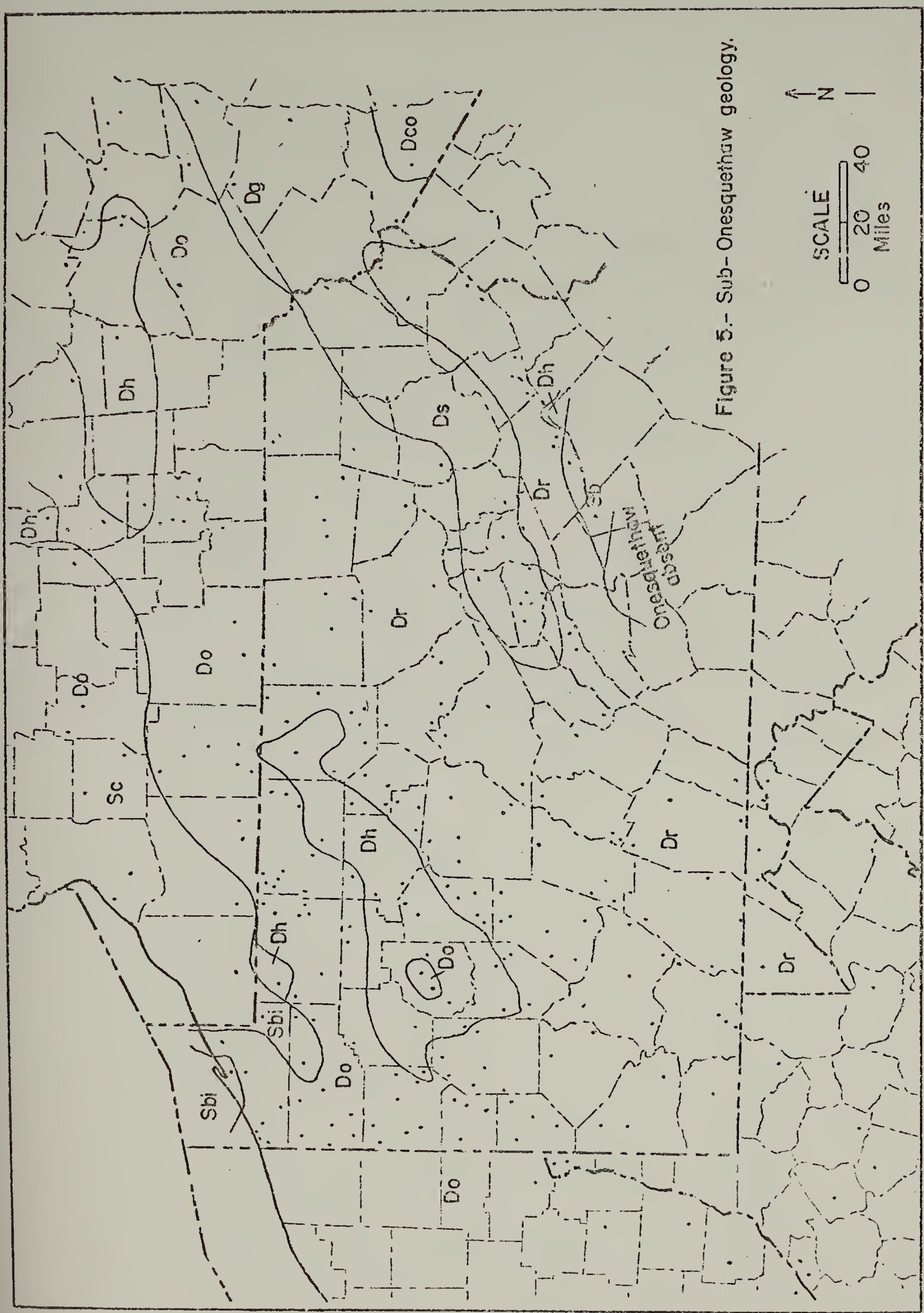

Figure 5.- Sub-Onesquethaw geology.

Legend for Figures 5, 10, 28, 52, 64, 71, 77, and 111

Dm	Marcellus Formation
Dc	Columbus Limestone
Don	Onondaga Limestone
m	Moorehouse Member
Dn	Needmore Formation
sl	Selinsgrove Limestone Member
cs	Calcareous shale member
csls	Calcitic shale and limestone subfacies
Dhu	Huntersville chert
Dbb	Bois Blanc Formation
Dsc	Schoharie Formation
De	Esopus Formation
Dp	Palmerton Sandstone
Dsc	Schoharie-Esopus formations, undivided
Dco	Connelly Conglomerate
Do	Oriskany Sandstone
Dr	Ridgeley Sandstone
Dg	Glenerie Limestone
Ds	Shriver chert
Dh	Helderberg Group
Dns	New Scotland Formation
DS	L. Devonian - U. Silurian rocks, undivided
Sc	Cobleskill Limestone
Sbi	Bass Islands Group
Sb	Bloomsburg Formation

Figure 5

subsurface of northwestern Pennsylvania (Potter to Armstrong counties), Onondaga Limestone overlies cherty limestone of probable Helderberg age. (4) In extreme northwestern part of the state (portions of Warren, Erie, and Crawford counties), the Bois Blanc Formation appears to rest on limestones and dolomites of the Bass Islands Group (Cayugan) (Cate, 1961, pl. 1, 2). The latter is an extension of the disconformity present between the Onondaga Limestone (and Bois Blanc Formation) and Cayugan rocks at outcrops in western New York (Grabau, 1900; Kindle, 1913).

Typically Onesquethawan rocks in Pennsylvania and nearby states are conformably overlain by dark gray to black shales and dark gray, silty, bituminous limestones of the Marcellus Formation. Along the Onesquethaw outcrop in central and western New York, the Tioga Metabentonite underlies the Seneca Member of the Onondaga Limestone (Oliver, 1954; 1956). In the subsurface of southwestern New York and northern Pennsylvania, limestones equivalent to the Seneca also occur above the Tioga (Rickard, 1969, pl. 13, 14).

Rocks of Onesquethaw age are unconformably absent only in central Dauphin and southeastern Perry counties, Pennsylvania (Fig. 5). At Susquehanna Gap, the only locality in this area where the geologic relationships can be well observed, the Marcellus Formation disconformably overlies the Bloomsburg Formation

(Swartz and Swartz, 1931, p. 632; Willard, 1939, p. 148). This local disappearance of the Onesquethaw is the landward expression of the same unconformity cited earlier as present between the Onondaga Limestone and Bloomsburg Formation in Lebanon and Schuylkill counties.

The Onesquethaw Stage in Eastern Pennsylvania and Adjacent Areas

The Onesquethawan rock sequence in the narrow outcrop belt along the Delaware River in Sussex Co., N.J., and Monroe Co., Pa., and in the subsurface of the Pocono and Allegheny plateaus to the northwest is laterally continuous with the similar succession exposed in the Hudson Valley of New York State. The Esopus Formation, Schoharie Formation, and Onondaga Limestone are clearly represented. Further to the west and southwest, however, changes in lithology render use of the New York rock-stratigraphic terminology increasingly difficult.

In northeastern Pennsylvania and adjacent areas, the Onesquethaw Stage is represented by a conformable sequence of silty shales, calcareous mudstone, and cherty limestones that aggregate several hundred feet in thickness over most of the area. The contact of the Esopus Formation with the underlying Deerparkian units (Glenerie Limestone, Shriver Chert, and Ridgeley, or Oriskany, Sandstone) is abrupt and probably disconformable in the northern and western portions of the area. However, Onesquethawan and Deerparkian strata may be conformable in the south between Greene Co., N.Y., and Monroe Co., Pa. The contact between the Onondaga Limestone and the overlying Marcellus Formation (Bakoven black shale or Union Springs black shale) is generally transitional at outcrops (Oliver, 1956, pp. 1464-1465) and in the subsurface.

The combined Esopus-Schoharie-Onondaga interval reaches its maximum thickness in Orange Co., N.Y., and Pike Co., Pa., where it includes about 800 feet of strata (Fig. 4). To the north of this depocenter, all three formations thin gradually toward the Adirondack Dome. To the northwest, the Schoharie and Esopus formations wedge-out on the southeast side of the platform-basin element discussed previously (p. 15), while the Onondaga Limestone thins to less than 50 feet in Cortland and adjacent counties, New York. In eastern Pennsylvania, this same element had an even more profound influence on deposition in the Onesquethaw basin. Between western Lackawanna and eastern Lycoming counties, a distance of fifty miles, the thickness of the combined Onesquethawan units decreases from 780 feet to about 115 feet. Depositional thinning on the southern basin margin in Monroe, Carbon, and Schuylkill counties is accompanied by change to the siliceous Lehigh Gap facies.

Isopachs of the combined Onesquethaw Stage rock units trend roughly normal to the main outcrop belt in eastern New York, northwestern New Jersey, and northeastern Pennsylvania (Fig. 4). This fact, plus the occurrence of a thick Onesquethaw section in the Green Pond-Schunemunk Mountain outlier indicates that prior to deformation and erosion the basin extended far to the east. Prominent sandstone units in the Onesquethaw at Highland Mills, N.Y. (Highland Mills Member of the Esopus Formation and Kanouse Sandstone), as well as the entirely clastic nature of the rocks in the outlier, probably reflect proximity to the eastern Onesquethaw shoreline.

Esopus Formation

Definition and Reference Section

Dark gray shales and siltstones that occur above the Oriskany and below the Schoharie in eastern New York were named the "Cauda-galli grit" by Vanuxem (1842), a reference to the common occurrence in them of bedding-plane markings that resemble a cock's tail. Later Darton (1894, p. 403) called them the Esopus slate from excellent exposures along Esopus Creek and near the Esopus settlement (Kingston) in Ulster Co., N.Y.

The equivalence of the "Cauda-galli grit" of New York with similar rocks in Monroe County, Pennsylvania, was recognized by

Rogers (1858). I. C. White (1882) described in great detail the lithology and distribution of the "Cauda-galli" in Monroe County. Willard (1936, p. 583) first used the term Esopus in Pennsylvania.

Until recently, the name Esopus (or Cauda-galli) in Pennsylvania was used for the entire interval between the Ridgeley Sandstone and the Onondaga (or Buttermilk Falls) Limestone. Trexler (1953) and Johnsen (1957) distinguished the Schoharie in beds formerly included in the Esopus. Subsequent workers have restricted use of Esopus Formation to rocks that lie between the sandstones of the Ridgeley and the limy mudstones of the Schoharie (Epstein and Epstein, 1967, p. 10; 1969, p. 138; Epstein, 1970).

A type section for the Esopus has never been formally named, but the most complete section in the type area lies along Esopus Creek (Chadwick, 1944, p. 92). The excellent exposure of the Esopus Formation on the northeast bank of Brodhead Creek, 0.4 mile west of Minisink Hills, Monroe Co. (P8), is herein designated a reference section for the unit in eastern Pennsylvania.

Lithology

The characteristic lithology of the Esopus Formation in eastern New York, northwestern New Jersey, and eastern Pennsylvania is massive, dark gray (N3), strongly cleaved, silty mudstone (Fig. 6). Locally significant rock types include arenaceous siltstone, fine grained sandstone, calcareous shale, laminated mudstone, and nodular and bedded chert. The Esopus is replete with horizontal burrows, especially the Taonurus caudagalli markings from which it received its original non-geographic name.

In the Green Pond-Schunemunk Mountain outlier, the Esopus has been divided into five members: in ascending order, the Mountainville Member, lower black mudstone member, the Highland Mills Member, the upper black mudstone member, and the Woodbury Creek Member (Boucot, 1959; Southard, in Jaffe and Jaffe, 1973). The Mountainville, Highland Mills, and Woodbury Creek members are predominantly sandstone and/or siltstone (Boucot, 1959; Johnsen and Southard, 1962; Jaffe and Jaffe, 1973). The upper black mudstone member consists of Taonurus-bearing mudstone (Boucot, 1959, p. 733), similar to the Esopus of the main outcrop belt.

The mudstones which compose the bulk of the Esopus in the main outcrop belt between Albany Co., N.Y., and Monroe Co., Pa., are nondescript, massive, medium dark gray (N4) to dark gray (N3), non-calcareous to slightly calcareous, pyritic and silty.[1] Bedding is generally obliterated by intense development of steeply-dipping cleavage, but can usually be observed as faint, irregular, alternating

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[1] As well stated by Chadwick (1944, p. 88), it is difficult "to convey a precise impression of this almost unstratified, strongly vertically-cleaved, and gravelly-crumbling mass of uniform, barren dark gray stuff."

Figure 6.—Anticline in Esopus Formation, south side of Catskill Creek (Y10), 0.1 mile south of Leeds, Greene Co., N.Y. Contact of Esopus mudstone with underlying Glenerie chert lies at base of cliff. Prominent bed about one-third distance up cliff is Unit 4 of measured section.

dark gray and brown bands 1/16- to 1-inch thick. On closer examination, this banding is seen to be pervasively disrupted by horizontal burrows, usually Taonurus (Fig. 7, 8). Pyrite is disseminated throughout the mudstone, as indicated by ubiquitous rusty stains, and also is commonly found as nodules up to 1/2-inch in diameter. In the gorge of Catskill Creek (Y10) at Leeds, N.Y., pyrite nodules up to 2 inches in maximum diameter, flattened in the plane of bedding, occur in mudstone near the base of the Esopus.

In the northern Helderberg area, New York, the lower 8 to 10 feet of the Esopus is often siliceous and filled with Taonurus-markings (Goldring, 1935, p. 136). Similar siliceous beds occur at Cherry Valley, Olsego Co., but none are reported in the Schoharie Valley. At Cherry Valley (Y4), very tough, medium to thick bedded, medium gray (N5) to dark gray (N3), fossiliferous, calcareous to non-calcareous, siliceous siltstone ("chert") comprises the lower 13 feet of the Esopus. Thin sections show that rod-shaped sponge spicules are very abundant in these siliceous beds (Fig. 9). Somewhat similar, grayish black (N2) "flint beds" are called Glenerie at Leeds (Y10) and Catskill (Y12), N.Y. (Chadwick, 1944, p. 86; Waldo, 1971, personal communication).

Two well-defined local lithologies have been recognized at outcrops in Greene and Ulster counties, N.Y. Massive, medium dark

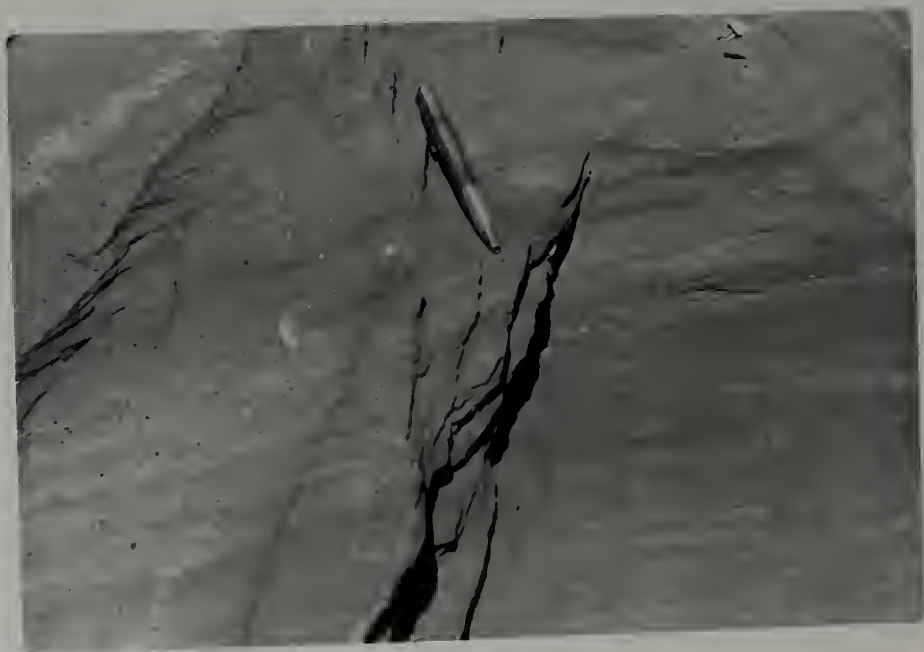
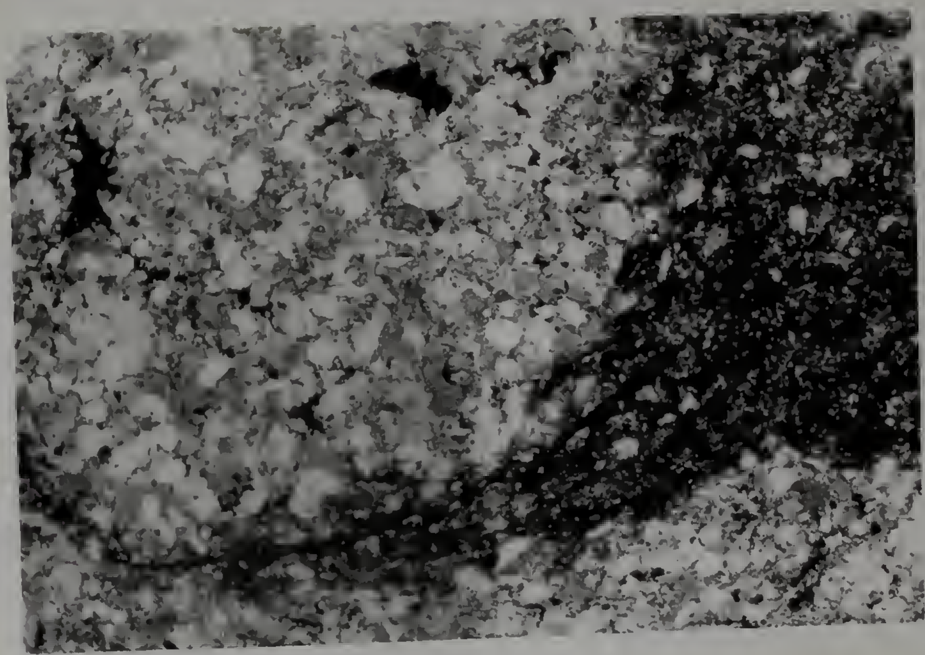
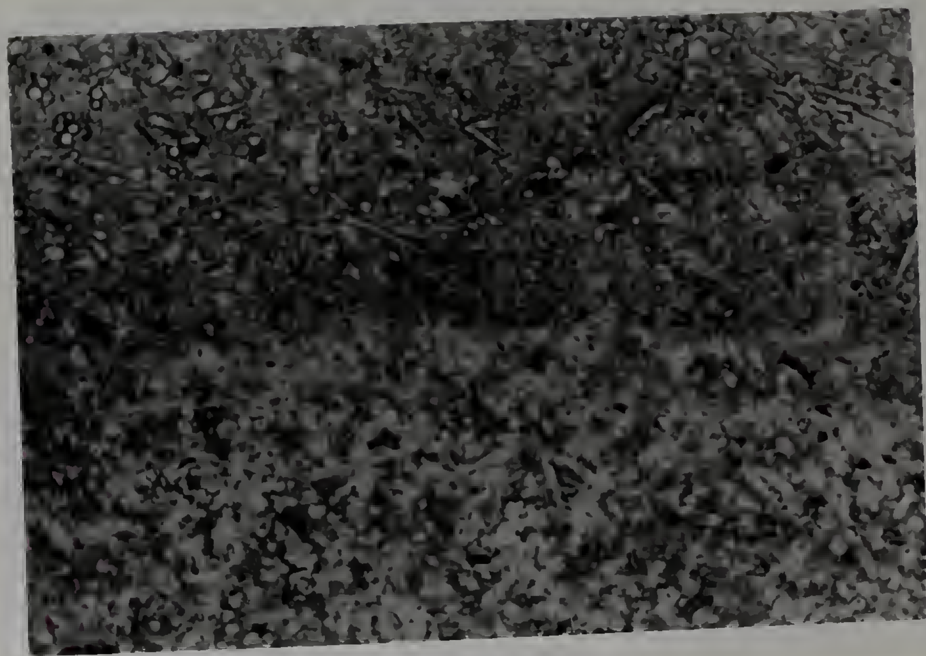


Figure 7.—Taonurus-markings in upper part of Esopus Formation, cut on west side of U.S. Rte. 209, near Buttermilk Falls, Monroe Co., Pa. (P7-3). Beds are rightside up.



0.5 mm.

Figure 8.—Photomicrograph of calcareous, quartz-rich, silty mudstone, Esopus Formation, P8-3, Brodhead Creek, Monroe Co., Pa. Quartz silt is angular, poorly sorted. Matrix consists of terrigenous mud and microcrystalline calcite. Dark area is part of a Taonurus-marking seen in cross-section. (Polarized light.)



0.5 mm.

Figure 9.—Photomicrograph of calcareous, siliceous siltstone, lower part of Esopus Formation, Y4-2, Cherry Valley, Otsego Co., N.Y. Rod-shaped sponge spicules are siliceous at top, but are secondarily replaced by calcite at bottom. (Plane light.)

gray (N4), yellowish gray (5Y7/2) weathering, fossiliferous, calcareous mudstone (or shale) occurs about 20 feet above the base of the Esopus Formation (Y10-3, Appendix) near Catskill and Leeds. The areal extent of this unit is unknown, however. In this same area, a very distinctive, dark gray (N3), slightly calcareous, laminated, siliceous mudstone, about 15 feet thick, is present at the top of the Esopus (Y10-7, Y11-3). Bedding consists of very thin (1/64- to 1/16-inch thick), alternately dark gray and brownish gray (5YR4/1 laminae with thin, medium light gray (N6), lenticular quartz streaks. The brownish gray laminae are rich in pyrite. Waldo (1971, personal communication) has found that this "laminite bed" is persistent over an area of several square miles and usually proves to be more resistant to erosion than adjacent beds. A similar laminated unit (without quartz stringers), 17 feet thick, occurs about 75 feet below the top of the Esopus on the Penn Central Railroad, about 1.0 mile south of Kingston (Y17). The laminae consist of alternating brown weathering (pyritic) bands, 1/64- to 1/16-inch thick, and dark gray bands, 1/16- to 1/4-inch thick. Weathered cleavage fragments have a ribbed appearance with the brown laminae recessed. Laminated units were not noted in the Esopus south of Kingston.

In the subsurface of southeastern New York and northeastern Pennsylvania, the Esopus is predominantly gray shale (mudstone) and siltstone (Rickard, 1969, pl. 11-13). In the Richards No. 1 well (P68), the 180-foot interval assigned to the Esopus on the basis of the gamma-ray log (Fig. 15) consists of dark gray, finely micaceous, slightly limy shale at the base, medium dark gray, non-calcareous shale in the middle, and medium dark gray, slightly limy, pyritic shale at the top (Kehn, Glick, and Culbertson, 1966, p. 77, pl. 2). Dark gray, non-calcareous shale at the same stratigraphic position in the Hettick No. 1 well (P75), Bradford Co. (Fettke, 1960, p. 363), is also assigned to the Esopus.

Contact Relations

Throughout eastern New York and adjacent Pennsylvania and New Jersey, the Esopus Formation usually overlies rocks of Deerpark age (Oriskany, or Ridgeley, Sandstone, Glenerie Limestone, or Shriver Chert), and always underlies rocks of middle Onesquethaw age (Carlisle Center Member of the Schoharie Formation, or equivalent strata).

Fig. 10 shows the relationship of the Esopus Formation to underlying units.

In parts of Otsego and Chenango counties, N.Y., just south and southeast of the "zero-isopach," the Esopus disconformably

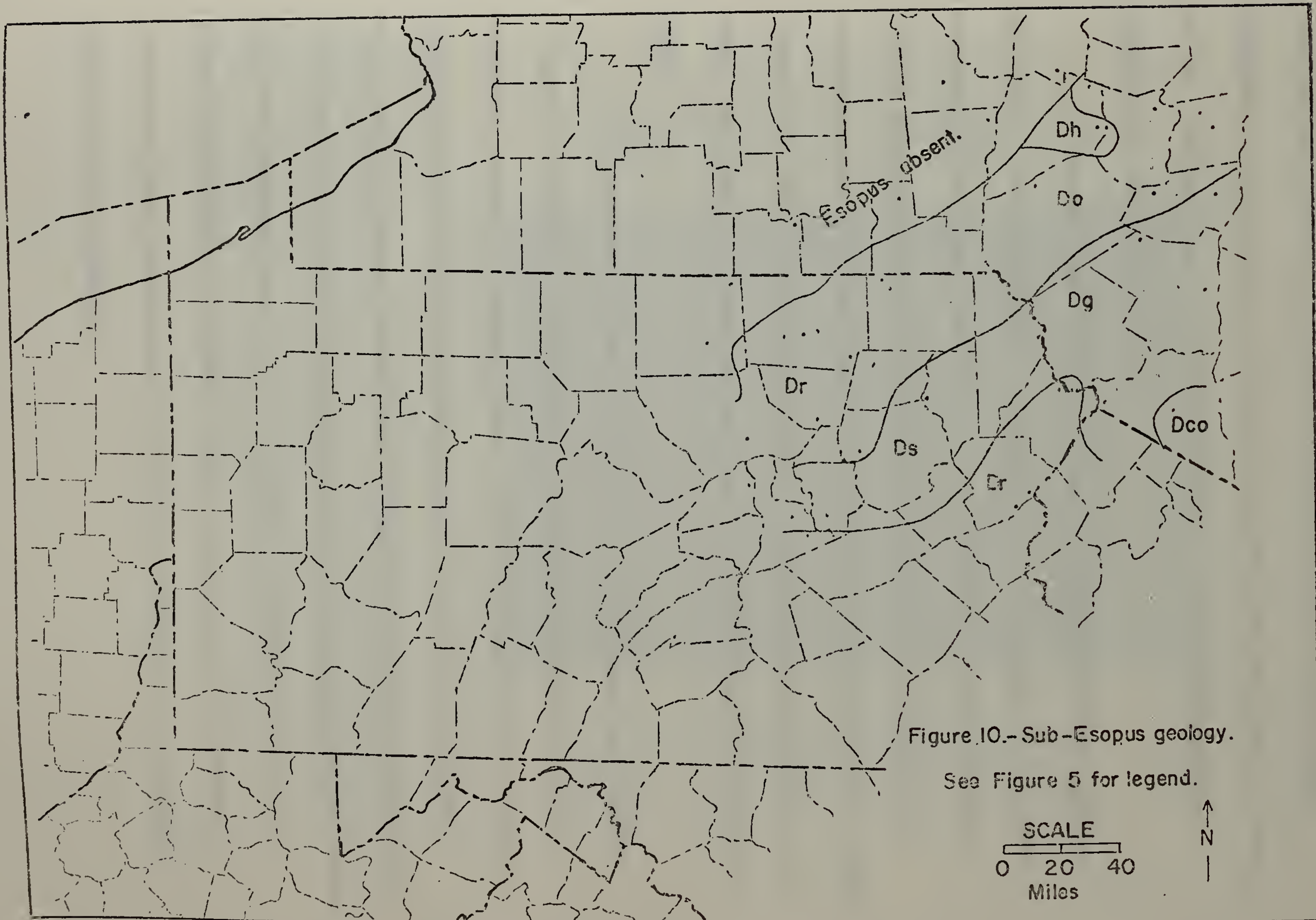


Figure 10.- Sub-Esopus geology.

See Figure 5 for legend.

overlies the Kalkberg Limestone (Helderbergian), the Oriskany Sandstone being absent or discontinuous (Rickard and Zenger, 1964, p. 59). No outcrops showing the Kalkberg-Esopus contact were observed in the present study.

Over a broad belt that extends southwestward from Albany Co., N.Y., to northeastern Pennsylvania, the Esopus overlies the Oriskany (= Ridgeley) Sandstone. The contact is generally abrupt, both at outcrops and in the subsurface. It can be advantageously observed at several outcrops at the northeast end of this area, notably along U.S. Rte. 20, 2.0 miles north of Cherry Valley (Y4) (Fig. 11), and in the gorge of Onesquethaw Creek, 1.0 mile east of Clarksville (Y8).

At outcrops in Monroe Co., Pa., the Esopus overlies the Ridgeley Sandstone in a belt that is probably continuous with the northern Oriskany-Ridgeley area. Along Brodhead Creek, between Minisink Hills and East Stroudsburg (P8, P10), dark gray (N3), fossiliferous, cherty, calcareous sandstone at the base of the Esopus succeeds light gray (N7), coarse grained, calcareous sandstone at the top of the Ridgeley (Fig. 12). The Esopus sandstone is, in part, deeply weathered to a friable, rusty-brown sandrock and contains scattered quartz granules up to 1/8-inch in diameter. The contact appears to be gradational.

Figure 11.—Contact of Esopus Formation (above) and Oriskany Sandstone, on U.S. Rte. 20, 2.0 miles northeast of Cherry Valley, Otsego Co., N.Y. (Y4). Basal beds of Esopus are medium bedded, blocky fractured, cherty, fossilferous, calcareous siltstone. The Oriskany, only 2.5 feet thick, is highly fossilferous, calcareous orthoquartzite. Contact is abrupt and probably disconformable.

Figure 12.—Conformable (?) contact (at hammer) of the Esopus Formation (left) with the Ridgeley Sandstone, north side of Brodhead Creek, 0.4 mile east of East Stroudsburg, Monroe Co., Pa. (P10). Basal Esopus is dense, medium gray, fossiliferous sandstone. Note quartz pebbles in uppermost Ridgeley. Attitude of bedding is N 45° E/62° SE (overturned).

Over the broad area in southeastern New York, northeastern Pennsylvania, and adjacent New Jersey where the Oriskany (Ridgeley) Sandstone is absent, the Esopus overlies the Glenerie Limestone, or its equivalent, the Shriver Chert. Near Leeds and Catskill, N.Y., the contact of massive, dark gray silty mudstone of the Esopus with thick bedded, grayish black cherty siltstones of the Glenerie appears gradational. In the gorge of Catskill Creek (Y10), dense, grayish black chert nodules occur 2 feet above the base of the Esopus, and grayish black shale is interbedded with the Glenerie siltstones. Further south, near Saugerties and Kingston, Ulster Co., the basal Esopus is also cherty (Chadwick, 1944, p. 91), indicating a gradational contact with the Glenerie. In the subsurface of northeastern Pennsylvania, east of Bradford and Sullivan counties, the Esopus-Shriver (Glenerie) contact appears abrupt.

The Esopus Formation disconformably overlies the Connelly Conglomerate (Deerparkian) in the Green Pond-Schunemunk Mountain outlier (Boucot, 1959, p. 731).

The contact of the Esopus Formation and the Carlisle Center Member of the Schoharie Formation is abrupt, and at least locally disconformable at outcrops and in the subsurface north and northwest of Kingston, N.Y. The Esopus-Schoharie disconformity is most pronounced in Otsego County (Fig. 13) and becomes somewhat less

Figure 13.—Abrupt, disconformable contact between Carlisle Center siltstone (above) and Esopus shale, Cherry Valley, Otsego Co., N.Y. (Y4). The Carlisle Center is crowded with Taonurus caudagalli and contains abundant glauconite at base.

prominent to the southeast. At Leeds and Catskill (Y10, Y11, Y12), Greene Co., the upper "laminite bed" of the Esopus is succeeded abruptly by pebbly, glauconitic Carlisle Center mudstone (Fig. 29). No trace of erosional truncation can be observed, however. Similar relations exist at the Kingston railroad cut (Y17), although the basal Carlisle Center may here truncate the upper Esopus (Fig. 30; Johnsen and Southard, 1962, p. A18). Further south in the vicinity of Stroudsburg, Pa. (P7, P8), the upper Esopus is calcareous and apparently conformable with the Carlisle Center.

The Esopus-Schoharie contact can usually be closely approximated in the subsurface. (See Rickard, 1969, pl. 11-14.) In the Richards No. 1 well (P68), Lackawanna Co., Pa., the change from upper Esopus to lower Schoharie (Carlisle Center) at a depth of 8,000 feet is clearly shown on the gamma-ray log (Fig. 15). The upper 50 feet of the Esopus in the well cuttings is slightly limy, medium dark gray, pyritic shale with brachiopods. (See Kehn, Glick, and Culbertson, 1966, p. 77.) This interval could be placed with the Schoharie, but on the basis of the gamma-ray log, it is included in the Esopus. The log of the Hettick No. 1 well (P75), Bradford Co., Pa., shows a clear distinction between dark gray and very dark gray shale (Esopus) below a depth of 5,074 feet and dark gray, calcareous shale with beds of fine grained limestone (Schoharie) above 5,074 feet. (See Fettke, 1933, pp. 652-653; 1961, p. 363.)

Distribution and Thickness

The Esopus Formation is recognized throughout eastern New York, northeastern Pennsylvania, and northwestern New Jersey, as well as in the Green Pond-Schunemunk Mountain outlier (Boucot, 1959) in Orange Co., N.Y., and Passaic Co., N.J., 25 miles to the southeast of the main outcrop belt.

Isopachs of the Esopus Formation define a basin with a depocenter in the vicinity of Tristates, N.Y. (Fig. 14). The "zero-isopach" on the northwest can be traced from Madison and Otsego counties, N.Y., southwestward to Bradford Co., Pa. Since isopachs tend to be perpendicular to the main outcrop belt, it appears that rocks in the Green Pond-Schunemunk Mountain outlier were once continuous with those in the main outcrop area.

Thinning of the Esopus Formation toward the northwest in New York is probably caused chiefly by pre-Carlisle Center erosion and non-deposition of upper Esopus strata. Occurrence of lower Esopus "chert" beds at outcrops in Albany and Otsego counties probably indicates deposition of lower Esopus rocks at least as far as the "zero-isopach" in this area. Pre-Carlisle Center erosion is suggested by angular black chert pebbles at the base of the Carlisle Center at Cherry Valley (Y4). In northern Bradford Co., Pa., and

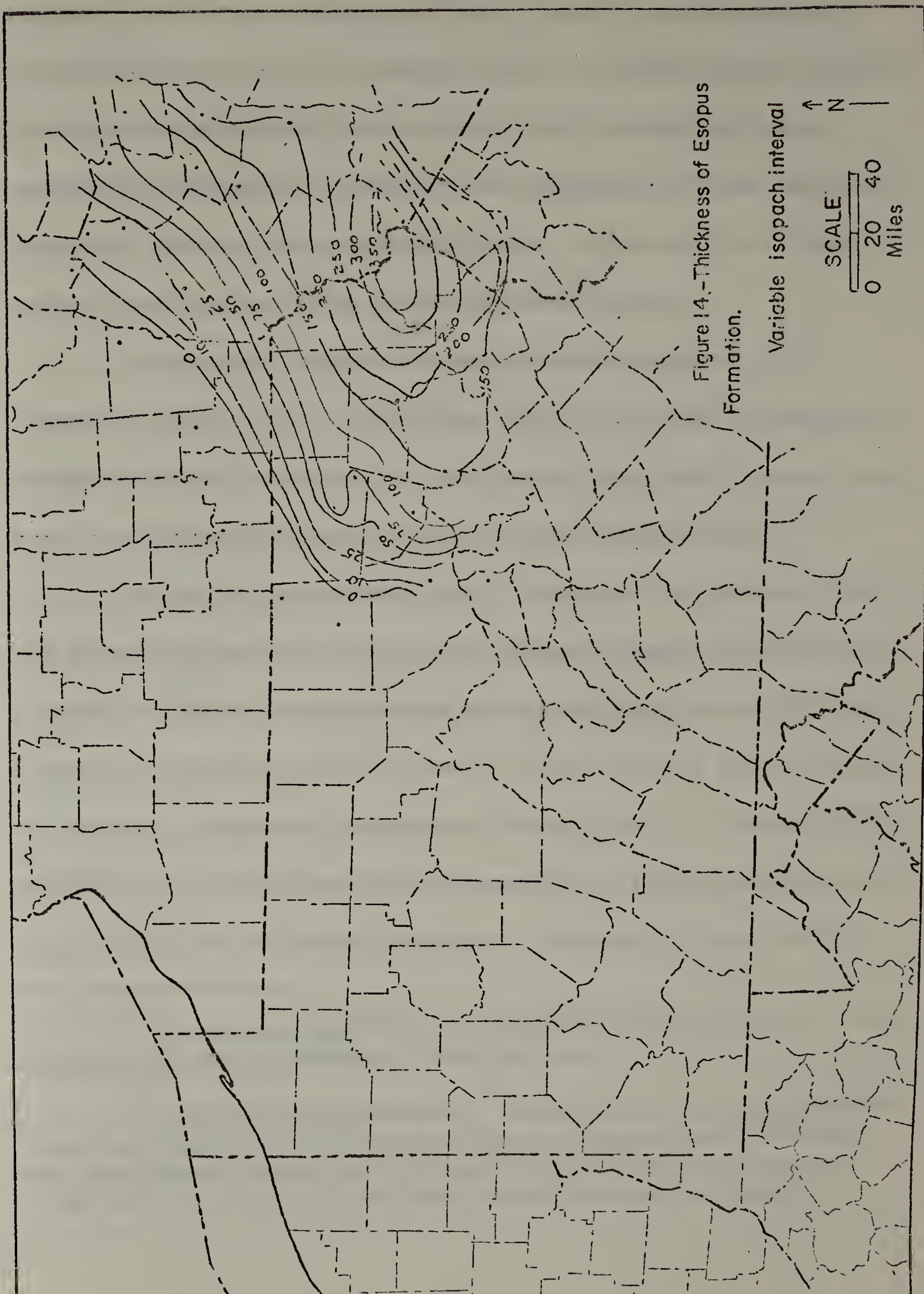


Figure 14.-Thickness of Esopus Formation.

Variable isopach interval

adjacent New York, the Esopus probably thins by a combination of slow-deposition and pre-Onondaga erosion. Thinning in east-central Pennsylvania is believed to be caused in part by extremely slow deposition (starved basin conditions) as suggested by black shale and phosphate nodules in the basal Needmore. In the Lehigh-Schuylkill region, the Esopus pinches out on the basin margin.

The Esopus thickens regularly along its outcrop in the Helderberg area, N.Y., from 18 feet at Cherry Valley[2] to approximately 70 feet at Schoharie, 75 to 80 feet at John Boyd Thacher State Park, and 90 feet on Onesquethaw Creek at Clarksville (Y8).[3]

South of Onesquethaw Creek, the Esopus is involved in Valley and Ridge structure and is generally intensely cleaved and faulted. As a result, thickness measurements are not reliable. About 200 feet are present on Catskill Creek at Leeds (Y10) and probably somewhat more at Kingston. Southwest of Kingston, Berkey (1911, p. 40) estimated a thickness of over 800 feet for the Esopus (i.e., Esopus and Schoharie) in drill holes for the Catskill Aqueduct. Allowing 217 feet for the

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[2]The Esopus appears to be absent in the Skramko No. 1 well, Herkimer Co. (Y30) (Rickard, 1969, pl. 11).

[3]Thicknesses at Schoharie, Thacher Park, and Onesquethaw Creek are based on measurements cited by Grabau (1906, pp. 252, 255, 284, 295) of 85-95 feet, 100 feet, and 121 feet, respectively. These figures include the Carlisle Center beds with the Esopus.

Schoharie (measured at Kingston, Y17), the Esopus itself would be nearly 600 feet thick. As at most exposures in the fold belt of eastern New York, the Esopus is probably much overthickened by faulting in the drill hole sections. In the present study, no exposures of the Esopus were examined between Kingston and Tristates, N.Y. In a new rock cut through Trilobite Mountain on Interstate Rte. 84, 0.4 mile south of Tristates (Y23), about 300 feet of Esopus mudstone and siltstone, intensely cleaved and faulted, are exposed. Shimer (1905, p. 192) gives an approximate maximum thickness of 550 feet in the same area, but the actual stratigraphic thickness is probably nearer 300 to 400 feet. South of Tristates the Esopus thins to 215 feet at outcrops along Brodhead Creek, near East Stroudsburg, Monroe Co., Pa. (P8). It is less than 50 feet thick at Saylorsburg (P17), 12 miles farther to the southwest.

In the subsurface northwest of the outcrop belt in Pennsylvania, the Esopus maintains a thickness of about 200 feet as far west as Lackawanna Co. It then thins rapidly to 90 feet in eastern Bradford Co. before pinching out completely in western Bradford Co. In the subsurface of Luzerne, Sullivan, and Columbia counties, the Esopus also thins, but not so rapidly. It is 110 feet thick in the Bennett No. 1 well, Sullivan Co. (P81). (See Rickard, 1969, pl. 13.) Farther southwest, the Esopus may be represented, in part, by the Beaverdam

Shale Member of the Needmore Formation (Swain and Rogers, 1966), about 15 feet thick at outcrops near Lewisburg, Union Co. (P35), and Montoursville, Lycoming Co. (P36). Shales at the base of the Needmore at outcrops and in wells in central Northumberland Co. are also probably correlative with the Esopus.

Fauna and Age

Except for Taonurus caudagalli, whose origin is greatly disputed, fossils are generally rare along the main outcrop belt of the Esopus in New York, New Jersey, and Pennsylvania. The brachiopods Leptocoelia flabellites and Leptocoelina acutiplicata are present at many localities, but are usually not common (Table 1). Other fossils from the Esopus are noted in Van Ingen and Clarke (1903, p. 1204), Howell (1942, pp. 87-97), and Chadwick (1944, p. 91). Because of the intense development of cleavage in the Esopus mudstones, fossil preservation is poor. Identification at the species level is, therefore, very difficult.

A large, comparatively well-preserved Esopus fauna does occur in the Green Pond-Schunemunk Mountain outlier near Highland Mills and Monroe, Orange Co., N.Y. Numerous invertebrate species (Table 2) are present in the Mountainville and Highland Mills members (Boucot, 1959; Jaffe and Jaffe, 1973), and Taonurus caudagalli is replete through the Mountainville, Highland Mills and upper black mudstone members. Since the Woodbury Creek Member is

TABLE 1

FAUNA OF THE ESOPUS FORMATION IN THE MAIN OUTCROP BELT
(1 = New York; 2 = Pennsylvania)

Fauna	1	2
Brachiopoda		
Leptocoelia flabellites (Conrad)	×	
Leptocoelina acutiplicata (Conrad)	×	×
Ambocoelia sp.	×	
Hysterolites (?) sp.		×
Incertae sedis		
Taonurus caudagalli (Vanuxem)	×	×

TABLE 2

FAUNA OF THE ESOPUS FORMATION IN THE GREEN POND-SCHUNEMUNK MOUNTAIN OUTLIER
(1 = Mountainville Member; 2 = Highland Mills Member; 3 = upper black mudstone member)

(Boucot, 1959, p. 233; Jaffe and Jaffe, 1973, p. 52)

Fauna	1	2	3
Coelenterata			
Unidentified conularids	x		
Brachiopoda			
Orbiculaidea sp.	x		
Platyorthis planoconvexi (Hall)		x	
"Chonetes" cf. "C." nectus Clarke		x	
Eodevonaria cf. E. gaspensis Clarke		x	
Camarotoechia sp.		x	
Leptocoelia flabellites (Conrad)	x	x	
Cyrtina rostrata (Hall)		x	
Acrospirifer macrothyris	x		
Hysterolites perimele (Clarke)		x	
Etymothyris sp.		x	
Prionothyris diobolaris (Clarke)		x	
Meganterella finksi (Boucot)		x	
Gastropoda			
Unidentified platystomids and loxonemids	x		
Trilobita			
Coronura myrmecophorus (Green)	x		
Incertae sedis			
Taonurus caudagalli (Vanuxem)	x	x	x

probably a facies equivalent of the Carlisle Center Member of the Schoharie Formation (Johnsen and Southard, 1962, p. A14), its fauna will be discussed later.

The Esopus Formation is presumably upper Siegenian and/or lower Emsian in age (Rickard, 1964: Oliver and others, 1969).

Schoharie Formation

Definition and Reference Section

The Schoharie Formation is a highly variable sequence of sandy limestones, argillaceous limestones, calcareous mudstones, and calcareous shales that occurs above the Esopus Formation and below the Onondaga Limestone in eastern New York, northwestern New Jersey, and northeastern Pennsylvania. Vanuxem (1840) applied the name "Schoharie grit" to a thin, bluish-gray, highly fossiliferous, arenaceous limestone that occurs only in the Schoharie Valley and northern Helderberg regions, Schoharie and Albany counties, N.Y. That profound facies changes take place in the Schoharie south of the type area was first recognized by Clarke (1900, pp. 13-14) and Grabau (1903, pp. 1069-1070) who found typical Schoharie fossils in a thick mass of highly cleaved, calcareous mudstone on Becraft Mountain, Columbia Co., N.Y. Facies changes in the Schoharie Formation were first described in detail by Goldring and Flower

(1942) and were further elucidated by Johnsen (1957) and Johnsen and Southard (1962).

Four distinct members[4] have been recognized in the Schoharie Formation in eastern New York (Johnsen, 1957, and Johnsen and Southard, 1962). In descending order these are:

Schoharie Region	Hudson Valley Region
Rickard Hill Member	Saugerties Member
Carlisle Center Member[5]	Aquetuck Member
	Carlisle Center Member

The Carlisle Center Member (originally the Sharon Springs Formation) was first recognized as a distinct unit by Goldring and Flower (1942). It was named for exposures near Carlisle Center, Schoharie Co., N.Y. (Goldring and Flower, 1944, p. 340). The Rickard Hill Member is the fossiliferous "Schoharie grit" of Vanuxem (1840) and other early workers. Its type locality is along Rickard Hill Road, 2 miles east of Schoharie Village (Johnsen, 1957, p. 25). The Aquetuck Member was named for exposures on the north side of the secondary road bordering Hannacroix Creek, 0.3 mile northwest of where the secondary road joins N.Y. Rte. 143 and 1.4 miles northwest of Aquetuck, Albany Co. (Johnsen, 1957, p. 45). The

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[4]Called "lithofacies" by Johnsen (1957).

[5]Goldring and Flower (1942, 1944) and Rickard (1964) have considered the Carlisle Center to be a formation separate from the Schoharie.

Saugerties "formation" was informally named by Chadwick for an incomplete exposure of the upper Schoharie on N.Y. Rte. 212, 1.2 miles west of Saugerties, Ulster Co. The type locality of the Saugerties Member, however, has been designated by Johnsen (1957, p. 49) as in the cut on the Penn Central Railroad, 0.1 mile north of the West O'Reilly Street underpass, about 1.0 mile south of Kingston.

Although Cooper and others (1942) had inferred that the Schoharie Formation is present in eastern Pennsylvania, Trexler (1953) and Johnsen (1957) first clearly demonstrated that about 100 feet of calcareous siltstone and mudstone formerly assigned to the Esopus Formation actually represents the Schoharie. Two subdivisions can be delineated in the Schoharie Formation in eastern Pennsylvania. The lower half of the unit consists of massive, medium dark gray, highly cleaved, pyritic, calcareous mudstone with horizontal Taonurus burrows, whereas the upper half consists of massive, medium dark gray, siliceous, calcareous mudstone and sandy, calcareous, siliceous siltstone with vertical burrows. (See also Epstein and Epstein, 1969, pp. 100, 157.) These two subdivisions probably correspond to the Carlisle Center and Aquetuck-Saugerties (undivided) members, respectively. A similar two-fold division of the Schoharie in the subsurface is indicated in the gamma ray and sample logs of the Richards No. 1 well, Lackawanna Co., Pa. (P68) (Fig. 15; Kehn,

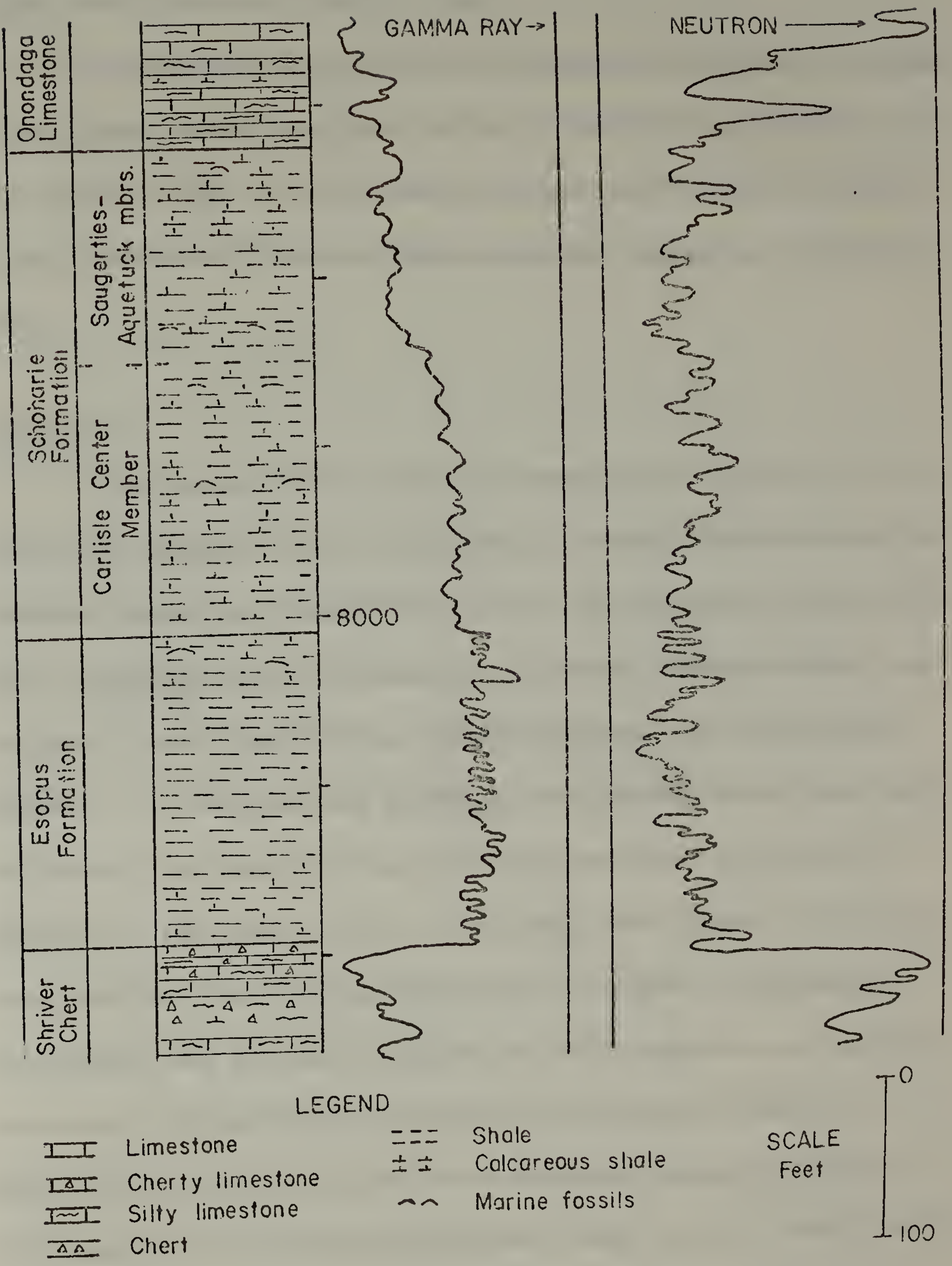


Figure 15.—Stratigraphic section and radiometric logs of the Esopus and Schoharie in the Richards No. 1 well, Lackawanna Co., Pa. (P68). (Modified from Kehn, Glick, and Culbertson, 1966, pl. 2.)

Glick, and Culbertson, 1966, p. 72).

The reference section for the Schoharie Formation in eastern Pennsylvania and adjacent New Jersey is herein designated as the cut on U.S. Rte. 209, 0.1 mile west of Buttermilk Falls and 2.3 miles south of Marshalls Creek village, Smithfield Township, Monroe Co. (P7).

Lithology

The Schoharie Formation is composed of a variety of rock types with complex facies relationships. In the Schoharie Valley and northern Helderberg region of New York, the formation consists of a lower *Taonurus*-bearing siltstone, the Carlisle Center Member, and an upper, highly fossiliferous, sandy limestone, the Rickard Hill Member. To the south and southeast, the Carlisle Center maintains its identity, but becomes less a siltstone and more a calcareous mudstone. The Rickard Hill, on the other hand, grades, in the same direction, into much thicker calcareous mudstones, argillaceous limestones, and siliceous mudstones of the Saugerties and Aquetuck members. The Schoharie Formation is dominantly mudstone (siliceous in part) and argillaceous limestone between Kingston and Tristates, N.Y. (Johnsen and Southard, 1962, pp. A11-A13). Further southwest in New Jersey and eastern Pennsylvania, the uppermost Schoharie is a calcareous, sandy siltstone, whereas the lower portion remains calcareous mudstone with some siliceous beds. In the subsurface the Schoharie is mostly calcareous, silty shale and siltstone (calcareous mudstone) and argillaceous limestone. (See Fettke, 1933, pp. 652-653; 1960, pp. 362-363; Kehn, Glick and Culbertson, 1966, p. 77; Rickard, 1969, pl. 11-14.)

Carlisle Center Member

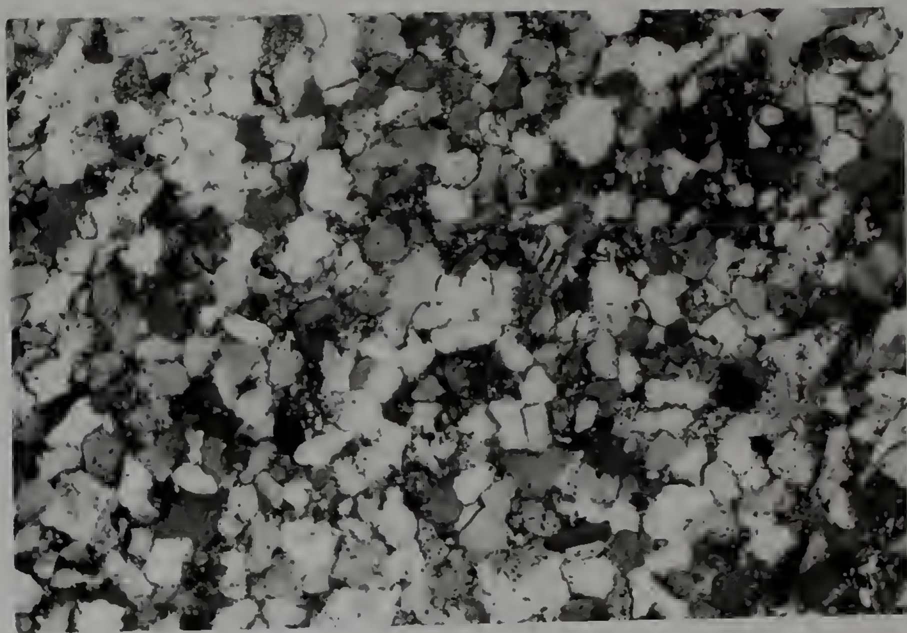
In the type area, the Carlisle Center Member is massive, light gray (N7), calcareous, glauconitic quartz siltstone with profuse Taonurus-markings (Fig. 37). The member maintains this lithology eastward into the Helderberg region, but changes to massive, medium dark gray (N4) to medium gray (N5), pyritic, locally glauconitic, calcareous mudstone south of the Helderbergs. In the mid-Hudson Valley region, the Carlisle Center tends to be distinctly banded, consisting of alternating beds of medium dark gray and yellowish gray (5Y 7/2) weathering mudstones. Taonurus-markings are abundant throughout. Banding and Taonurus-markings are also characteristic of the Carlisle Center Member in Monroe Co., Pa.

A distinctive "black bed," one-foot to 4 feet thick, consisting of laminated, grayish black (N2), dark brownish gray (5YR 3/1) weathering, slightly calcareous and dolomitic, siliceous siltstone, lies in the lower third of the Carlisle Center Member in the mid-Hudson Valley. (See Y11-5 and Y17-5, Appendix; Fig. 28.) Johnsen and Southard (1962, p. A11) report that the "black bed" is present in all sections in the main outcrop belt between Leeds, Greene Co., and Wawarsing, Ulster Co. A unique horizon of dense, black (N1) chert, 2 inches thick, in the middle of the Carlisle Center Member at Buttermilk Falls, Monroe Co., Pa. (P8-5), may represent the same horizon as the "black bed" (Fig. 16).

Typical petrographic thin sections from the Carlisle Center Member are shown in Fig. 17-21. The change from coarse, glauconitic quartz siltstone in the type area (Fig. 17) to fine, silty, calcareous mudstone in eastern Pennsylvania (Fig. 18) is apparent. Also note the characteristic presence of detrital plagioclase feldspar and silicified wood fragments. Glauconite (Fig. 17, 19) is not known to occur south of Kingston. At Leeds (Y11) and Kingston (Y17), the "black bed" contains abundant authigenic dolomite, pyrite, and glauconite (Fig. 20, 21). Scattered subangular to subrounded quartz pebbles are present at Leeds (Fig. 20) but absent at Kingston.

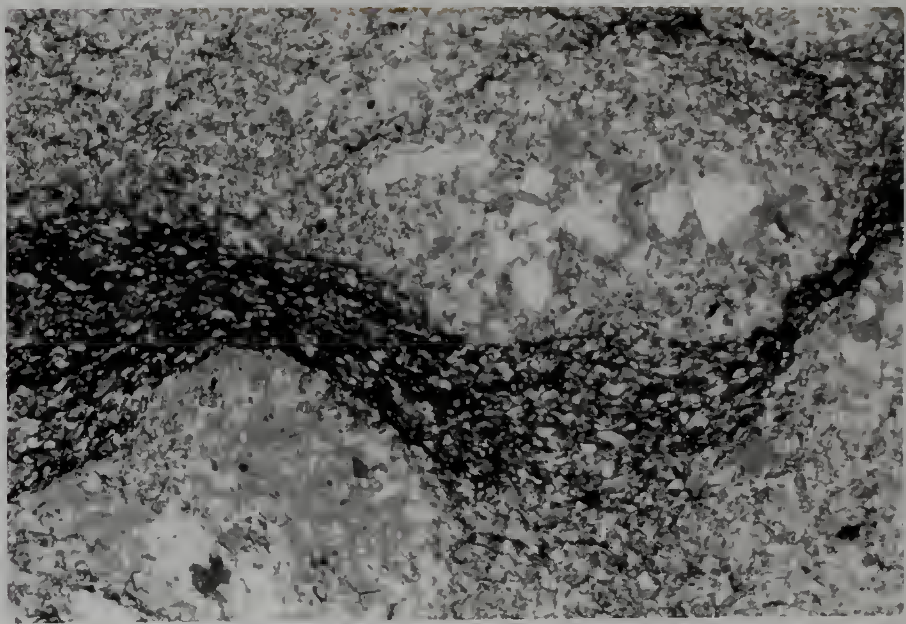
In the subsurface immediately south of the outcrop belt in the Schoharie Valley-Helderberg region, New York, the Carlisle Center is dominantly a gray shale (mudstone) and siltstone (Rickard, 1969, pl. 11, 12). Farther south in northeastern Pennsylvania, the Carlisle Center is represented by medium dark gray, limy, pyritic, fossiliferous shale (mudstone) between 7,850 and 8,013 feet depth in

Figure 16.—Lenticular bed of black chert in Schoharie Formation (Carlisle Center Member), cut on west side of U.S. Rte. 209, near Buttermilk Falls, Monroe Co. (P7-5). This chert horizon occurs about 13 feet above the base and 15 feet below the top of the Carlisle Center and may represent the "black bed" of the Hudson Valley area of New York.



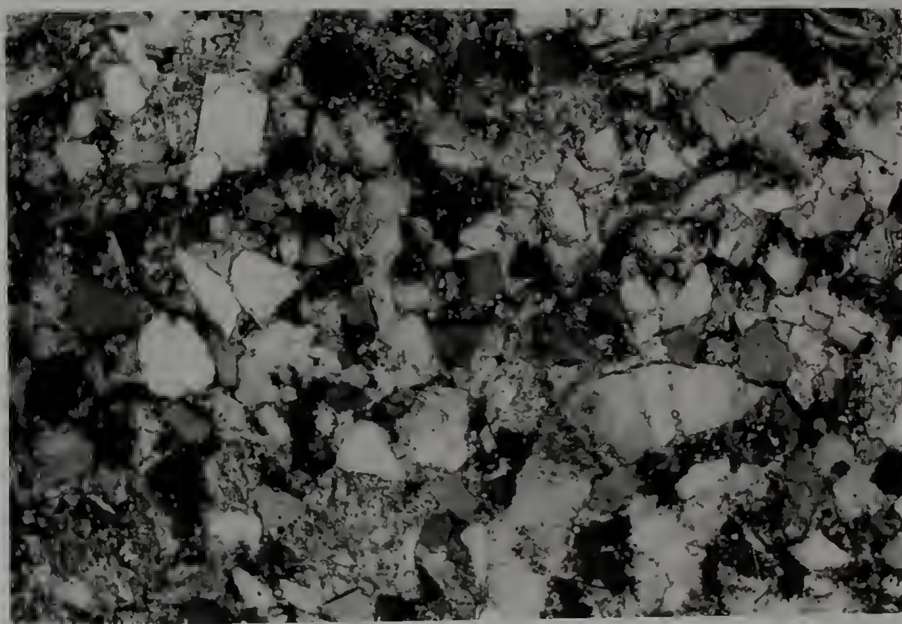
0.5 mm.

Figure 17.—Photomicrograph of moderately sorted, glauconitic quartz siltstone, Schoharie Formation (Carlisle Center Member), Cherry Valley, Otsego Co., N.Y. (Y4-6). Note twinned plagioclase grain in center. (Polarized light.)



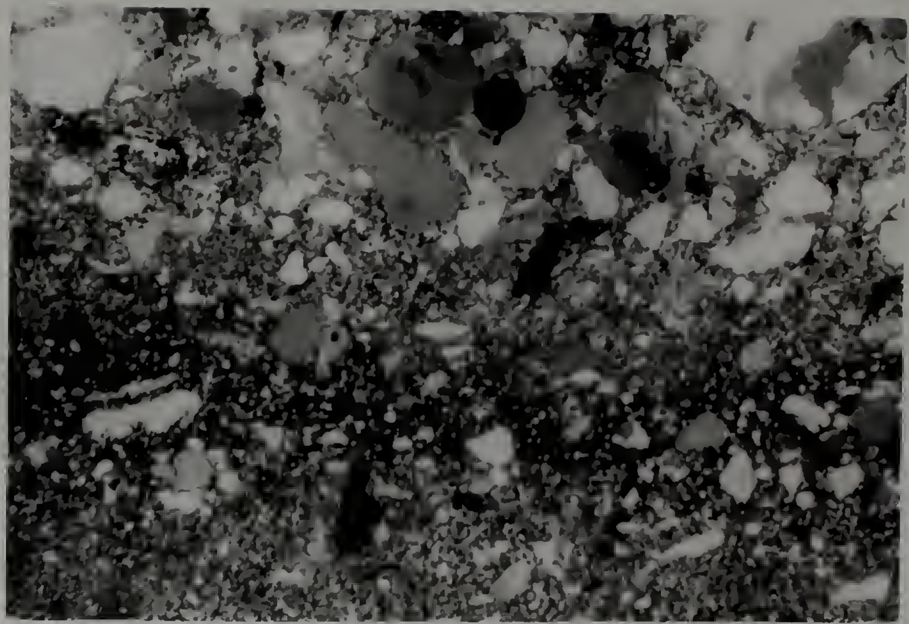
1.0 mm.

Figure 18.—Photomicrograph of intensely burrowed, siliceous, calcareous mudstone, Schoharie Formation (Carlisle Center Member), Buttermilk Falls, Monroe Co., Pa. (P7-5). Angular grains are predominantly silt-size quartz. Coarse, subhedral calcite spar occurs in highly silicified pods. (Polarized light.)



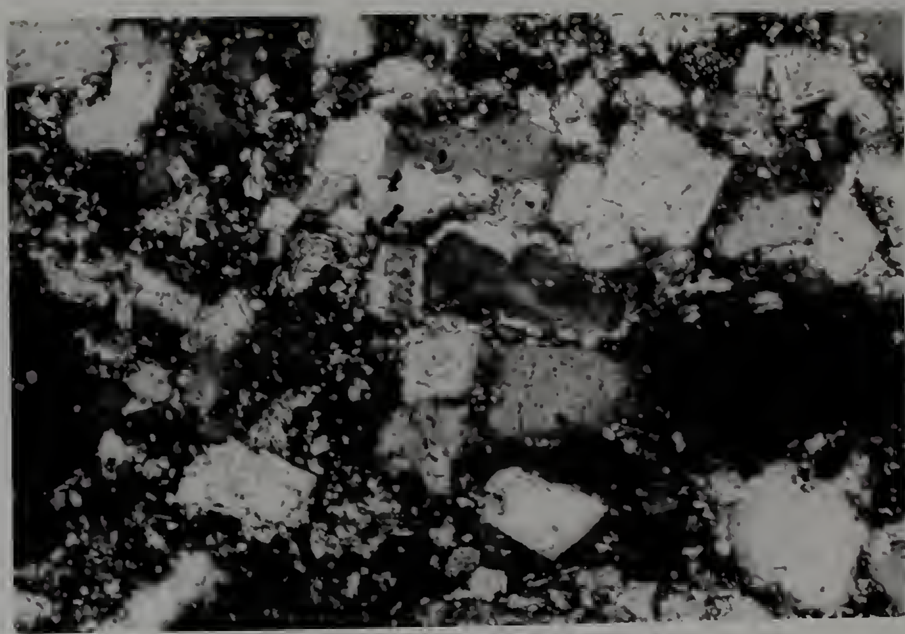
0.5 mm.

Figure 19.—Photomicrograph of glauconitic, fossiliferous, calcareous siltstone, Schoharie Formation (base of Carlisle Center Member), Kingston, Ulster Co., N.Y. (Y17-3). Note large dolomite rhomb at upper left, wood fragment at upper right, and trilobite fragment in lower left. (Polarized light.)



1.0 mm.

Figure 20.—Photomicrograph of poorly sorted, sandy, calcareous siltstone and mudstone, Schoharie Formation (Carlisle Center Member), Leeds, Greene Co., N.Y. (Y11-5/4). Sandy zone marks contact between "black bed" and underlying calcareous mudstone. Grains are mostly quartz. Note silicified wood fragment in upper left. (Polarized light.)



0.1 mm.

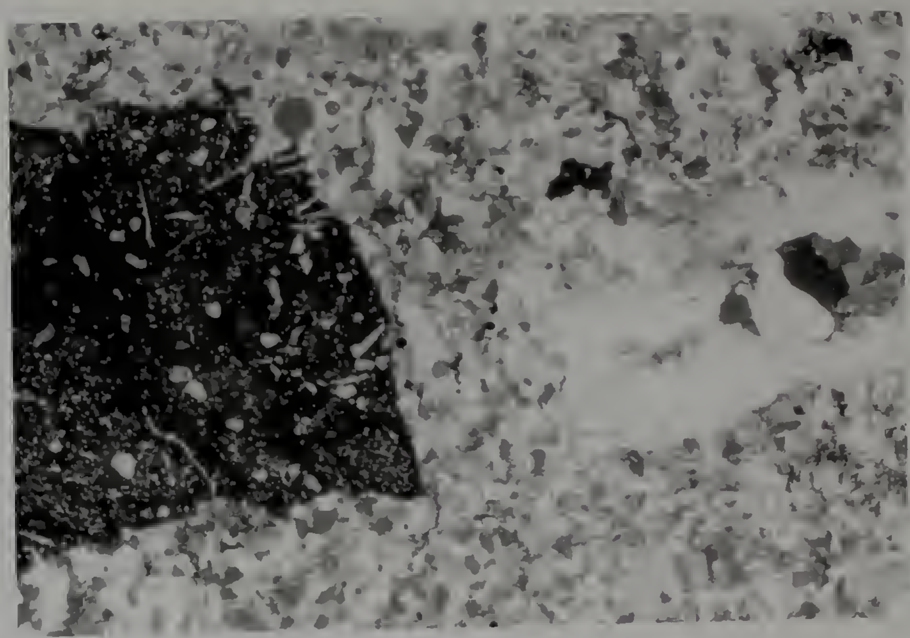
Figure 21.—Photomicrograph of euhedral dolomite rhombs in silty, calcareous mudstone, Schoharie Formation (Carlisle Center Member, "black bed"), Leeds, Greene Co., N.Y. (Y11-5). Note angular, corroded quartz grains. (Polarized light.)

the Richards No. 1 well (P68) (Fig. 15). (See Kehn, Glick, and Culbertson, 1966, p. 77, pl. 2.) West and northwest of the Richards well, the Carlisle Center cannot be differentiated from the upper Schoharie beds on sample logs. (See Fettke, 1933, pp. 652-653; 1961, pp. 362-363.) On gamma ray logs, however, the Carlisle Center can be distinguished at least as far west as Sullivan Co. (See Rickard, 1969, pl. 13.)

Rickard Hill Member

The typical "Schoharie grit" in the Schoharie region is a very tough, medium dark gray (N4), highly fossiliferous, locally glauconitic and phosphatic, sandy limestone, or calcareous sandstone, that weathers to brown, porous sandrock in which the fossils appear as myriads of external and internal molds. Phosphate pebbles, up to 50 mm. in diameter, are characteristic of the Rickard Hill, particularly near the contact with the overlying Onondaga Limestone (Laskowski, 1956, pp. 162, 169).

In thin section a specimen of the Rickard Hill from Thompsons Lake, Albany Co., N.Y. (Y7) is seen to be composed of very fine (diameter 0.06 to 0.25 mm.), angular quartz and calcite sand cemented by calcite spar (0.1 to 0.4 mm.) (Fig. 22). A few small plagioclase grains are present. Identifiable fossil fragments consist of tabulate corals, brachiopods, and trilobites. Pyrite (to 0.05 mm.)



1.0 mm.

Figure 22.—Photomicrograph of moderately sorted, fossiliferous, sandy limestone (or calcareous sandstone), Schoharie Formation (Rickard Hill Member), Thompsons Lake, Albany Co., N.Y. (Y7). Rock consists predominantly of very fine grained, angular quartz and calcite sand. Phosphate nodule at left is probably detrital, as shown by sharp, eroded edges. (Polarized light.)

and glauconite (to 0.04 mm.) occur as authigenic minerals. Detrital phosphate pebbles are conspicuous.

Southeast of the Schoharie Valley the Rickard Hill "limestone" grades into calcareous mudstone and argillaceous limestone of the Aquetuck and Saugerties members (Johnsen and Southard, 1962, p. A8). In the subsurface south and west of the outcrop belt, the Rickard Hill may be represented by cherty limestone or shale, 25 feet thick, assigned to the Schoharie in the Gans No. 1 well, Greene Co., N.Y. (Y28). (See Rickard, 1969, pl. 11.)

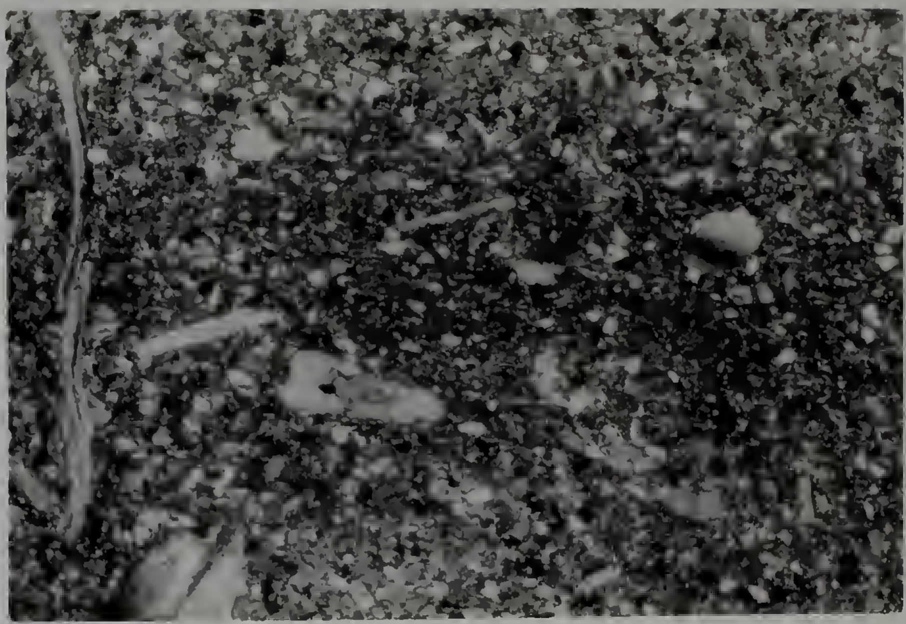
Aquetuck and Saugerties Members

In the mid-Hudson Valley, N.Y., the upper part of the Schoharie Formation consists of massive, calcareous mudstone, with sparse interbeds and nodules of fine grained, argillaceous limestone (Aquetuck Member) and interbedded highly calcareous mudstone and variably argillaceous, crystalline, fossiliferous limestone (Saugerties Member). South of Kingston crystalline limestone beds disappear from the Saugerties and, consequently, the two members cannot be differentiated from each other in southeastern New York and adjacent New Jersey and Pennsylvania (Saugerties-Aquetuck members, undivided). In the subsurface, the Aquetuck and Saugerties are also treated as a single unit.

The Aquetuck Member in its typical development is composed of massive, medium dark gray (N4), yellowish gray (5Y 7/2) weathering, calcareous mudstone, with nodules and lenticular beds of fine grained, medium gray (N5), light gray (N7) weathering, argillaceous limestone. Dark brownish gray (5YR 3/1) weathering bands, 1/16- to 1-inch thick, are conspicuous in the lower Aquetuck at Leeds (Y11), but are absent at Kingston (Y17). North of Kingston, glauconite is commonly present, generally in association with sand-size quartz grains (Johnsen and Southard, 1962, p. A8). At Leeds glauconite occurs in a 1.5-feet thick bed of mudstone at the very top of the member (Y11-8). Burrows are abundant throughout the member.

The Saugerties Member in Greene, Ulster, and Columbia counties, N.Y., consists of interbedded medium dark gray (N5), yellowish gray (5Y 7/2) weathering, highly calcareous mudstone in even beds 2 to 24 inches thick and medium gray (N5), light gray (N7) weathering, medium fine grained, crystalline limestone in even beds 2 to 12 inches thick. The lower part of the member is mostly massive mudstone, with thin limestone beds. The latter increase in proportion and thickness toward the top. Fossils are extremely abundant in the Saugerties, as are irregular burrows. In thin section a typical specimen of Saugerties limestone is seen to be composed predominantly of fossil fragments and calcite cement, with abundant terrigenous debris (Fig. 23).

At outcrops in northeastern Pennsylvania and adjacent



1.0 mm.

Figure 23.—Photomicrograph of moderately to poorly sorted, fine grained, quartzose biocalcarenite, Schoharie Formation (Saugerties Member), Leeds, Greene Co., N.Y. (Y11-9). Rock is composed of about 45 per cent allochems (trilobite and brachiopod fragments), 30 per cent terrigenous silt and sand (mostly quartz), and 25 per cent microcrystalline calcite matrix. Opaque grains are pyrite. (Polarized light.)

New York and New Jersey, the Saugerties-Aquetuck members, undivided, consist predominantly of massive to thick-bedded, medium dark gray (N4), fossiliferous, calcareous, argillaceous siltstone, with nodules of grayish black (N2), very siliceous siltstone in discontinuous nodule layers (Fig. 24). As in all three members of the Schoharie Formation in the Hudson Valley region, weathered rock surfaces exhibit alternate medium gray (N5) and yellowish gray (5Y 7/2) bands, 0.5 to 2 feet thick. Vertical burrows, 1/8 to 1/4 inch in diameter, are abundant throughout.

The upper beds of the Saugerties-Aquetuck are very limy in Orange Co., N.Y., and distinctly sandy in Sussex Co., N.J., and Monroe Co., Pa. (Johnsen, 1957). At Trilobite Mountain, N.Y. (Y21), the upper 10 feet is composed of medium-bedded medium dark gray (N4), very argillaceous limestone, replete with brachiopods and trilobites. At Buttermilk Falls (P7), Brodhead Creek (P9), and East Stroudsburg (P11), Pa., however, the upper 16 feet consists of massive, dark gray (N3), yellowish gray (5Y 7/2) weathering, sandy, siliceous, calcareous siltstone, in which vertical burrows, 1/4 to 1/2 inch in diameter and 6 inches long, are abundant.

Typical photomicrographs of rock types in the Saugerties-Aquetuck members, undivided, are shown in Fig. 25-27.

In the subsurface, the Saugerties-Aquetuck beds can be recognized on gamma ray logs throughout eastern New York and

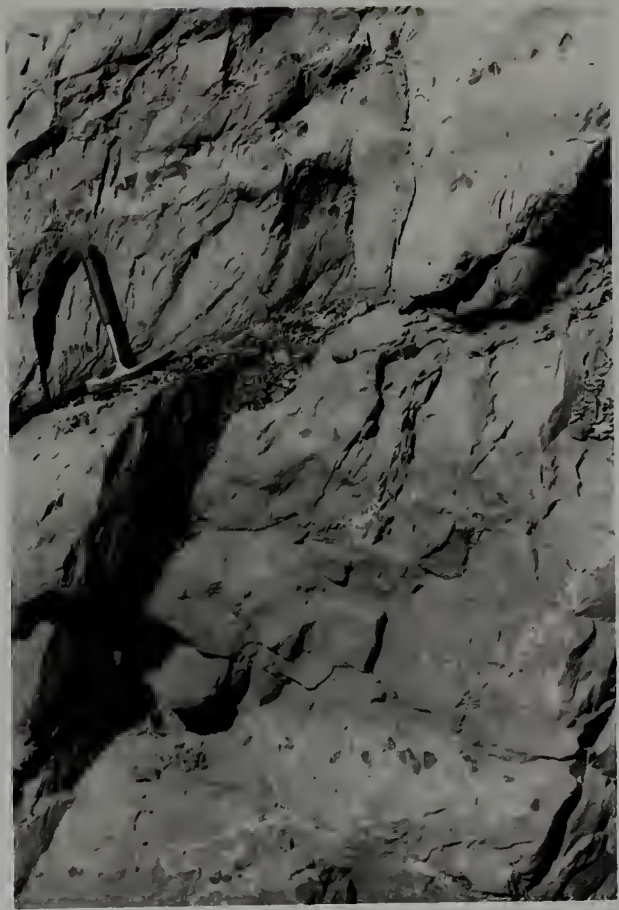


Figure 24.—Aquetuck-like lithology in Schoharie Formation, west side of U.S. Rte. 209, Buttermilk Falls, Monroe Co., Pa. (P7-6). Darker blotches are nodules of dark gray, siliceous siltstone that probably represent once-continuous beds disrupted by burrowing organisms.

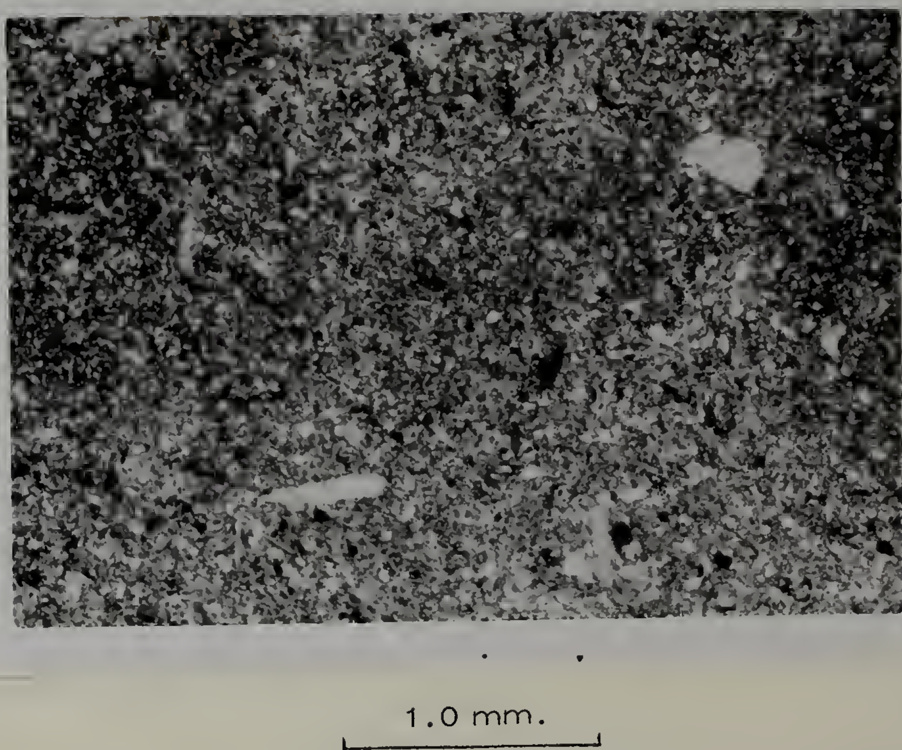
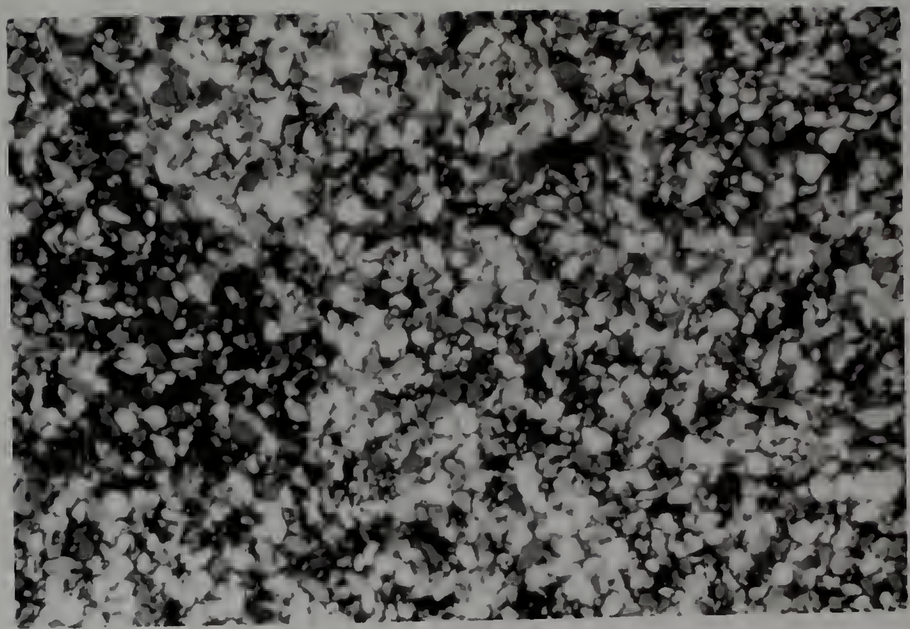
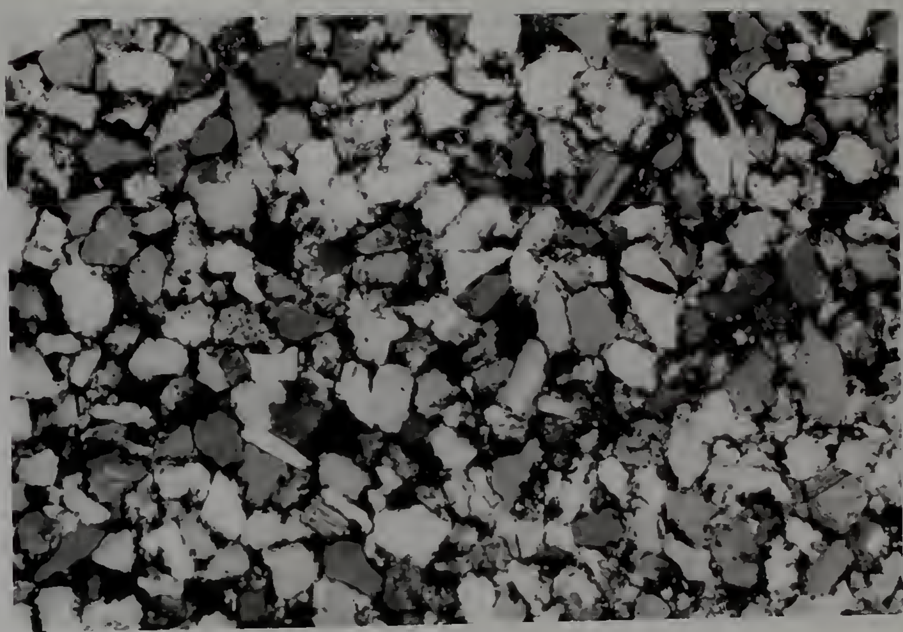


Figure 25.—Photomicrograph of sparsely fossiliferous, siliceous, calcareous siltstone, Schoharie Formation (Saugerties-Aquetuck members, undivided), Buttermilk Falls, Monroe Co., Pa. (P7-6). Rock is composed of quartz (50 per cent) and calcite (20 per cent) silt in a cherty, argillaceous matrix. (Polarized light.)



1.0 mm.

Figure 26.—Photomicrograph of moderately well sorted, coarse grained, sandy siltstone, Schoharie Formation (Saugerties-Aquetuck members, undivided), Buttermilk Falls, Monroe Co., Pa. (P7-8). Angular quartz grains are cemented by silica overgrowths and calcite. (Polarized light.)



0.5 mm.

Figure 27.—Photomicrograph of portion of same slide (enlarged) shown in Fig. 26. Note abundant detrital plagioclase (oligoclase to andesine) and corrosion of quartz and plagioclase by secondary calcite cement. (Polarized light.)

northeastern Pennsylvania. (See Fig. 15.) Identification of the unit from sample logs is rather conjectural, however, since it usually differs from the underlying Carlisle Center only in being more calcareous. West of the mid-Hudson Valley outcrop belt, the Saugerties-Aquetuck is calcareous shale (mudstone) and limestone, as in the Herdmann No. 1 well, Ulster Co. (Y27) and Hirsch No. 1 well, Delaware Co. (Y31) (Rickard, 1969, pl. 11, 12). Farther to the south in the Richards No. 1 well, Lackawanna Co., Pa. (P68), the Saugerties-Aquetuck is represented by medium dark gray, fossiliferous, pyritic, slightly siliceous, calcareous shale (mudstone). In the C. Blemle No. 1 and G. H. Hettick No. 1 wells (P74, P75), Bradford Co., Pa., some dense, gray and dark brownish gray, argillaceous limestone occurs in the middle and lower part of a sequence that is predominantly gray, calcareous shale (mudstone) (Rickard, 1969, pl. 13; Fettke, 1961, p. 362).

Contact Relations

The Schoharie Formation usually overlies the Esopus Formation and always underlies the Onondaga Limestone. Near its western outcrop pinch-out in Herkimer Co., N.Y., it may overlie older formations (e.g., the Oriskany Sandstone) (Johnsen, 1957). Similar relations probably exist in the subsurface of central New York (Rickard, 1969, pl. 12, 13; Fettke, 1961, pp. 493, 552). (Fig. 28.)

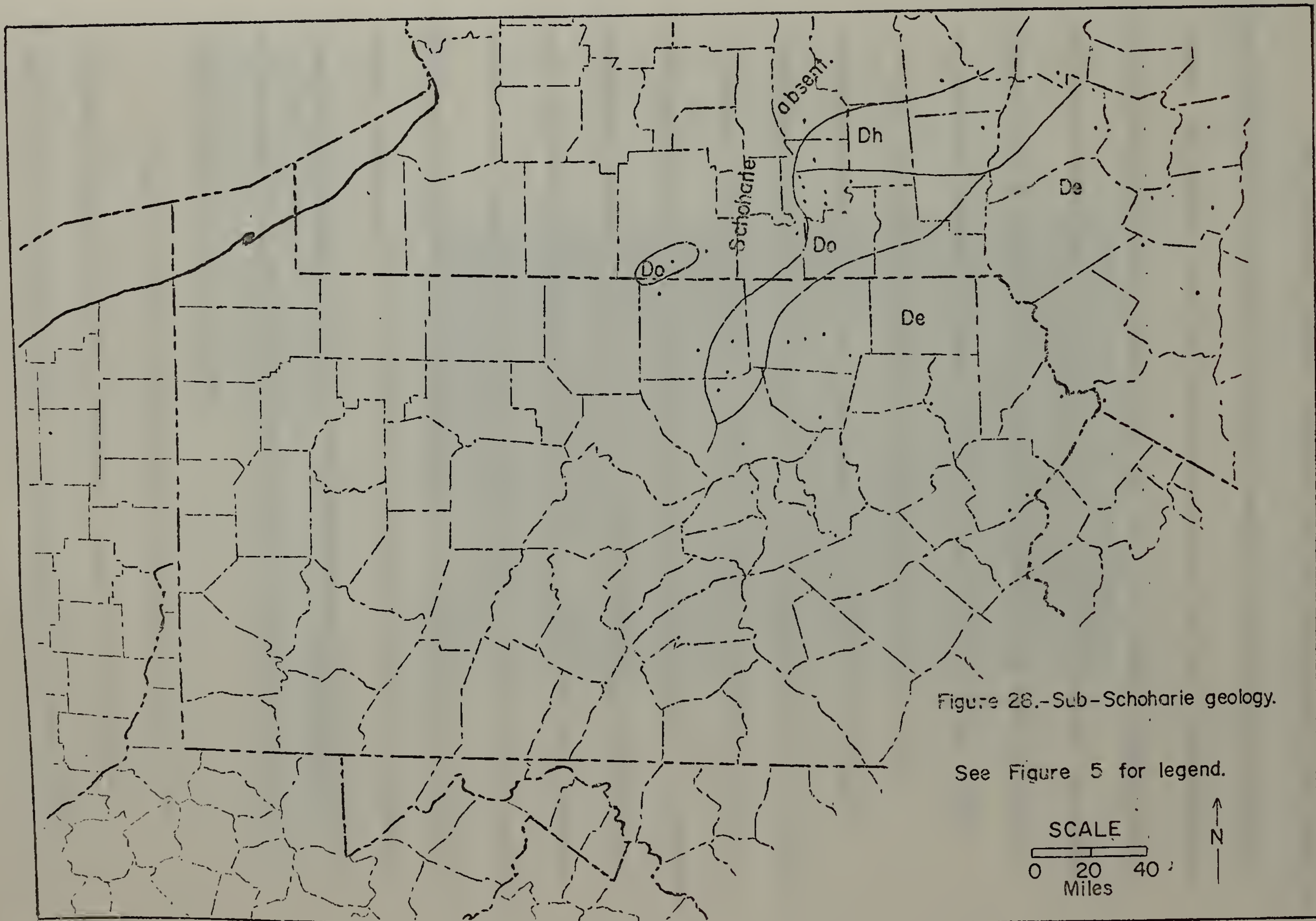


Figure 28.-Sub-Schoharie geology.

See Figure 5 for legend.

The Carlisle Center Member can be recognized at the base of the Schoharie Formation throughout eastern New York and adjacent areas. Its contact with the Esopus is abrupt and locally disconformable at and north of Kingston (Fig. 29, 30), but mostly gradational and conformable south of there (p. 37). Where the contact is abrupt, glauconite and quartz sand grains are present in the lowest beds of the Carlisle Center (Johnsen, 1957; Johnsen and Southard, 1962, p. A11). Although a gradational contact is presumed to exist throughout most of the area southwest of Kingston, the contact is clearly exposed only in Monroe Co., Pa. At Buttermilk Falls, about 2.3 miles south of Marshalls Creek (P7) and on Brodhead Creek, 0.4 mile west of Minisink Hills (P8), the lower Carlisle Center is characterized by distinct beds of yellowish gray-weathering, fossiliferous, very calcareous mudstone (Fig. 31). The contact with the Esopus is drawn at the base of the lowest of these beds. Johnsen (1957) reports that a persistent zone of Leptocoelia (i.e., Leptocoelina) acutiplicata marks the base of the Carlisle Center between Kingston and Experiment Mills (Brodhead Creek). The writer found Leptocoelina common in the upper 50 feet of the Esopus as well, though there may be a slight epibole near the contact.

The Schoharie (Carlisle Center) probably overlies the Oriskany Sandstone and/or Kalkberg Limestone at outcrops in Herkimer Co. (Johnsen, 1957). In the subsurface of south-central

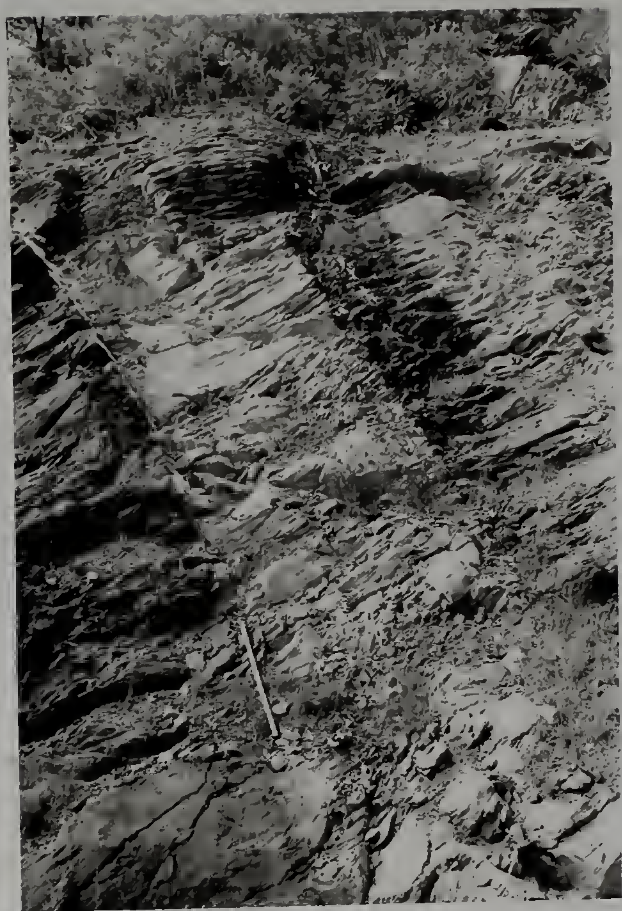


Figure 29.—Contact between the Schoharie Formation (Carlisle Center Member) (right of staff) and Esopus Formation, N.Y. Rte. 23, 0.25 mile south of Leeds, Greene Co., N.Y. (Y11). Persistent "black bed" occurs 7 feet above base of Carlisle Center.

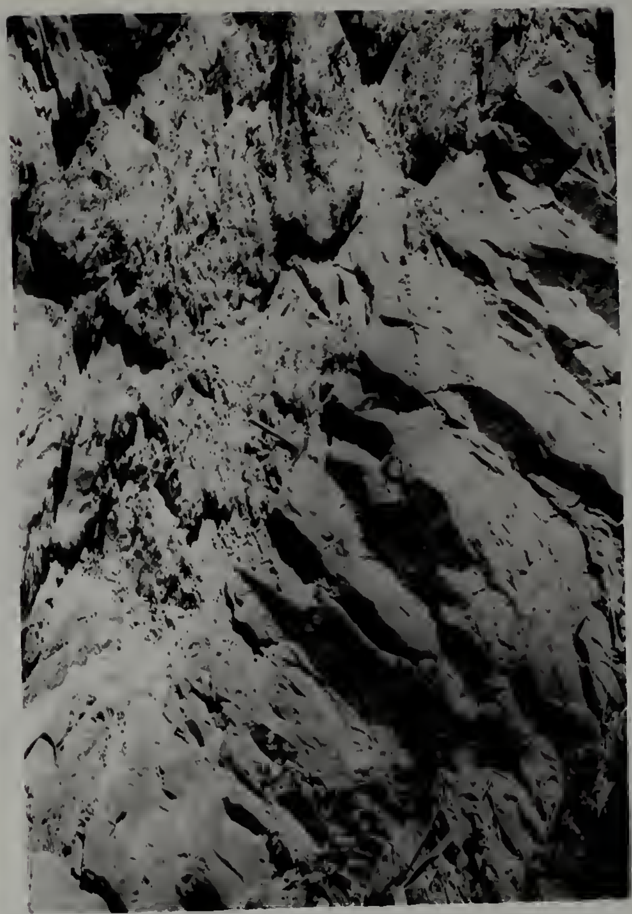


Figure 30.—Disconformable contact between Schoharie Formation (Carlisle Center Member) (left) and Esopus Formation, cut on Penn Central Railroad, 1.0 mile south of Kingston, Ulster Co., N.Y. (Y17). Hammer rests on sandy, glauconitic, calcareous siltstone at base of Carlisle Center (Unit 3). Both upper Esopus and lower Carlisle Center are crowded with Taonurus-markings.

Figure 31.—Contact of Schoharie Formation (Carlisle Center Member) (left) and Esopus Formation, along abandoned railroad grade on Brodhead Creek, 0.4 mile west of Minisink Hills, Monroe Co., Pa. (P8). Very limy mudstones in lower Carlisle Center weather yellowish gray and are recessed along weathered joint surface. Contact is drawn at base of lowest very limy mudstone.

New York and adjacent Pennsylvania, dark gray, glauconitic, cherty shale overlying the Oriskany Sandstone or Helderberg Limestone may represent the Carlisle Center. (See Fettke, 1961, pp. 309, 493, 552.)

The contact between the Schoharie Formation and the Onondaga Limestone is mostly disconformable west of Schoharie Co., N.Y. From Schoharie County southward to Monroe Co., Pa., it is probably conformable.

Along the western extremity of the Schoharie outcrop belt in Otsego and Herkimer counties, N.Y., the Carlisle Center Member usually occurs directly beneath the Onondaga (Oliver, 1956, p. 1446; Rickard and Zenger, 1964, p. 59). The contact is abrupt and disconformable. In an abandoned quarry, 0.2 mile north of Springfield Four Corners, Otsego Co., the top of the Carlisle Center is marked by a zone of phosphate nodules and glauconite (Oliver, 1956, p. 1446). On U.S. Rte. 20, 2.0 miles north of Cherry Valley (Y4), the Carlisle Center is abruptly overlain by thin-bedded, medium dark gray (N4), siliceous, highly fossiliferous limestone, 3 inches thick, which in turn is overlain by massive, medium light gray, cherty limestone typical of the Edgecliff Member of the Onondaga (Fig. 54). A sliver of Rickard Hill lithology may be present between the Edgecliff and Carlisle Center (Laskowski, 1956, p. 130), but it was not observed by the writer.

In the Helderberg Mountains and Schoharie Valley, where the Rickard Hill Member is developed, Rickard Hill ("Schoharie") and Onondaga lithologies are commonly interbedded at the top of the Schoharie (Ruedeman, 1930, pp. 60-61; Goldring and Flower, 1942, pp. 674-675). At other outcrops in the same area, however, as on Onesquethaw Creek (Y8) (Goldring, 1935, p. 137) and at Thompsons Lake (Y7), the Schoharie-Onondaga contact is abrupt.

Between the Helderbergs and Tristates, New York, the upper Schoharie is clearly gradational into the Onondaga. On N.Y. Rte. 23, south of Leeds (Y11), the upper 10 feet of the Saugerties Member consists of regular alternations of yellowish gray-weathering, calcareous mudstone and light gray-weathering crystalline limestone. The contact is delineated as the top of the highest yellowish gray-weathering mudstone bed (Fig. 32). On the Penn Central Railroad, 1.0 mile south of Kingston (Y17), the upper Saugerties is 9 feet of light gray-weathering, argillaceous, fossiliferous limestone with wavy, yellowish gray interbeds of calcareous mudstone (Fig. 33). At Trilobite Mountain, 1.0 mile north of Tristates (Y21), the upper 8 feet of the Schoharie (Saugerties-Aquetuck members, undivided) consists of highly cleaved, medium gray, fossiliferous, argillaceous limestone. At all three localities, the Schoharie is overlain by 3 or 4 feet of massive, medium gray to medium light gray, relatively chert-free Edgecliff limestone.

Figure 32.—Contact (marked by black line) between Schoharie Formation (Saugerties Member) (left) and Onondaga Limestone (Edgecliff Member), N.Y. Rte. 23, 0.25 mile south of Leeds, Greene Co., N.Y. (Y11). Contact is gradational through 10 feet of interbedded yellowish gray-weathering, argillaceous limestone and light gray-weathering crystalline limestone. Staff marks intense shear zone in Saugerties Member.

Figure 33.—Contact between Schoharie Formation (Saugerties Member) (below) and Onondaga Limestone (Edgecliff Member), cut on Penn Central Railroad, about 1.0 mile south of Kingston, Ulster Co., N.Y. (Y17). Upper 9 feet of Saugerties is replete with the coral Enterolasma. Chert, virtually absent in the lower 3 feet of the Edgecliff, is very abundant at the top of the exposure.

In Monroe Co., Pa., the upper Schoharie is dark gray, sandy, siliceous, calcareous siltstone with abundant large, vertical burrows. Its contact with the Onondaga is abrupt but not disconformable (Fig. 53).

In the subsurface, the Onondaga-Schoharie contact is probably disconformable in a belt that extends southwestward from Otsego and Herkimer counties to the Pennsylvania-New York border. In the Lobdell No. 1 well, Chenango Co., N.Y. (Y32), the Carlisle Center Member can be recognized as dark gray to very dark gray, calcareous shale, containing glauconite, with interbedded dark gray, argillaceous, porcelaneous chert, 13 feet thick, that occurs below light gray, cherty Onondaga Limestone. (See Fettke, 1961, p. 452.) In the Farkas No. 1 well, Thompkins Co., N.Y. (Y4), 60 miles to the southwest, 10 feet of dark gray, calcareous, glauconitic Carlisle Center shale underlies dark gray, shaly glauconitic limestone at the base of the Onondaga. (See Fettke, 1961, p. 552.)

In the basin south and southeast of the marginal area described above, the Onondaga-Schoharie contact is gradational and conformable. In the Richards No. 1 well, Lackawanna Co., Pa. (P68), the upper Schoharie is medium dark gray to dark gray, limy, pyritic shale (mudstone); whereas the lower Onondaga is medium grained, silty, fine grained limestone. (See Kehn, Glick, and Culbertson, 1966, pp. 76-77.) The contact is also clearly conformable in the Hettick No. 1 well, Bradford Co. (P75) (Fettke, 1961, p. 362).

Distribution and Thickness

The areal distribution and thickness of the Schoharie Formation and its major subdivisions are shown in Fig. 34-36. The Schoharie is best developed in eastern New York and immediately adjacent New Jersey and Pennsylvania. No outcrops are known west of Herkimer Co., N.Y., and Schuylkill Co., Pa., but in the subsurface the Schoharie extends far to the west, perhaps to Steuben Co., N.Y.

The Schoharie Formation attains its greatest thickness in an east-west trending, subsurface depositional basin located in Pike, Wayne, and Lackawanna counties, Pa. In the Richards No. 1 well, Lackawanna Co. (P68), near the axis of the basin, about 280 feet are assigned to the Schoharie, 150 feet of which belongs to the Carlisle Center and 130 feet to the Saugerties-Aquetuck. To the east the Schoharie thins to about 200 feet at Trilobite Mountain, Orange Co., N.Y. (Y21) (Johnsen and Southard, 1962, pp. A19-A20). The Carlisle Center Member is about 175 feet thick at Trilobite Mountain, its maximum known thickness. Even farther east along the basin axis, the Carlisle Center Member (represented by the Woodbury Creek Member of the Esopus Formation) is about 120 feet thick at Highland

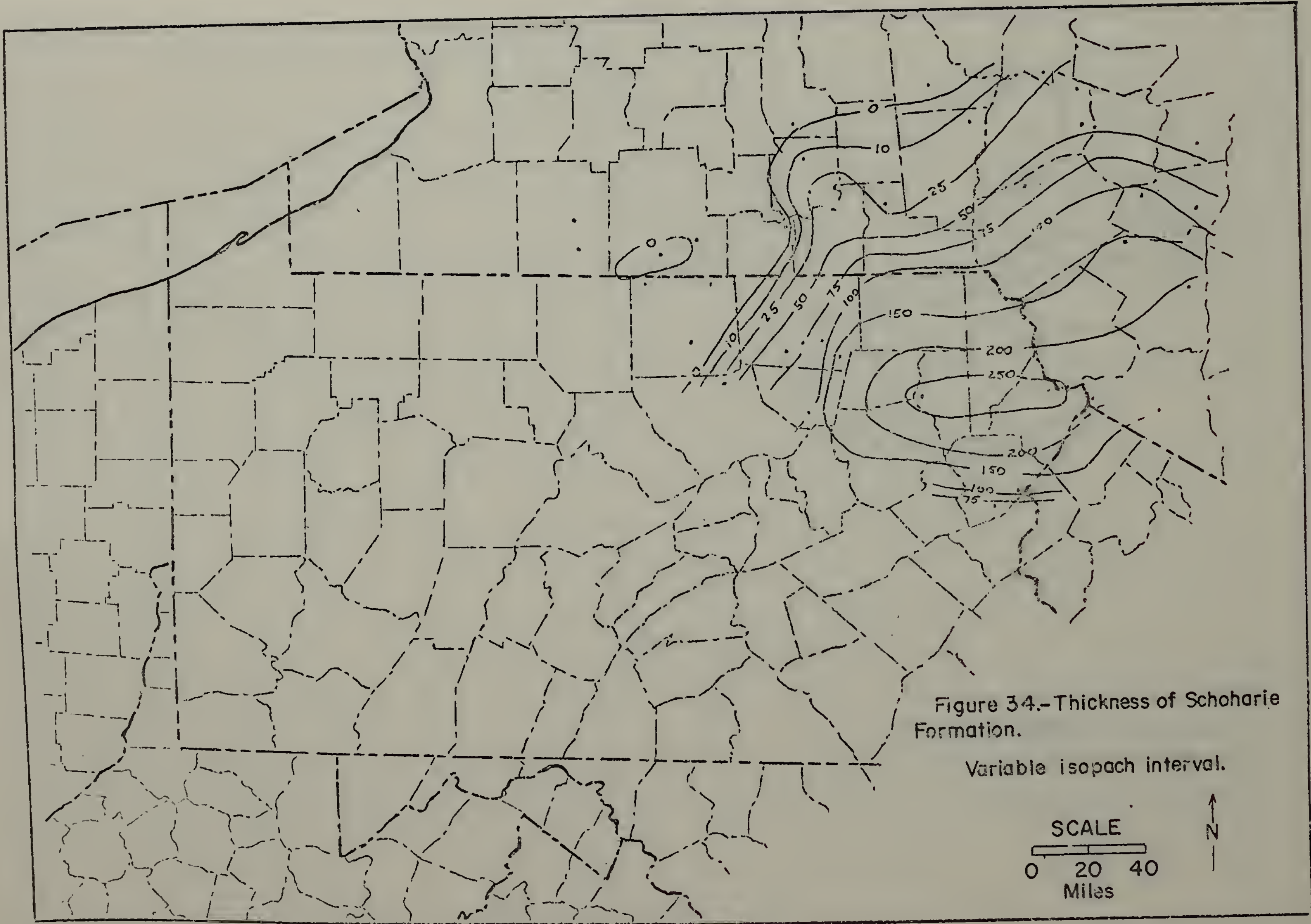


Figure 34.-Thickness of Schoharie Formation.

Variable isopach interval.

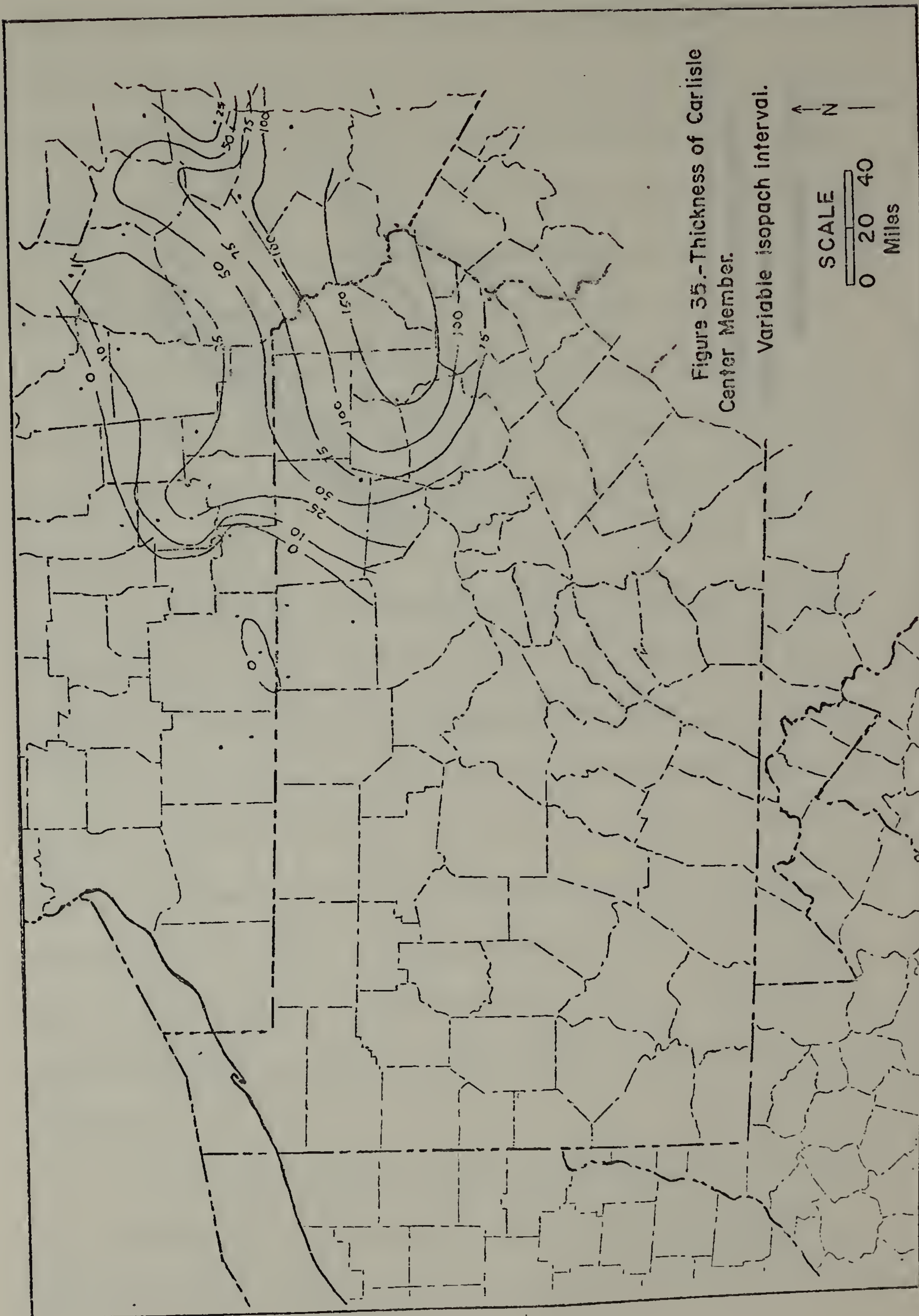


Figure 35.-Thickness of Carlisle Center Member.
Variable isopach interval.

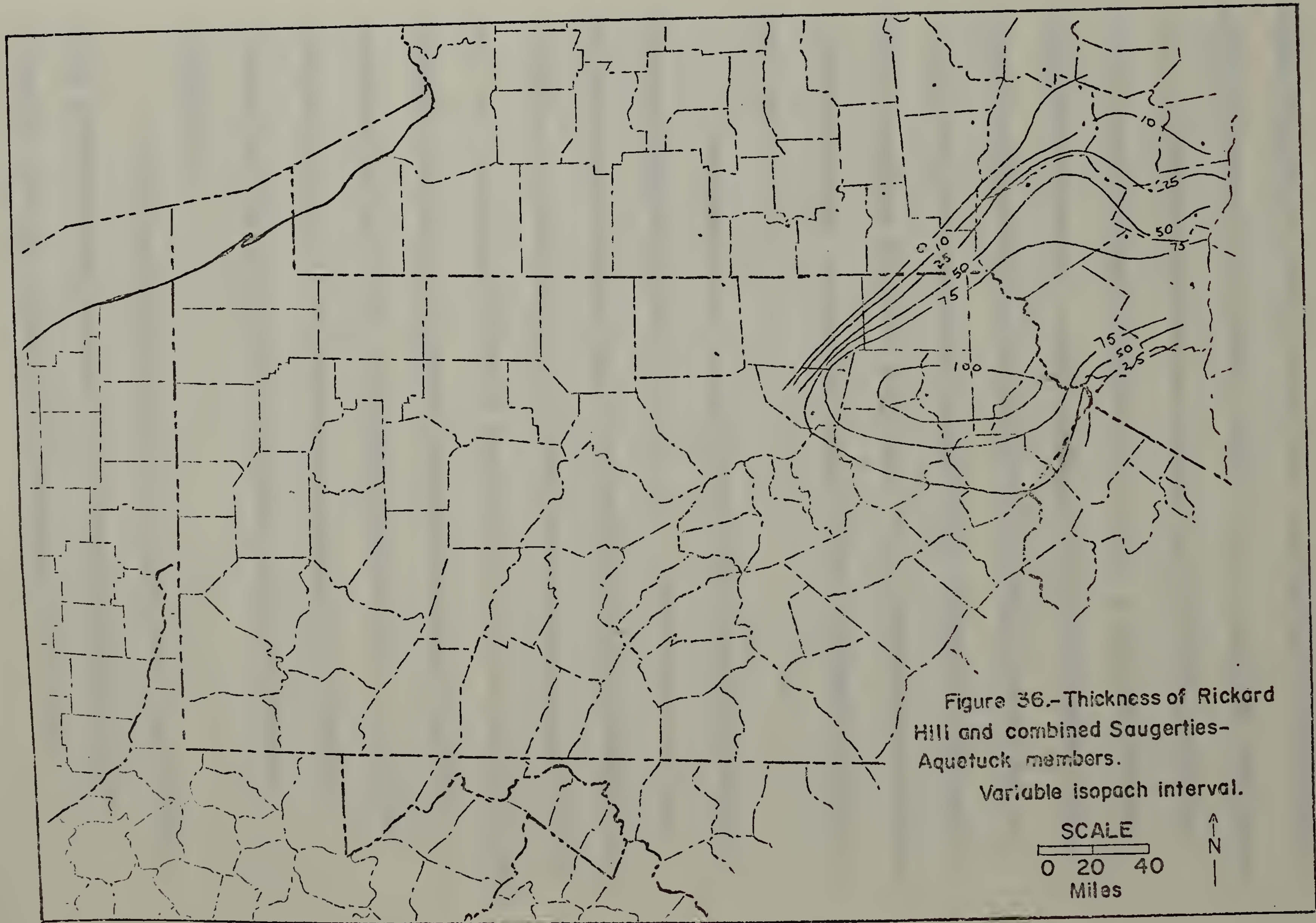


Figure 36.–Thickness of Rickard Hill and combined Saugerties-Aquetuck members. Variable isopach interval.

Mills, Orange Co. (Y25), in the Green Pond-Schunemunk Mountain outlier (Johnsen and Southard, 1962, p. A14). Decrease in thickness of the Schoharie Formation due west of the Richards No. 1 well is accompanied by gradual change into the lower shaly portion of the Needmore Formation. To the northwest the upper Schoharie is cut out by a disconformity at the base of the Onondaga Limestone, and, consequently, the Saugerties-Aquetuck beds extend only into southeastern Bradford Co., Pa. (Fig. 36). The Carlisle Center Member, on the other hand, is probably present as far as southern Tioga Co. (Fig. 35).

The Schohar ie Formation thins rather abruptly to the south and southwest of the basin axis (Fig. 34). The formation is about 180 feet thick at Walpack Center, Sussex Co., N.J. (Johnsen, 1957, p. 90) and 120 feet thick in the vicinity of the Stroudsburgs, Monroe Co., Pa. At Buttermilk Falls, Monroe Co. (P7), the Carlisle Center Member is 68 feet thick and the Saugerties-Aquetuck members, undivided, 52 feet thick. In southwestern Monroe Co. the typical Schoharie calcareous mudstones and siltstones grade into the Schoharie-Esopus formations, undivided, and the Palmerton Sandstone.

To the northeast and north of its depocenter, the Schoharie thins gradually along the Neversink-Hudson Valley outcrop belt (Johnsen, 1957, p. 73) and in the subsurface of the Catskill

Mountain-Allegheny Plateau region. At Kingston (Y17) the Schoharie is about 217 feet thick, and at Leeds (Y11), about 84 feet thick. Between these two points, the Carlisle Center Member decreases from 131 feet to 23 feet in thickness, while the combined thickness of the Aquetuck and Saugerties members declines from 86 to 61 feet. In the subsurface to the west, the Schoharie is truncated by the disconformity at the base of the Onondaga. Although the Saugerties-Aquetuck can be recognized only as far west as Chenango and Broome counties, N.Y., the Carlisle Center reaches at least into Tompkins and Tioga counties and may even occur as an erosional outlier in the Roy W. Herrington No. 1 well, Steuben Co., N.Y. (Y50). (See Fettke, 1961, p. 493.)

Along the outcrop belt north of Leeds, abrupt northward decrease in thickness of the Schoharie Formation is associated with change in the upper Schoharie from the Leeds facies (Aquetuck and Saugerties members) into the much thinner "Schoharie grit" facies (Rickard Hill Member) (Goldring and Flower, 1942, pp. 681-683; Johnsen, 1957, pp. 44-46). From the Helderbergs, Albany Co., westward to Cherry Valley, Otsego Co. (Y4), the formation maintains a thickness of about 25 to 40 feet. The Rickard Hill Member ranges in thickness from a thin sliver at its western pinch-out near East Springfield, Otsego Co., to 5 or 6 feet in Schoharie and Albany counties (Johnsen and Southard, 1962, p. A8). The Carlisle Center

Member is about 30 feet thick at Onesquethaw Creek (Y8), about 25 feet thick at John Boyd Thacher Park, 42 feet thick at Cherry Valley (Y4), and 20 feet thick in the Skramko No. 1 well, Herkimer Co. (Y30), just south of the outcrop belt. Pre-Onondaga erosion has completely removed the Carlisle Center west of the Skramko well.

Fauna and Age

The Schoharie Formation contains a rich and diversified marine fauna. Fossils are especially abundant in the Rickard Hill Member (Schoharie Valley and Helderberg regions), the Saugerties Member (mid-Hudson Valley), and in the upper part of the Saugerties-Aquetuck members, undivided (southeastern New York). Generally the Carlisle Center and Aquetuck members are conspicuously less fossiliferous than the upper beds, although in eastern Pennsylvania this distinction between the several members of the Schoharie becomes blurred.

The fauna listed in Table 3 includes only species collected from Schoharie outcrops between Leeds, N.Y. (Y11) and Foxtown Gap, Monroe Co., Pa. (P14). More complete information concerning Schoharie fossils can be obtained in Prosser and Rowe (1899), Grabau (1906), Goldring and Flower (1942), and Johnsen (1957).

In Otsego, Schoharie, and Albany counties, N.Y., the Carlisle Center Member is crowded with the enigmatic *Taonurus*

TABLE 3

FAUNA OF THE SCHOHARIE FORMATION (CARLISLE CENTER, AQUETUCK, AND SAUGERTIES MEMBERS ONLY), EASTERN NEW YORK AND NORTHEASTERN PENNSYLVANIA

(1 = Carlisle Center Member, N.Y.; 2 = Aquetuck and Saugerties members, N.Y.; 3 = Carlisle Center Member, Pa.; 4 = Saugerties-Aquetuck members, undivided, Pa.)

Fauna	1	2	3	4
Coelenterata				
Unidentified favositids		x		
Enterolasma sp.		x		
Heterophrentis sp.		x		
Brachiopoda				
Lingula sp.				x
Eodevonaria arcuata (Hall)		x	x	x
Atrypa reticularis (Linnaeus)		x		
Coelospira camilla Hall	x			
Leptocoelina acutiplicata (Conrad)	x		x	
Acrospirifer duodenaria (Hall)		x		x
Mucrospirifer macra (Hall)		x		
Gastropoda				
Platyceras (*Platystoma*) sp.		x		
Trilobita				
Anchiopella anchiops (Green)		x		x
Phacops sp.		x		
Incertae sedis				
Taonurus caudagalli (Vanuxem)	x		x	

caudagalli (Fig. 37), but is apparently nearly destitute of shelly fossils. Between Greene Co., N.Y., and Monroe Co., Pa., Taonurus-markings are nearly as profuse as in the type area, and the member also contains a limited brachiopod fauna. The most characteristic species are Leptocoelina acutiplicata and the morphologically similar Coelospira camilla. Acrospirifer duodenaria and Eodevonaria arcuata are known only from Monroe Co., Pa. (P7,P8), but may also occur further north.[6]

Unquestionably the Rickard Hill Member (the type Schoharie "grit") is one of the most profusely fossiliferous units in the entire Appalachian Basin. Some idea of the great faunal richness and diversity in these beds is given by the fact that Grabau (1906, pp. 325-327) notes 2 species of bryozoans, 33 of brachiopods, 14 of bivalves, 12 of gastropods, 43 of cephalopods, 16 of trilobites, and 2 of cricolonarids—123 species in all. The most striking aspect of the Rickard Hill fauna is the abundance of cephalopods, mostly straight-shelled orthocerids, but also including curved and coiled forms. Especially characteristic are Michelinoceras pelops and M. luxum, the latter being most common (Grabau, 1906, p. 188). Brachiopods, including Leptostrophia perplana, Pentamerella arata, Meristina

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[6]Shimer (1905) and Goldring and Flower (1942, p. 688) report several other species (mostly brachiopods) from beds presumably equivalent to the Carlisle Center at Trilobite Mountain, Orange Co., N.Y. (Y21).

Figure 37.—Taonurus caudagalli in block of Carlisle Center siltstone (Schoharie Formation), Roadside Rest on U.S. Rte. 20, 2.0 miles north-northeast of Cherry Valley, Otsego Co., N.Y. Rock was presumably removed from nearby cut during road construction.

nasuta, Acrospirifer duodenaria, and Amphigenia elongata, are well represented, as are trilobites (Anchiopella anchiops, Phacops cristata, etc.). Bivalves include Praecardium dichotoma, Goniophora perangulata, and Conocardium cuneus, among others. The most common gastropods are Pleurotomaria arata, Bellerophon curvilineatus, and B. pelops (Grabau, 1906, pp. 183, 186).

The Aquetuck and Saugerties members, especially the latter, contain a fauna of moderate abundance and variety, in which the brachiopods Eodevonaria arcuata, Atrypa reticularis, and Acrospirifer duodenaria and the Trilobite Anchiopella anchiops, are most characteristic (Table 3). Locally other fossils are very abundant, as at Kingston, N.Y. (Y17), where the upper 9 feet of the Saugerties Member is replete with the diminutive rugose coral Enterolasma sp. Cephalopods are present, albeit rare, only in northern Greene Co., N.Y., the area of facies change into the Rickard Hill Member (Goldring and Flower, 1942, pp. 685-686). Vertical burrows in the Saugerties-Aquetuck members, undivided, in Monroe Co., Pa., indicate the local abundance of many soft-bodied, probably worm-like organisms.

The brachiopod fauna of the Woodbury Creek Member (Esopus Formation) and Kanouse Sandstone in the Green Pond-Schunemunk Mountain outlier, Orange Co., N.Y., is listed in Table 4. Johnsen and Southard (1962, p. A14) have shown that the lower part of the

TABLE 4

BRACHIOPOD FAUNA OF THE WOODBURY CREEK MEMBER (ESOPUS FORMATION) AND KANOUSE SANDSTONE IN THE GREEN POND-SCHUNEMUNK MOUNTAIN OUTLIER

(1 = Woodbury Creek Member; 2 = Kanouse Sandstone)

(Boucot, 1959, pp. 734-735)

Fauna	1	2
Rhipidomelloides musculosa (Hall)		x
Platyorthis planoconvexi (Hall)		x
Leptaena rhomboidalis (Wilckens)	x	x
Strophodonta (Strophodonta) demissa (Conrad)		x
Megastrophia hemispherica (Hall)		x
Protoleptostrophia sp.		x
Schuchertella sp.	x	x
Anoplia nucleata (Hall)	x	
Eodevonaria arcuata (Hall)	x	x
Chonostrophia sp.	x	
Camarotochia (?) sp.		x
Atrypa reticularis (Linnaeus)		x
Meristina nasuta (Conrad)		x
Pentagonia unisulcata (Conrad)	x	
Cyrtina rostrata (Hall)	x	
Hysterolites macrothyris (Hall)		x
Hysterolites sp.	x	
Mucrospirifer macra (Hall)	x	x
Elita fimbriata (Conrad)	x	x
Centronella sp.		x
Amphigenia elongata (Vanuxem)	x	x
Etymothyris sp.	x	
"Prionothyris" sp.		x

Woodbury Creek and the lower part of the Carlisle Center are facies equivalents. The upper Woodbury Creek Member and Kanouse Sandstone are roughly contemporaneous with the combined Aquetuck-Saugerties members of the main outcrop belt. (See Boucot, 1959, pp. 734-737; 1968, p. B3).

The Schoharie Formation is Emsian (upper Lower Devonian in age) (Rickard, 1964; Oliver and others, 1969).

Onondaga Limestone

Definition and Reference Section

The Onondaga Limestone is part of a great blanket of lower Middle Devonian calcareous rocks that extends from eastern New York and Pennsylvania westward into the Mid-Continent region. It is named for exposures of massive, cherty, fossiliferous limestone in Onondaga County, N.Y. (Hall, 1839, p. 309). As originally defined, only the lower portion of the Onondaga of present usage was included, the upper portion being variously known as the "Corniferous" or "Seneca" limestone. Later Hall (1851) originated the term "Upper Helderberg" to apply to the entire limestone unit. Early in this century, Onondaga Limestone replaced "Upper Helderberg" as the recognized designation for these rocks in New York.

In Pennsylvania the Onondaga Limestone has experienced similar nomenclatural vicissitudes. It was the "Post-Meridian limestone" of Rogers (1858), the "Corniferous limestone" of White (1882) and Lesley (1892), and the "upper member, cherty limestone of the Onondaga Formation" of Willard (1935). More recently, Willard (1938, p. 14) proposed the name Buttermilk Falls limestone for dark gray, cherty limestone that crops out at Buttermilk Falls on Marshalls Creek, Monroe Co. (P7). Since the cherty limestone that is exposed at Buttermilk Falls can be traced continuously northeastward through New Jersey into the lithologically-similar Onondaga Limestone that crops out at Tristates Point, Orange Co., N.Y. (Y22), a separate name for these rocks in Pennsylvania is unnecessary.

Oliver (1954, 1956) has described the following four members in the Onondaga Limestone in eastern and central New York (in descending order):

Seneca Limestone (with Tioga Metabentonite at base)
Moorehouse Member
Nedrow Member
Edgecliff Member

The Edgecliff Member, the Onondaga limestone of early reports, was named by Oliver (1954, pp. 626-627) from exposures at Edgecliff Park, southwest of Syracuse, 1.0 mile northeast of Howlett Hill and 2.0 miles southeast of Camillus, Onondaga Co., N.Y. The type locality of the Nedrow Member is in the Indian Reservation Quarry, 1.2 miles south of Nedrow, between Quarry Road and Interstate Rte. 81-U.S. Rte. 11, Onondaga Co. (Oliver, 1954, p. 627). The Moorehouse Member was named from exposures on the southwest extremity of Moorehouse Flats at the Onondaga County Prison Quarry, 0.5 mile south of the County Penitentiary at Jamesville, Onondaga Co. (Oliver, 1954, p. 628). The "Seneca limestone" was originally described by Vanuxem (1840, p. 377; 1842, p. 144) from exposures in Seneca Co., N.Y. The Seneca Member, as defined by Oliver (1954, p. 629), includes essentially the same strata as the "Seneca limestone" of Vanuxem. Only the Edgecliff and Moorehouse members have been recognized in the vicinity of Tristates, Orange Co., N.Y. (Oliver, 1956).

In Monroe Co., Pa., the Onondaga can be conveniently divided into four distinct and laterally persistent members. These are, in descending order:

Member D (Echo Lake Member)
Member C with metabentonite in upper part
Member B
Member A (Edgecliff Member)

The Echo Lake Member is named for an exposure of the upper Onondaga on U.S. Rte. 209, 1.3 miles northeast of Echo Lake, Middle Smithfield Township, Monroe Co.[7]

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[7]Epstein (1970) has subdivided the Buttermilk Falls Limestone of the Stroudsburg area into the Foxtown, McMichael, and Stroudsburg members (in ascending order). These three members correspond exactly to Member A, Member B, and combined members C and D, respectively, of the present report.

A complete exposure of the Onondaga Limestone in a cut on the Delaware, Lackawanna and Western Railroad, 0.5 mile south of the railroad station, East Stroudsburg, Monroe Co. (P11), is herein designated a reference section for the formation in eastern Pennsylvania.

Lithology

In its typical development the Onondaga Limestone is a massive, fine to medium grained, generally bioclastic limestone, replete with nodules of light gray to black chert. It is the presence of chert (or "hornstone") which gave rise to the name "corniferous" of early reports. The Onondaga contains numerous other lithologies, including non-cherty limestone, argillaceous limestone, and calcareous shale. The most striking feature of the formation in New York State is the occurrence of coral patch reefs in the Edgecliff Member. Along the outcrop belt, reefs are exposed between Buffalo, Erie Co., and Leroy, Genesee Co., in western New York (Grabau, 1924, pp, 424-426; Oliver, 1966, pp. 38-39) and between Richfield Springs, Otsego Co., and Coxsackie, Greene Co., in the eastern part of the state (Oliver, 1956b). Similar coral reefs, some of which serve as traps for commercial quantities of natural gas (pp. 301-305), have recently been discovered in the subsurface of Steuben Co., south-central New York (Kelley and others, 1970, pp. 59-60).

Oliver's New York Members are defined partly on the basis of lithology and partly on faunal criteria (Oliver, 1954; 1956 a; 1962). Since they are described on the basis of exposures in central New York, differentiation of the various members is sometimes difficult in eastern areas.

The Edgecliff Member, consists mostly of massive to thick bedded, medium to coarse grained, medium light gray (N6), bioclastic limestone, with nodular masses of medium light gray (N6) to medium gray (N5) chert (Fig. 33). Large crinoid columnals are characteristic of the Edgecliff throughout eastern and southeastern New York. The coral reefs are composed of massive, light gray (N7), coralline biolithite, with a matrix of fossiliferous calcilulite. Adjacent reef flank deposits consist of thick bedded, coarse grained, light gray bioclastic limestone (biocalcirudite) (Fig. 38).

The Nedrow Member is shaly to massive, fine grained, light gray (N7), argillaceous limestone in central New York (Oliver, 1954) and medium to thick bedded, medium to coarse grained, medium light gray (N6) limestone, with nodules of light brownish gray (5YR 6/1) chert in eastern New York.[8] A distinctive feature of the Nedrow

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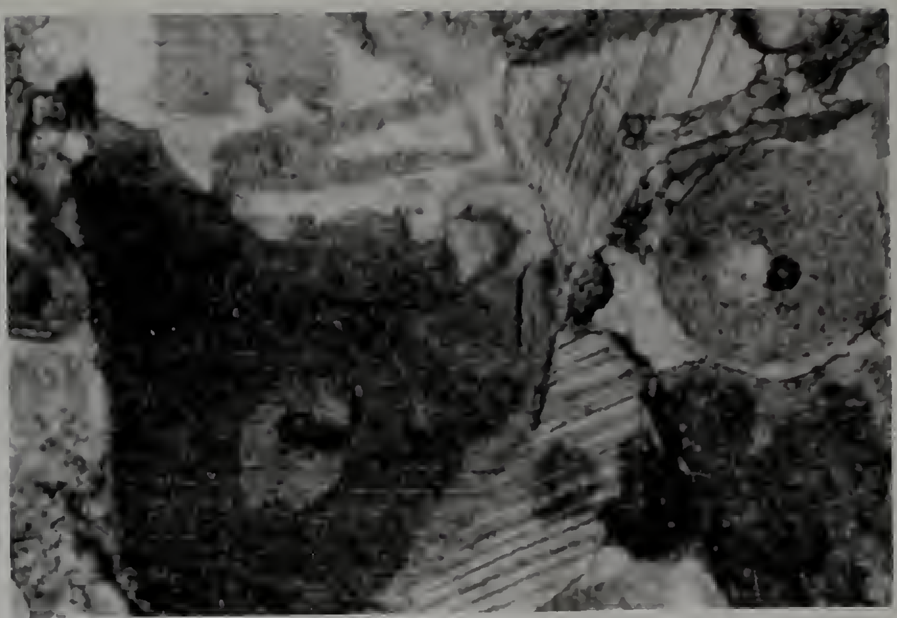
[8] In western New York, the Nedrow Member, as well as the upper Edgecliff and lower Moorehouse members, are replaced by the Clarence Member of Ozol (1963), which is comprised of fine grained limestone, with copious black chert (Oliver, 1966, pp. 39-40).



1.0 mm.

Figure 38.—Photomicrograph of moderately well sorted, sparry, crinoidal biocalcirudite, Onondaga Limestone (Edgecliff Member), Hannacroix, Greene Co., N.Y. (Y9). Note calcite overgrowths in optical continuity with crinoid plates. Specimen is from the flank of the Roberts Hill Reef. (Polarized light.)

Member in both areas is the presence of abundant platycerid gastropods (Oliver, 1956a, pp. 1453-1454).

The Moorehouse Member is composed of thick bedded, fine grained, medium gray (N5) cherty limestone, containing nodules of black (N1) chert, especially in the upper half (Oliver, 1956a, pp. 1458-1459) (central N.Y.) and medium to thick bedded, medium grained, medium gray (N5), highly fossiliferous limestone (biocalcisiltite to biocalcirudite) (Fig. 39), with nodular, dark gray (N3) chert in the upper part (eastern N.Y.).

The Seneca Member is thick bedded, fine to medium grained, medium dark gray (N4), somewhat cherty, fossiliferous limestone (Oliver, 1956a, p. 1466; 1962, p. 43). East of Cherry Valley, Otsego Co., the Seneca grades into the Union Springs black shale (Marcellus Formation) and can no longer be recognized.

In southeastern New York and adjacent New Jersey, the Edgecliff and Moorehouse members become darker and finer grained as they grade into the "Buttermilk Falls" lithology of eastern Pennsylvania (Oliver, 1962, p. A5).

At outcrops in Monroe Co., Pa., the Onondaga Limestone is predominantly a massive, fine to medium grained, fossiliferous, very cherty limestone (biocalcisiltite and biocalcilutite) (members A and C), with calcareous shale (Member B) near the middle and

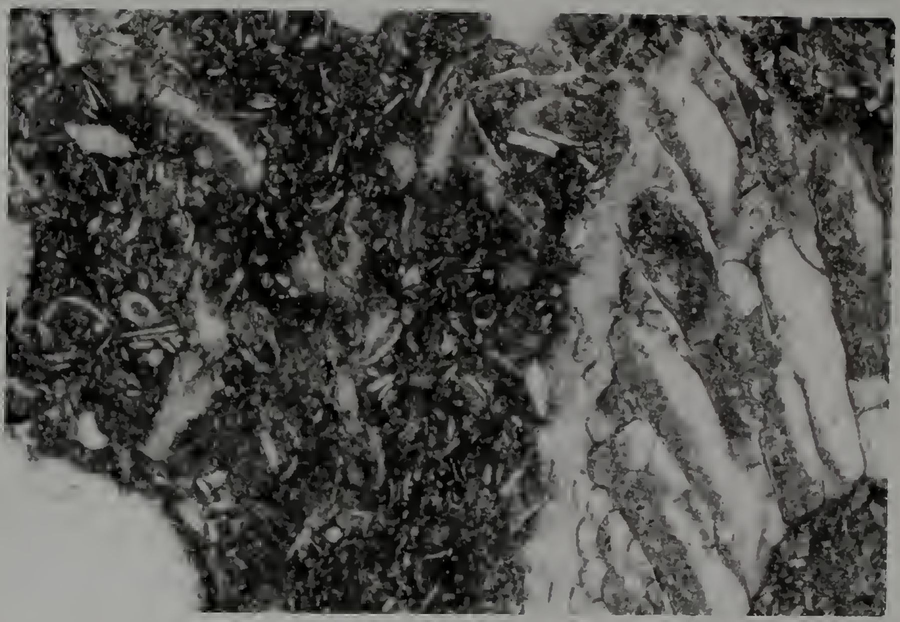


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Figure 39.—Photomicrograph of poorly sorted, intensely burrowed biocalcisiltite, Onondaga Limestone (Moorehouse Member), Saugerties, Ulster Co., N.Y. (Y15-Z). Note bryozoan colony with geopetal structure which indicates top to upper right. Fragmented fossils are trilobites, styliolines, bryozoans, and corals. (Plane light.)

coquinitic limestone (biocalcirudite) at the top (Member D, Echo Lake Member) (Fig. 40). These lithologic subdivisions have not been recognized in the subsurface of northeastern Pennsylvania, where the Onondaga is represented by argillaceous limestone and calcareous shale containing little or no chert (Fletcher and Woodrow, 1970, p. 5; Kehn, Glick, and Culbertson, 1966, p. 76; Fettke, 1960, p. 362).

Member A (Edgecliff Member)

Member A consists of medium to thick bedded, fine to medium grained, medium gray (N5), light gray (N7) weathering, fossiliferous, cherty limestone. The chert is grayish black (N2), slightly calcareous, and occurs in nodules up to 6 inches in diameter. The lower 50 feet of the member contains the large crinoid columnals (up to 1-1/2 inches in diameter) that characterize the Edgecliff Member in New York (Fig. 41).

In thin section the limestones of Member A are seen to be composed of abundant, fragmented fossil debris in a fine grained, siliceous calcisiltite matrix (Fig. 42). Fossil fragments include bryozoans, crinoids, brachiopods, and trilobites. The matrix is composed of silt- and clay-size carbonate grains (in part comminuted fossils), less than 0.01 mm. in diameter and partially recrystallized. Extensive bioturbation is evident, and texturally the limestones of Member A are mud-supported and immature. Chert, which is

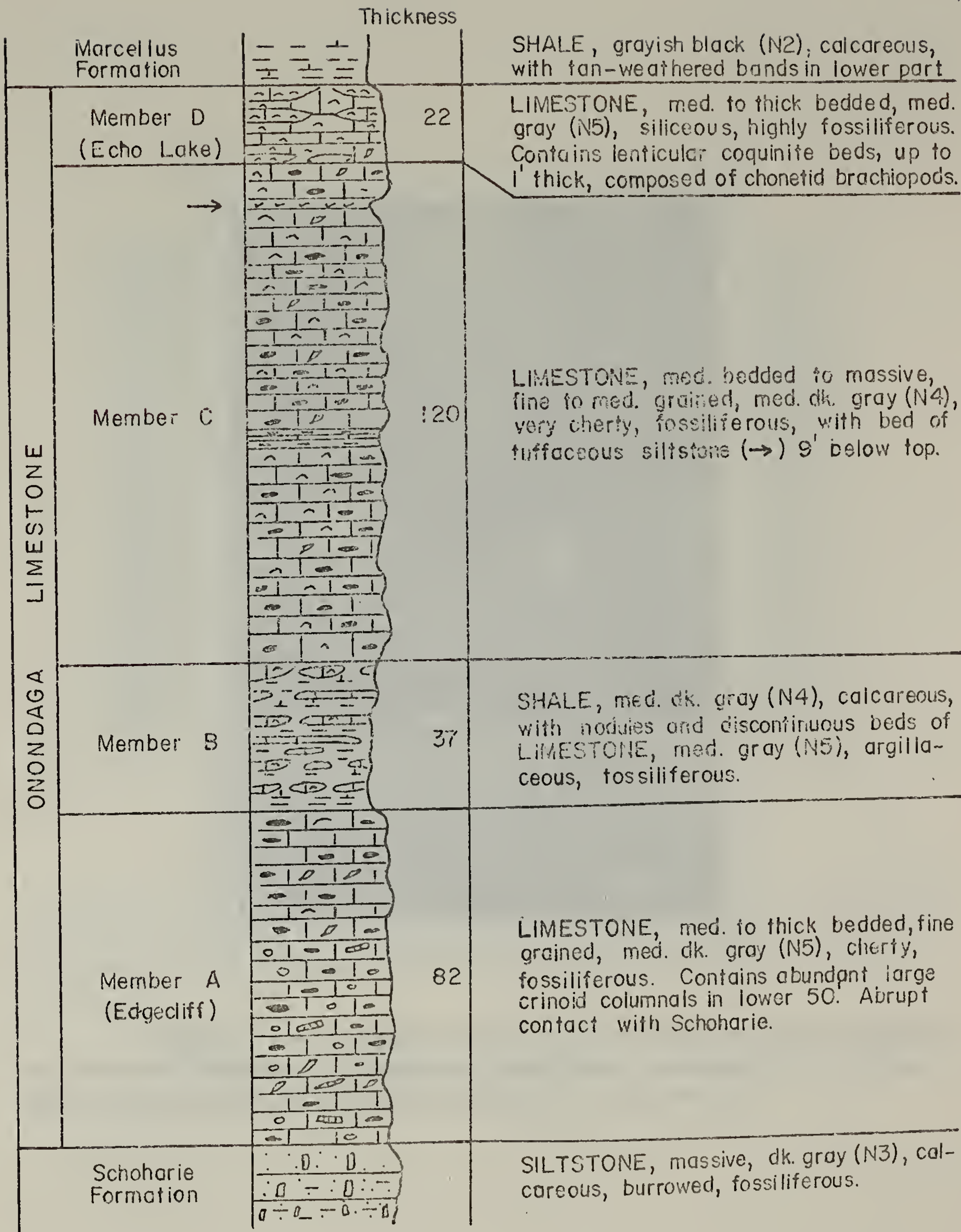


Figure 40.—Generalized composite section of the Onondaga Limestone in Monroe Co., Pa.

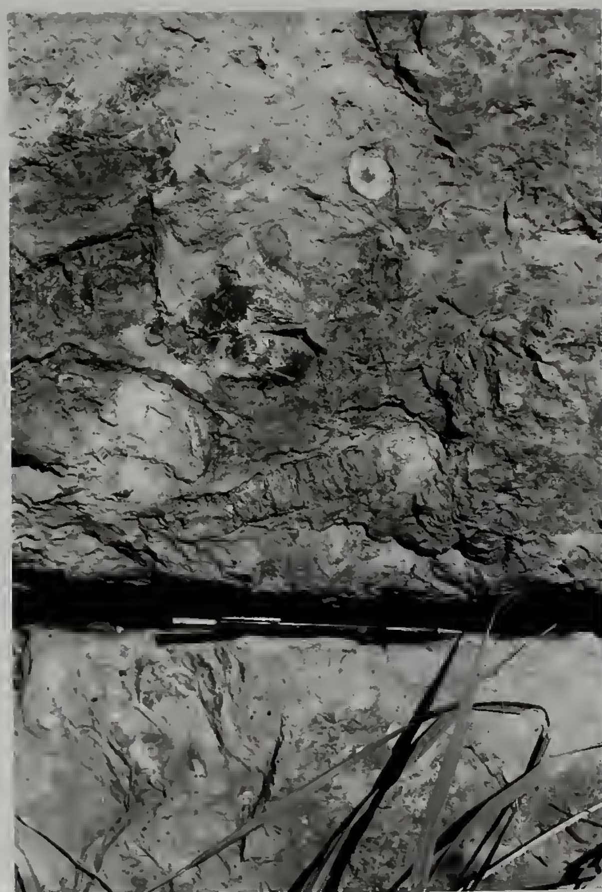
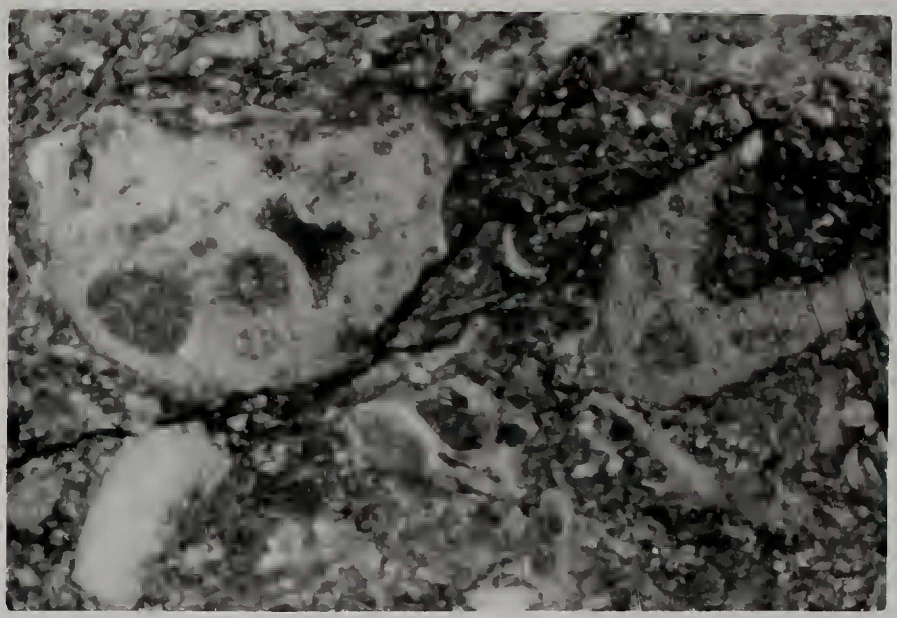


Figure 41.—Large crinoid columns in lower part of Member A (Edgecliff Member), Onondaga Limestone, west side of U.S. Rte. 209, near Buttermilk Falls, Monroe Co., Pa. (P7-9).



1.0 mm.

Figure 42.—Photomicrograph of poorly sorted, burrowed, crinoidal biocalcirudite, Onondaga Limestone (Member A, Edgecliff Member), East Stroudsburg, Monroe Co., Pa. (P11-1). Abundant crinoidal debris occurs in a siliceous calcisiltite matrix. (Plane light.)

equigranular-cryptocrystalline, rims and partially replaces numerous fossil fragments, and also occurs as large patches (parts of nodules) in the matrix. Numerous tiny, rhomb-shaped dolomite (?) crystals (up to 0.06 mm. in diameter) float in the large silicified areas.

Insoluble residues derived from the Member A limestones consist of medium gray (N5) to light gray (N7) siliceous aggregates.

Member B

Member B consists of medium dark gray (N4), highly cleaved, calcareous shale, in beds 3 to 12 inches thick, with nodules and discontinuous beds (2 to 12 inches thick) of fine grained, medium gray (N5), fossiliferous, argillaceous limestone (biocalcilutite and biocalcisiltite) (Fig. 43). Chert is conspicuously absent. This portion of the eastern Pennsylvania Onondaga strongly resembles the Nedrow Member of central New York, of which it is a close facies and possible time equivalent.

Member C

Member C is composed of thick bedded to massive, fine to medium grained, medium gray (N5) to medium dark gray (N4), medium light gray (N6) weathering, very cherty limestone (Fig. 44). Grayish black (N2), calcareous chert occurs in discontinuous lenses and nodules up to 12 inches thick. Near the top of Member C is a

Figure 43.—Highly cleaved, calcareous shale and nodular, argillaceous limestone of Member B, Onondaga Limestone, east side of railroad cut, East Stroudsburg, Monroe Co., Pa. (P11-3). Attitude of bedding is about N 60° E/68° SE (overturned) and of cleavage, about N 60° E/50° SE.

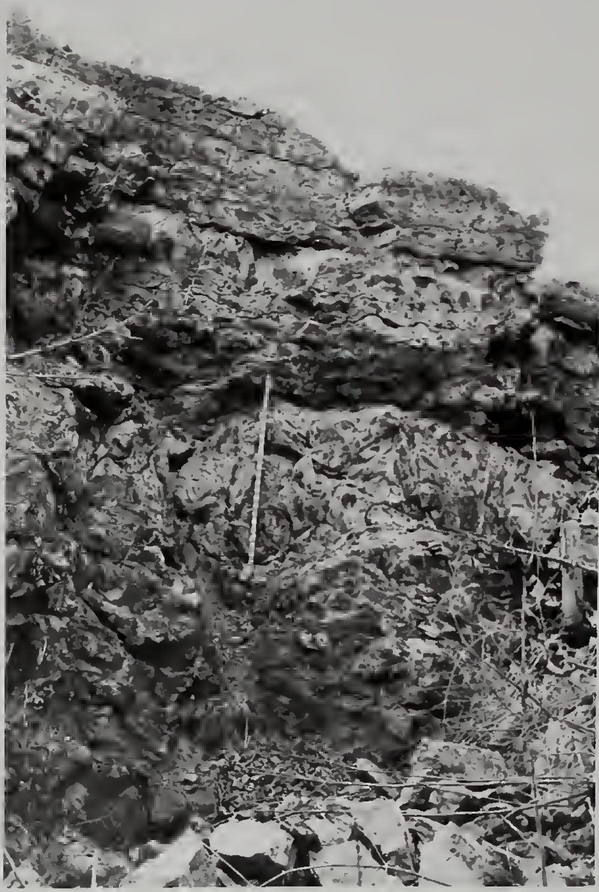
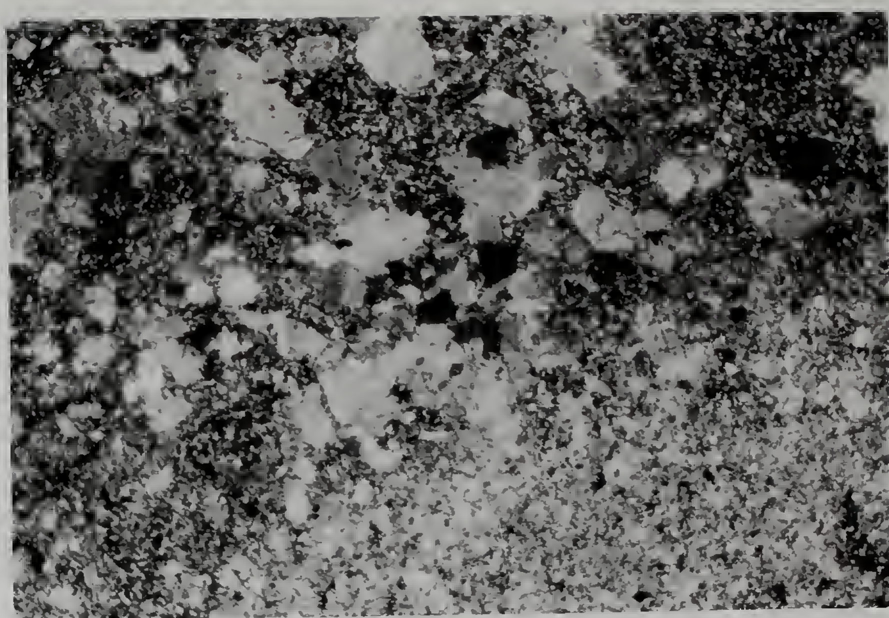


Figure 44.—Massive, cherty limestone of Member C, Onondaga Limestone, in abandoned quarry on U.S. 209, 1.1 miles northeast of Echo Lake, Monroe Co., Pa. (P1-12). Note dark, irregular masses of chert. Lower part of Echo Lake coquinite (Member D) at top (Unit 13).

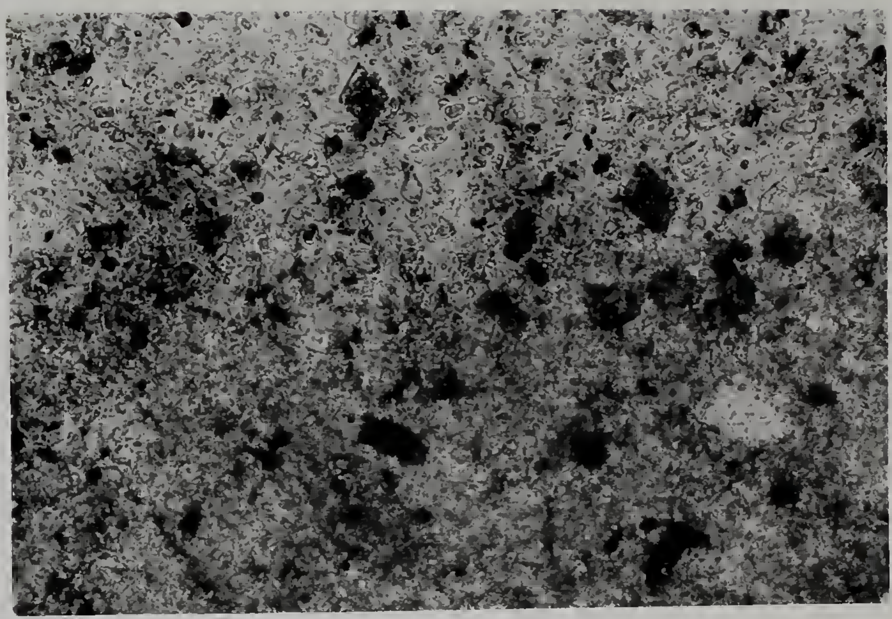
1-foot thick bed of medium light gray, greenish gray (5GY 6/1) weathering, tuffaceous siltstone that forms a key marker bed in the Stroudsburg area. On Interstate Rte. 80, at the Pa. Rte. 191 overpass, Stroudsburg (P13), the cherty limestone beds above the tuffaceous siltstone are overthickened and extensively disrupted. Closely-spaced, irregular calcite-quartz-fluorite veins transect the partially brecciated and deformed limestone beds.

Thin sections of typical Member C limestones show abundant fossil debris in a fine grained, siliceous matrix (biocalcilutite and biocalcisiltite). Fossils include trilobite, stylioline, crinoid, brachiopod, and bryozoan fragments and ostracodes. Grain size of the matrix is less than 0.01 mm. Extensive recrystallization is evidenced by fossils rimmed and replaced by chert and by abundant sparry calcite grains that occur on the edges of and inside chert masses (Fig. 45). Numerous obscure ghosts of rod-shaped, somewhat siliceous aggregates (about 0.1 mm. long) may represent either original aragonite pellets or sponge spicules similar to those in the Esopus chert at Cherry Valley, N.Y. (Y4; Fig. 9). Authigenic minerals include abundant pyrite (very small grains and irregular masses) and ferroandolomite (small euhedral, rhomb-shaped crystals to 0.06 mm. in diameter) in chert (Fig. 46). Texturally the limestones are mud-supported, immature, and intensely burrowed.



1.0 mm.

Figure 45.—Photomicrograph of contact between chert nodule (top) and calcilutite, Onondaga Limestone (Member C), East Stroudsburg, Monroe Co., Pa. (P11-4). Note recrystallized calcite spar in chert. (Polarized light.)



0.1 mm.

Figure 46.—Another photomicrograph of chert (top) - calcilutite contact, Onondaga Limestone (Member C), Marshalls Creek, Monroe Co., Pa. (P3). Dark, rhomb-shaped crystals are probably ferroan-dolomite. (Plane light.)

Insoluble residues from the Member C limestones are medium dark gray (N4) to dark gray (N3), organic, argillaceous, and, in part, highly siliceous.

The tuffaceous siltstone bed (Fig. 47) that occurs about 9 feet below the top of Member C is medium light gray (N6) to dark gray (N3), greenish gray weathering, non-calcareous, and micaceous. At exposures in which the bed is steeply dipping (East Stroudsburg railroad cut, P11), fracture cleavage is strongly developed, whereas at gently dipping exposures (Stroudsburg highway cut, P13), smooth, steeply dipping, transverse joints, spaced 0.5 to 1-foot apart, are conspicuous. At the latter locality the lower 1.0 to 1.5 feet of the bed is medium gray (N4.5), with a slight greenish cast, and the upper 6 inches is dark gray (N3), the boundary between the two portions being relatively abrupt. Thin sections reveal that ragged biotite flakes and finely disseminated pyrite are abundant (Fig. 48).

Member D (Echo Lake Member)

Member D consists of fine to medium grained, medium gray (N5), light gray (N7) weathering, fossiliferous, cherty limestones, in beds 2 to 12 inches thick. Lenticular, fining-upward coquinite beds (biocalcirudites and biocalcarenites), up to 1-foot thick, are inter- bedded with the dominant, finer limestone (Fig. 49). Grayish black

Figure 47.—Tuffaceous siltstone in Member C, Onondaga Limestone, cut on south side of Interstate Rte. 80, Stroudsburg, Monroe Co., Pa. (P13). Note sharp upper and lower contacts and prominent transverse joints.

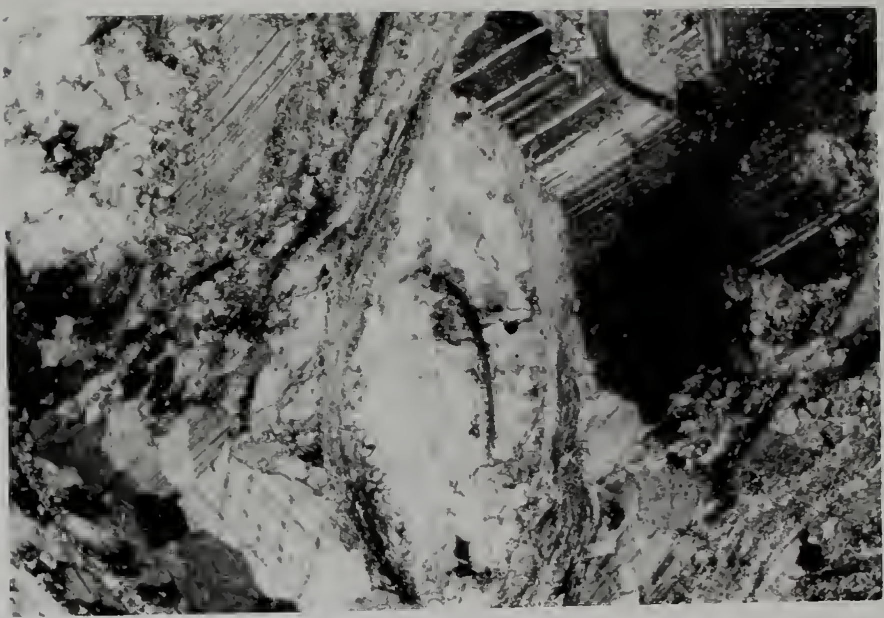
Figure 48.—Photomicrograph of tuffaceous siltstone, Onondaga Limestone (Member C), Stroudsburg, Monroe Co., Pa. (P13-2). Note biotite and abundant disseminated pyrite. (Plane light.)

Figure 49.—Chonetid brachiopod coquinite at base of Member D (Echo Lake Member), Onondaga Limestone, cut on south side of Interstate Rte. 80, Stroudsburg, Monroe Co., Pa. (P13). Very cherty limestone of Member C underlies coquinite bed.

(N2), calcareous chert, that weathers yellowish brown and spongy, occurs in irregular nodules, up to about 4 inches in diameter.

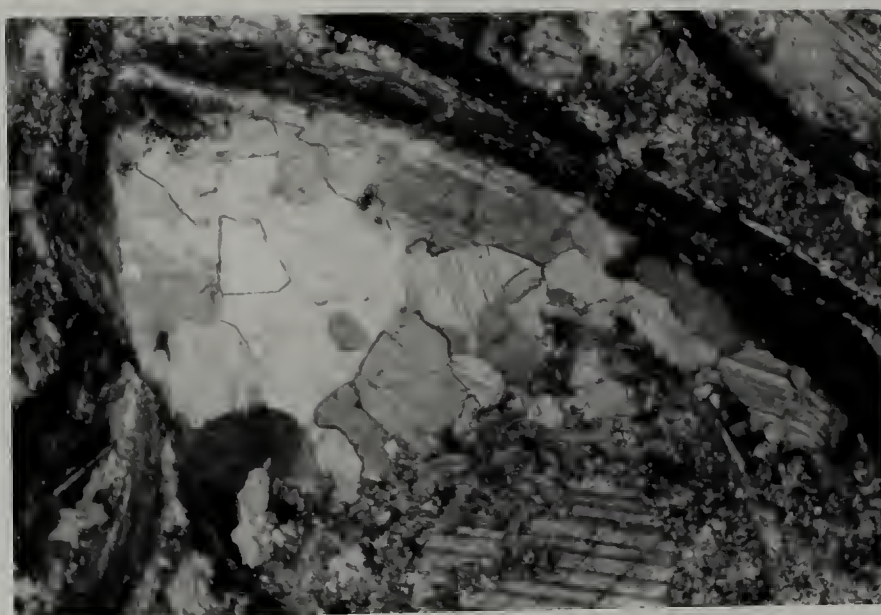
Petrographic thin sections of the coquinite limestone beds show a profusion of brachiopod (mostly chonetid) and crinoid debris in a moderately sorted, fine to medium grained, cherty matrix. The chonetid valves range from 2 to 6 mm. in diameter (Fig. 50). Geopetal structures are common (Fig. 51). In thin section the more prevalent calcisiltite or calcilutite beds resemble those of Member C in texture, but are somewhat coarser and more fossiliferous. Chert occurs in both rock types as small nodules and as rims around and partial replacement of fossils. Silicification has apparently been most intense in originally more porous areas, such as very shelly bands. Recrystallization is indicated by medium to coarse, neomorphic spar in silicified areas. Ghosts of rod- and needle-shaped aggregates, common in Member A and Member C calcilutites and calcisiltites, also occur in the Member D beds. In terms of textural maturity, the limestones of the Echo Lake Member range from mud-supported, immature (biocalcilutites) to grain-supported, submature (biocalcirudites).

Insoluble residues are medium dark gray (N4), highly siliceous aggregates.



1.0 mm.

Figure 50.—Photomicrograph of moderately sorted, siliceous, sparry biocalcirudite, Onondaga Limestone (Member D, Echo Lake Member), Echo Lake, Monroe Co., Pa. (P1-13). Fossils are chonetid brachiopods (center) and crinoid plates (upper left). Note scattered patches of calcisiltite matrix. (Polarized light.)



1.0 mm.

Figure 51.—Photomicrograph of geopetal structure formed by brachiopod valves, Onondaga Limestone (Member D, Echo Lake Member), Echo Lake, Monroe Co., Pa. (P1-13). Note patch of coarsely crystalline quartz in center of calcite mass that fills top of shell cavity. (Polarized light.)

<u>Contact Relations</u>

In eastern and southeastern New York, northwestern New Jersey and northeastern Pennsylvania, the Onondaga Limestone overlies the Schoharie Formation and underlies the Marcellus Formation. While basal contact relations vary greatly to the west and southwest (Fig. 52), the occurrence of the Marcellus above the Onondaga is constant.

As discussed previously (pp. 75-79), the lower contact is generally conformable in Schoharie Co., N.Y., and areas to the southeast (Fig. 53), but mostly disconformable west of the county. The disconformity at the base of the Onondaga, first apparent in Otsego Co. (Fig. 54), increases in magnitude to the west (Fig. 52). Along the outcrop belt the Onondaga successively overlies the Oriskany Sandstone, Manlius Limestone, and Cobleskill-Akron-Bertie formations (Grabau, 1900; Kindle, 1913; Oliver, 1954; Rickard, 1964). Similar relations exist in the subsurface of western New York and northwestern Pennsylvania.

The occurrence of the Bois Blanc Formation, a limestone unit with a Schoharie fauna, beneath the Onondaga at outcrops in Erie, Genesee, and Monroe counties, N.Y., has recently been elucidated by Oliver (1966, 1967) and Boucot and Johnson (1968). Undoubtedly much of the so-called Onondaga in the subsurface of

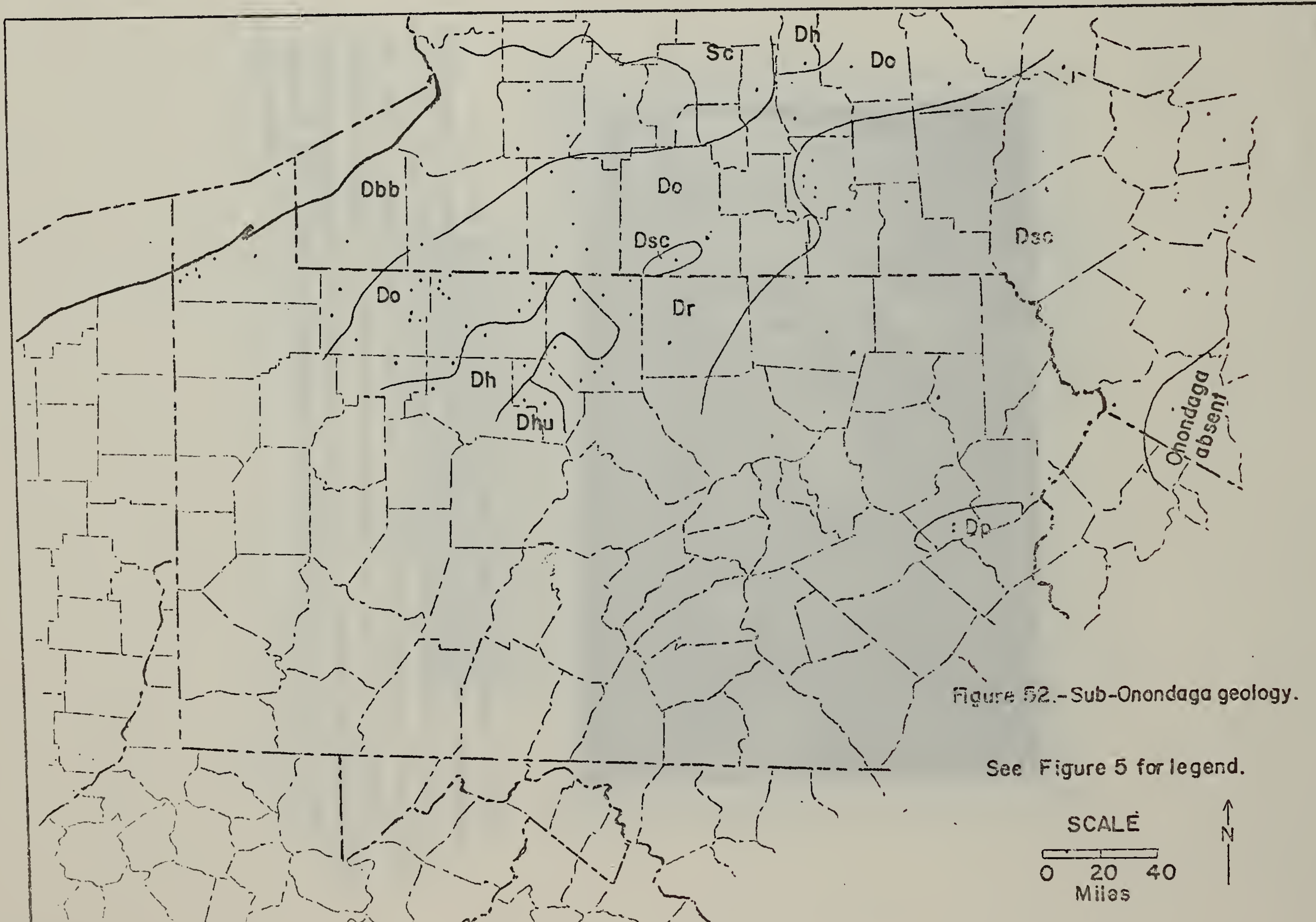


Figure 52.–Sub-Onondaga geology.

See Figure 5 for legend.

Figure 53.—Abrupt, but conformable, contact between Onondaga Limestone (at left) and Schoharie Formation, west side of U.S. Rte. 209, 0.1 mile west of Buttermilk Falls, Monroe Co., Pa. (P7). Upper part of Schoharie consists of massive, dark gray, siliceous, sandy siltstone with large vertical burrows. Lower Onondaga (Member A, Edgecliff Member) is medium to thick bedded, medium gray, cherty limestone with characteristic large crinoid columnals.

Figure 54.—Onondaga Limestone (Edgecliff Member, at top) and Schoharie Formation (Carlisle Center Member) on U.S. Rte. 20, 2.0 miles north-northeast of Cherry Valley, Otsego Co., N.Y. (Y4). Disconformable contact occurs at recess in cliff.

western New York and northwestern Pennsylvania actually represents the Bois Blanc. The Onondaga-Bois Blanc contact is disconformable at outcrops in western New York (Oliver, 1967, p. A6), but probably conformable in the subsurface further south.

The Onondaga Limestone is everywhere overlain by the Marcellus Formation, the contact becoming progressively younger to the west, both at the outcrop and in the subsurface (Rickard, 1964; Oliver and others, 1969). In eastern New York and northeastern Pennsylvania, the Marcellus overlies the Moorehouse Member and its equivalents (e.g., Member C, Echo Lake Member), whereas in central and western New York and adjacent Pennsylvania, the Marcellus rests on the Seneca Limestone Member, the equivalent of the Cherry Valley Limestone and Union Springs Shale members (Marcellus Formation) of eastern New York. The basal Marcellus black shale in western areas is assigned to the Oatka Creek Shale Member.

At most outcrop localities in New York, the Onondaga-Marcellus contact is gradational and conformable (Clarke, 1901; Oliver, 1954, pp. 645-647; 1956, pp. 1464-1465). In the Helderberg region, the transition zone between the Onondaga (Moorehouse Member) and Marcellus is reported to consist of 3 or 4 feet of black shale with thin grayish-black limestone interbeds (Goldring, 1943, p. 243; Oliver, 1956, p. 1464). Locally, however, the contact may be disconformable. On Kaaterskill Creek, below the Webber Bridge (N.Y. Rte. 23A), 3.0 miles southwest of Catskill (Y14), the basal Marcellus (one inch of thin bedded, grayish-black, bituminous, fossiliferous limestone) rests abruptly on an eroded (?) bedding surface at the top of the Onondaga (Fig. 55; Chadwick, 1944, p. 103). While Chadwick (1944) believed that relationships at Webber Bridge indicate regional disconformity between the Onondaga and Marcellus, both Cooper (1930, p. 123) and Oliver (1956, p. 1465) have argued that the break is of only local significance. Because of the marked difference in competence of the two formations, the Onondaga-Marcellus contact is commonly a decollement zone. Such a condition is apparent in the crumpled upper Onondaga and lower Marcellus on Onesquethaw Creek north of Wolf Hill (Y8) (Goldring, 1935, p. 156, Fig. 56) and in the contorted Marcellus black shale on Kaaterskill Creek at the Webber Bridge (Y14).

No localities where the Onondaga-Marcellus contact can be examined are known at outcrops south of Catskill, N.Y. In Monroe Co., Pa., the top of the Onondaga (Echo Lake Member) commonly forms the dip slope of a low cuesta, or hogback, with the Marcellus only rarely exposed some distance down slope. The basal Marcellus in Monroe Co. consists of highly cleaved, medium gray, calcareous shale that weathers tan and gray banded. (See White, 1882.) The

Figure 55.—Abrupt (disconformable ?) contact of Onondaga Limestone (Moorehouse Member) and Marcellus Formation (Bakoven Black Shale Member) on Kaaterskill Creek, below the Webber Bridge (N.Y. Rte. 23A), 3.0 miles west of Catskill, Greene Co., N.Y. (Y14). Hammer rests on thin bedded, grayish black, bituminous, fossiliferous limestone at base of Marcellus.

most accessible exposure of this portion of the Marcellus is located on the northwest side of U.S. Rte. 209, 0.5 mile northeast of Echo Lake, Middle Smithfield Township. According to White (1882, p. 113), the upper Onondaga was once exposed in a temporary excavation just across the highway from this outcrop. The scarcity of exposures of the Onondaga-Marcellus contact is undoubtedly a result of glacial action, the soft, easily eroded Marcellus shales having been everywhere scoured off the hard, upper ledge of the Onondaga.

On subsurface gamma ray logs, the upper contact is marked by an abrupt decrease in radiation intensity in passing from the Marcellus black shale into the Onondaga Limestone (Kehn, Glick and Culbertson, 1966, pl. 2; Rickard, 1969, pl. 11, 12, 13, 14). Sample logs show the contact to be gradational, however. In the Hess No. 1 well, Pike Co., Pa. (P66), a 40-foot transition zone of very limy shale separates the two formations (Fletcher and Woodrow, 1970, p. 5, pl. 2). The lower 155 feet of the Marcellus in the Richards No. 1 well, Lackawanna Co. (P68) consists of very limy, dark gray shale (Kehn, Glick and Culbertson, 1966, p. 76, pl. 2). Other wells throughout eastern and central New York and northern Pennsylvania have encountered similar conditions (Fettke, 1961, pp. 340, 347, 362, etc.).

Distribution and Thickness

The name Onondaga Limestone is applied throughout eastern, central, and western New York and northeastern, north-central, and western Pennsylvania, as well as western portions of Maryland, West Virginia, and Virginia. Lithologically similar limestones occur in Ohio (Columbus Limestone), Indiana (Jeffersonville Limestone), and Illinois (Grand Tower Limestone). Fig. 56 shows the thickness of the Onondaga in New York and northern Pennsylvania. Its areal distribution and thickness in western and southern areas will be discussed later in this report (pp. 285-287).

The Onondaga attains its maximum thickness, about 315 feet, in the Onesquethawan basin that centers in northern Luzerne, Wyoming, Lackawanna, Pike, and Monroe counties, Pa. (See Fig. 4.) As indicated on stratigraphic cross sections DD' (Plate 3) and KK' (Plate 4), about 60 feet of this total thickness may be attributed to a thick, localized sequence of limestone above the Tioga Metabentonite (?).[9] Maximum outcrop thickness, 260 feet, all being Onesquethawan in age, is apparently at East Stroudsburg, Monroe Co., Pa. (P11). However, complete sections of the Onondaga are not known

[9]Three distinct metabentonite horizons may occur in the Richards No. 1 well (P68) (Kehn, Glick and Culbertson, 1966, p. 76, pl. 2). The highest of these lies at a depth of 7,464 feet, or 54 feet below the top of the Onondaga. It is possible that the lower two metabentonite horizons (at 7,512 and 7,521 feet) may be cavings from the upper bed.

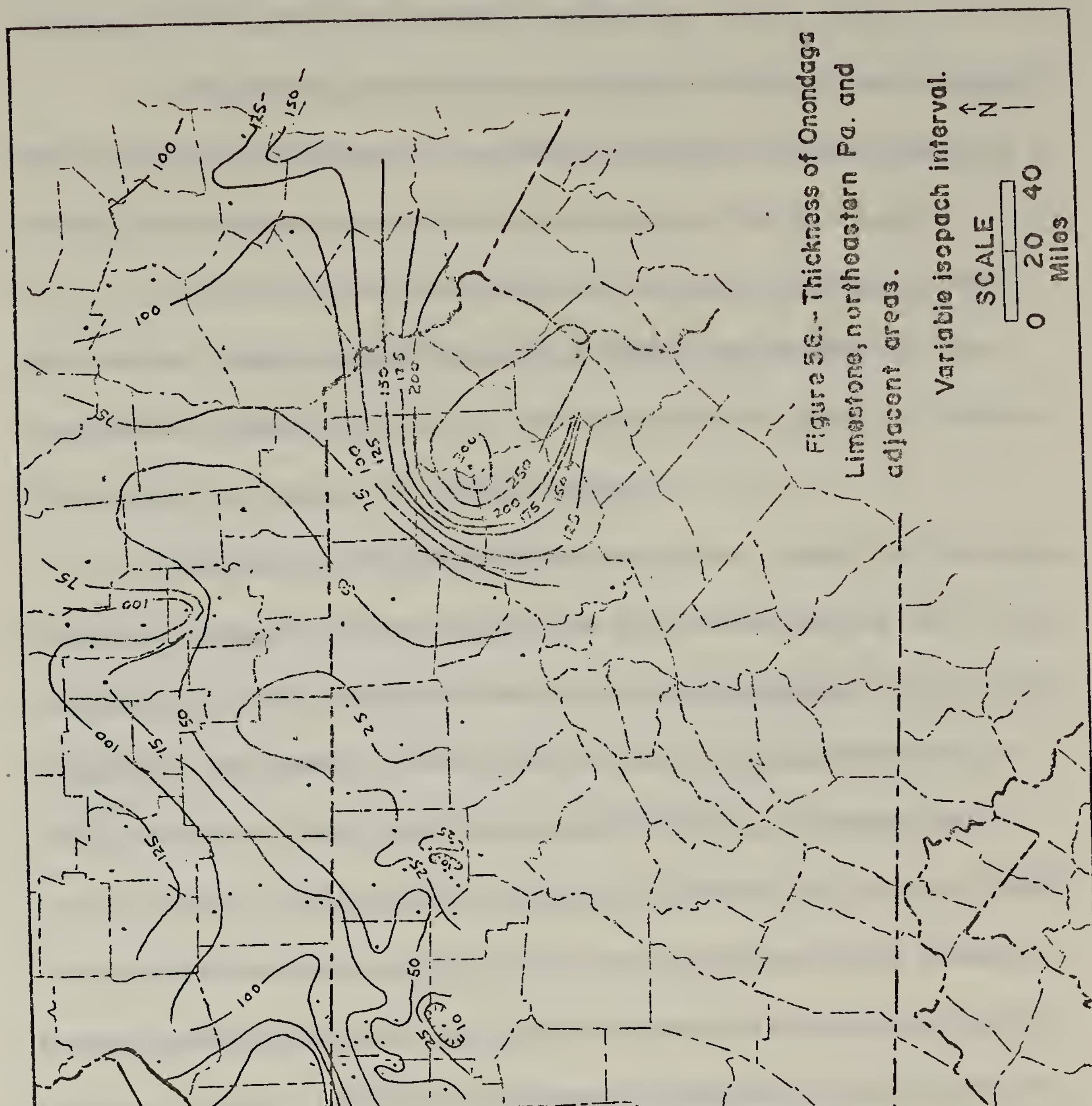


Figure 56.- Thickness of Onondaga Limestone, northeastern Pa. and adjacent areas.

Variable isopach interval.

between that locality and Kingston, Ulster Co., N.Y. (Y17).

Immediately south of the Northeastern Basin, the Onondaga thins to less than 50 feet in the Lehigh-Schuylkill region, partly as a result of non-deposition of the lower portion of the formation.

To the north and northeast the Onondaga thins somewhat, but another smaller depositional axis extends northwesterly from Saugerties, Ulster Co., N.Y., 162± feet (Oliver, 1956a, p. 1458) to Cherry Valley, Otsego Co. (Y4), 120 feet.

West and northwest of the Richards No. 1 well, the Onondaga thins very abruptly, being only 55 feet thick in the Hettick No. 1 well, Bradford Co., Pa. (P75); 29 feet thick in the Ida Wheeler No. 1 well, Tioga Co., Pa. (P95); 17 feet thick in the L. E. Shoemaker No. 1 well, Tioga Co. (P94); and 18 feet thick in the L. Dickerson No. 1 well, Tioga Co. (P96) (Fettke, 1950, p. 99; 1961, pp. 340, 347, 362). The latter three wells were drilled in an area where a late Onesquethawan hydrographic basin succeeded an early Onesquethawan shallow platform element. Minimum thickness of less than 10 feet is present in the East Fork-Wharton Gas Field, Southern Potter Co. (Fettke, 1949). Subsurface Onondaga reefing is associated with this trend in Steuben Co., south central N.Y. (Kriedler and others, 1968; Kelley and others, 1970a, p. 60). Locally these Onondaga reefs may attain thicknesses of 150-200 feet (Kelley and others, 1970b, p. 33; W.

Traeder, 1971, personal communication).

Westward of the platform-basin area, the Onondaga gradually thickens across the border counties of Pennsylvania and New York. A thickness of about 180 feet is attained in Erie Co., Pa., this being based on an assumed thickness of about 100 feet for the Bois Blanc Formation. (See Dow, 1962, pl. 1.) Northwest of the platform-basin, the Onondaga increases in thickness to about 130-135 feet in the subsurface of Wyoming and Livingston counties, N.Y. (Luther, 1894, pp. 277-281; Rickard, 1969, pl. 11, 14). Similar thicknesses are present at outcrops in Genesee and Erie counties (Oliver, 1966).

South of the northern tier counties of Pennsylvania, much of the Onondaga Limestone changes into a very cherty and argillaceous phase that is included in the Huntersville chert. This accounts in part for the thinness of the Onondaga in northern Elk Co., only 8 feet being present in the Warrent 3788, No. 3337 well (Fettke, 1961, pp. 286-287).

Thickness variations of the individual members of the Onondaga Limestone along the outcrop belt in New York are given by Oliver (1954, 1956, 1962, 1966).

Members A, B, C, and D of the Onondaga Limestone are known only at outcrops in Monroe Co., Pa. With the subsurface information now available, it is not possible to trace their distribution beneath the Pocono Plateau region. They can probably be recognized at outcrops along the Delaware River in New Jersey, but no attempt was made to do so for the present studies. Representative thicknesses in feet of the four members in Monroe Co. are as follows:

	P1	P9 (Epstein, 1970)	P11
Member A (Edgecliff)	—	80	82
Member B	—	42	37
Member C	138	—	120
Member D (Echo Lake)	20	—	22

Based on the fact that the Onondaga in the subsurface to the north is highly argillaceous and contains little chert, it is probable that Member B thickens in that direction at the expense of members A and C.

Fauna and Age

Marine, shelly fossils are very abundant in the Onondaga Limestone throughout its outcrop belt, and their presence in the subsurface is indicated on many well sample descriptions. Although lateral and vertical variation in frequency and diversity reflects mainly facies control, the stratigraphic range of a few species can be used for temporal zonation (Rickard, 1964; Oliver and others, 1969). Fossils collected from the various members of the Onondaga for the present study are listed in Table 5. Grabau (1906), Oliver (1954, 1956) and Willard (1939) note many species not included in this tabulation.

The Edgecliff Member of New York, in both its reef and non-reef manifestations, contains a rich coralline fauna (Oliver, 1954, 1956). Especially characteristic of the reefs in the eastern part of the state are Favosites basalticus, Cystiphylloides americanum, Acinophyllum stramineum, etc. Some reefs, such as the Thompsons Lake reef (Y7), are practically devoid of fossils other than corals, whereas others, for example the Roberts Hill reef (Y9), are rich in brachiopods (Fimbrispirifer divaricatus, Cupulorostrum tethys, Cyrtinaella biplicata) and trilobites (Proetus (Crassiproetus) crassimarginatus). Aside from the various corals (Breviphrentis sp., Blothrophyllum decorticum, Heterophrentis sp., etc.) (Oliver, 1956), the most prevalent fossil encountered in the non-reef facies is a large crinoid columnal, commonly 3/4 to 1 inch in diameter. Other common fossils in the non-reef facies include brachiopods (Atrypa reticularis, Leptaena rhomboidalis) and bryozoans (Fenestrellina sp.).

The fauna of the Nedrow Member in eastern New York is dominated by platycerid gastropods, particularly Platyceras (Platystoma) turbinatum. The brachiopods Atrypa reticularis,

TABLE 5

FAUNA OF THE ONONDAGA LIMESTONE, NEW YORK, NEW JERSEY, AND PENNSYLVANIA

(1 = Edgecliff Member, N.Y. and N.J.; 2 = Nedrow and Moorehouse members, N.Y. and N.J.; 3 = Member A, Pa.; 4 = members B, C, and D, Pa.)

Fauna	1	2	3	4
Coelenterata				
Unidentified favositids	x	x	x	x
Favosites basalticus (Goldfuss)	x			
Syringaxon sp.		x		
Heterophrentis inflata (Hall)	x			
Heterophrentis sp. B				x
Brevisphrentis sp.	x			
Cylindrophyllum compactum (Hall)	x			
Acinophyllum stramineum (Billings)	x			
Cystiphylloides americanum (Edwards and Haime)	x			
Bryozoa				
Unidentified fenestellids		x		
Fenestrellina sp.	x			
Lichenalia sp.		x		
Brachiopoda				
Leptaena rhomboidalis (Wilckens)	x	x	x	x
Strophodonta (Strophodonta) demissa (Conrad)		x		
Megastrophia (Megastrophia) concava (Hall)		x		
Cupulorostrum tethys (Billings)	x	x		
Atrypa reticularis (Linnaeus)	x	x	x	x
Spinatrypa spinosa (Hall)		x		
Cyrtinaella biplicata (Hall)	x			
Acrospirifer varicosus (Hall)				x
Kozlowskiellina (Megakozlowskiella) raricosta (Conrad)		x		
Paraspirifer acuminatus (Conrad)		x		x
Fimbrispirifer divaricatus (Hall)	x			

TABLE 5—Continued

Fauna	1	2	3	4
Gastropoda				
Platyceras (Platystoma) turbinatum (Hall)		x		
P. (Platyceras) dumosum Conrad		x		
Paleozygopleura hamiltoniae (Hall)		x		
Trilobita				
Proetus (Crassiproetus) crassimarginatus (Hall)	x			
Odontocephalus selenourus (Eaton)		x		
Phacops pipa (Hall)		x		
Cricoconarida				
Tentaculites bellulus Hall				x
Echinodermata				
Large crinoid columnals	x		x	

Kozlowskiellina (Megakozlowskiella) raricosta, Levenia lenticularis, and Pentagonia unisulcata are also abundant (Oliver, 1956, p. 1457).

Brachiopods, gastropods, and trilobites are the dominant faunal elements in the Moorehouse Member. Some characteristic brachiopods are A. reticularis, Spinatrypa spinosa, K. (M.) raricosta, Strophodonta (Strophodonta) demissa, Megastrophia (Megastrophia) concava, Leptaena rhomboidalis, Schellwienella pandora,[10] Coelospira camilla,[10] Acrospirifer duodenaria,[10] and Paraspirifer acuminatus. Gastropods are represented by P. (P.) turbinatum, Platyceras (Platyceras) dumosum, and Palaeozygopleura hamiltoniae, and trilobites by Odontocephalus selenourus and Phacops pipa.

The Seneca Member in New York is marked by great abundance of the brachiopods Devonochonetes (?) lineatus and Chonostrophia reversa (Oliver, 1956, p. 1455).

In eastern Pennsylvania and adjacent New Jersey and New York, the Edgecliff Member (Member A) contains fewer fossils than its mid-Hudson Valley equivalent. Corals, especially small unidentified rugose forms, brachiopods (L. rhomboidalis, A. reticularis), and trilobites (Odontocephalus selenourus) are relatively common.

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[10]Reported in Oliver (1956, pp. 1462–1463).

Member A is also rich in ostracodes (Epstein, 1970, p. 107). The large crinoid columnals, a distinguishing feature of the Edgecliff in New York, occurs only in the lower 50 feet of Member A in Monroe Co., Pa.

Although Member B is apparently a near facies equivalent of the Nedrow Member of New York, the platycerid gastropods so characteristic of the Nedrow do not occur in the Pennsylvania rocks. Atrypa reticularis and unidentified rugose corals were the only fossils collected from Member B during the present study. Epstein (1970, p. 108) lists a large silicified ostracode faunule.

Member C contains a relatively abundant brachiopod fauna, in which A. reticularis is common.

The most fossiliferous portion of the Onondaga in Monroe Co., Pa., is Member D, the Echo Lake Member, which is characterized by lenticular beds replete with chonetid brachiopods and small rugose corals. Especially abundant of these groups are Longispina mucronatus and Heterophrentis sp. B., respectively. Other diagnostic brachiopods include Eodevonaria sp., Paraspirifer acuminatus, and Acrospirifer varicosus. The cricoconarid Tentaculites bellulus is also common.

The Onondaga Limestone is probably entirely Eifelian (lower Middle Devonian) in age (Rickard, 1964; Oliver and others, 1969).

The Onesquethaw Stage in the Lehigh-Schuylkill Region, Pennsylvania

The Onesquethawan rock sequence that crops out north of Blue Mountain between Monroe and Lebanon counties, Pa., is strikingly different from the sequence exposed in the Delaware Valley and southeastern New York. In western Monroe, Carbon, and eastern Schuylkill counties, it consists, in ascending order, of the Schoharie-Esopus formations, undivided, the Palmerton Sandstone, and the Onondaga Limestone (Fig. 57). The Schoharie-Esopus and Palmerton pinch out in eastern Schuylkill County, and only the Onondaga Limestone is represented at the western end of the outcrop belt (Fig. 58). The Onondaga Limestone likewise disappears west of Swatara Gap, Lebanon Co. The Tioga Metabentonite is present at, or near, the contact of the Onondaga Limestone and the overlying Marcellus Formation.

Major distinguishing characteristics of the Onesquethawan sequence in the Lehigh-Schuylkill region are as follows:

1. The combined Schoharie-Esopus formations are represented by less than 100 feet of shaly siliceous siltstone and siliceous siltstone, containing *Taonurus* in the lower part, and a rich brachiopod fauna in the upper part;

Figure 57.—Lehigh-Schuylkill facies of Onesquethaw Stage, Northeast Extension, Pennsylvania Turnpike, cut through Stony Ridge at West Bowmans, Carbon Co., Pa. (P22). The section ranges from Lower Devonian New Scotland chert (Dns, rubble at extreme right) to Middle Devonian Marcellus black shale (Dm, at left). The Ridgeley Sandstone (Dr), Schoharie-Esopus Formations, undivided (Dse), Palmerton Sandstone (Dp), and Onondaga Limestone (Don), with reddish Hazard Member (h) at base, are completely exposed.

Figure 58.—Onondaga Limestone (Don), along Interstate Rte. 81, 0.5 mile northeast of Swatara Gap, Lebanon Co., Pa. (P29). To the left is the Marcellus Formation (Middle Devonian) and to the right, the upper sandstone member of the Bloomsburg Formation (Sbu) (Upper Silurian). Beds of the Tioga Metabentonite (Dtm) appear as light bands between the Onondaga and Marcellus.

2. The Palmerton Sandstone, a massively bedded quartz sandstone and conglomerate unit, occurs in the position of the upper Schoharie of the Stroudsburg area;

3. The Onondaga Limestone, 260 feet thick and extremely cherty at Stroudsburg, is generally less than 50 feet thick, highly argillaceous, and sparingly cherty in the Lehigh-Schuylkill area; and

4. A distinctive, ferruginous limestone, the Hazard "paint ore" Member, occurs at the base of the Onondaga Limestone in the vicinity of Lehigh Gap.

These features are probably related to the greater proximity of the Lehigh-Schuylkill area to the southeastern Onesquethaw shoreline.

The basal contact of the Onesquethawan sequence in the Lehigh-Schuylkill region is always disconformable. Marked increase in the magnitude of the pre-Onesquethaw hiatus west of the Schuylkill River is caused by merger of pre-Onesquethaw and pre-Deerpark disconformities. The relationships are shown in stratigraphic cross section GG' (Plate 3). Extent of the disconformities in the Schoharie-Esopus, Ridgeley, Shriver, Helderberg, Keyser, Tonoloway and Wills Creek are probably present in the subsurface of northwestern Schuylkill Co. (Wood, Trexler, and Kehn, 1969, pp. 20-23).

Schoharie-Esopus Formations, Undivided

Definition and Reference Section

In eastern Schuylkill, Carbon, and western Monroe counties, the Schoharie-Esopus interval is represented by a local development of dark gray to white siliceous siltstone. Separation of a lower, dark gray, Taonurus--bearing siltstone from an upper, white, fossiliferous siltstone is generally possible. These two units cannot everywhere be clearly differentiated, however, and it is likely that they are in part interfingering facies.

The Schoharie-Esopus siltstone in the Lehigh Gap region was first recognized as a distinct formation by Swartz and Swartz (1938). They named it the Bowmanstown chert for its occurrence along the state highway, one-half mile east of Bowmanstown, Carbon Co. (Swartz and Swartz, 1941, p. 1178). Willard (1939, p. 151; 1957, p. 2300) restricted use of Bowmanstown to the upper, fossiliferous, "white chert" subdivision and referred the lower, dark gray, somewhat shaly-weathering beds to the Esopus. Epstein and Epstein (1967, 1969) have used the designation Schoharie-Esopus formations, undivided, for these same beds. The latter terminology is adopted in the present report for several reasons:

1. The upper portion usually contains a rich Schoharie-age fauna and is clearly laterally continuous with the Schoharie Formation of eastern Monroe Co.;
2. The lower portion contains the Taonurus-markings so typical of the Esopus and Carlisle Center;
3. Precise definition of the Schoharie and Esopus subdivisions is not possible.

An excellent reference section for the Schoharie-Esopus siltstone is the exposure in the Pennsylvania Turnpike cut through Stone Ridge, 0.1 mile south of West Bowmans, Carbon Co. (P22).

Lithology

The Schoharie-Esopus formations, undivided, contains predominately medium gray (N5) and light gray (N7) to white (N9), chalky weathering, siliceous siltstone. Everywhere it has been subjected to marked alteration by weathering, a process which has been accelerated by the usual steep dip and intense fracturing of the beds. In fresh exposures the upper part of the unit is reported to consist of dark gray, slightly calcareous siltstone (Epstein and Epstein, 1967, p. 12). No such calcareous lithology was recognized in the Schoharie-Esopus during the present study, however. What follows is, therefore, descriptive of the typically exposed, but in part secondarily altered rock.

The Schoharie-Esopus siltstone can be divided into two informal subdivisions: a lower, gray and dark red weathering unit (the Esopus Shale of Willard, 1939, p. 151; 1957, p. 2300) and an upper, light gray to white weathering unit (the Bowmanstown Chert of Willard, 1939; 1957). Both subdivisions are laterally persistent and can be recognized at outcrops east of the Lehigh River from Bowmanstown, Carbon Co., to Saylorsburg, Monroe Co. West of the Lehigh, differentiation of the two units is less satisfactory.

The lower subdivision consists of medium dark gray (N4), sparingly fossiliferous, argillaceous, siliceous siltstone that occurs in medium to thick beds, 4 inches to 24 inches thick. The rocks weather very dark red (5R2/6) and yellowish gray (5Y 8/1) with rusty stains and develop a chalky surface after prolonged exposure. More argillaceous beds show a distinct shaly fracture on weathering. *Taonurus*-markings are locally very abundant.

Thin sections of the lower siltstones reveal that they are composed of about 70 per cent quartz, 10 per cent sericite, 10 per cent silica cement, and 10 per cent hematite (Fig. 59). Opaque minerals occur sparingly. The quartz grains are angular to subangular and generally exhibit moderate to strong undulose extinction.

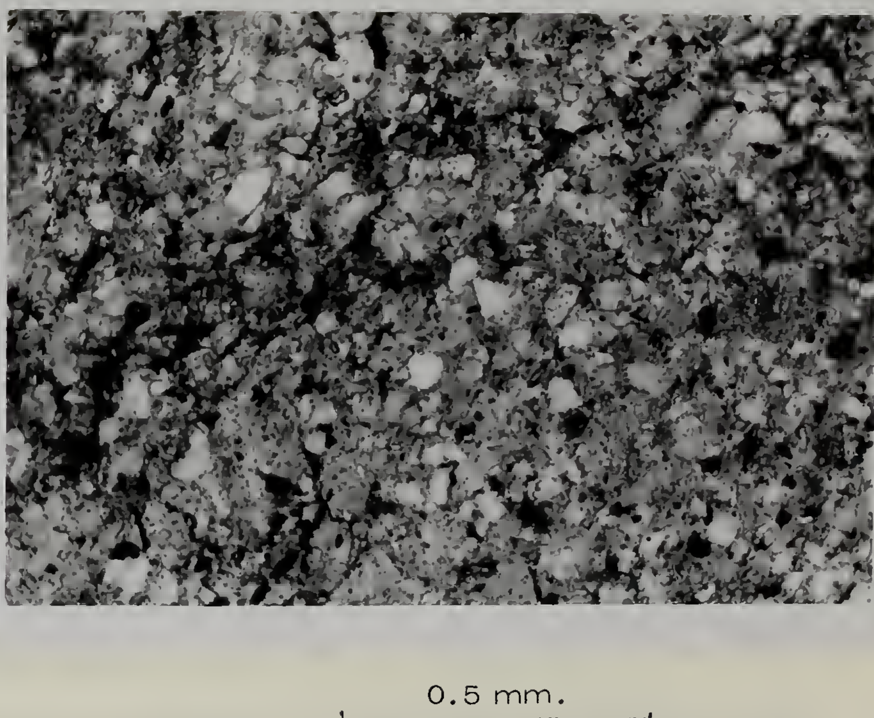


Figure 59.—Photomicrograph of poorly sorted, intensely burrowed, argillaceous quartz siltstone, Schoharie-Esopus formations, undivided (lower part), Bowmanstown, Carbon Co., Pa. (P21-1). Rock is composed of angular quartz silt in argillaceous matrix, with secondary silica and hematite cement. Dark grains are organic detritus. (Polarized light.)

They are often partially replaced by sericite and hematite. Grain contacts are usually sutured and show development of finely crushed quartz. The sericite represents argillaceous material that was a primary, though not particularly abundant, constituent of the rock. The silica cement consists of finely crystalline chalcedony that, as far as can be determined, was the original cementing agent. Hematite was later introduced along fractures by circulating ground water and partially replaced the silica cement and quartz grains.

The upper subdivision consists of medium to thick bedded, light gray (N7) to white (N9), chalky weathering, porous, very fossiliferous, quartzose siltstone and fine grained, quartzose sandstone. Floating quartz sand grains are characteristic of the upper half. At Saylorsburg, the uppermost 9 feet of the Schoharie-Esopus consists of thick bedded, moderately sorted, fine grained sandstone, that is easily distinguished from the finer grained beds below.

Thin sections of typical siltstones from the upper Schoharie-Esopus are composed of about 70 per cent quartz silt, 20 per cent silica cement, and 10 per cent pore space (Fig. 60, 61). The quartz grains are angular to subangular and range from 0.005 to 0.125 mm. in diameter with a mean size of about 0.05 mm. Most are single grains with moderate to strong undulose extinction. Grain contacts are sutured and crushed. The silica cement consists of finely

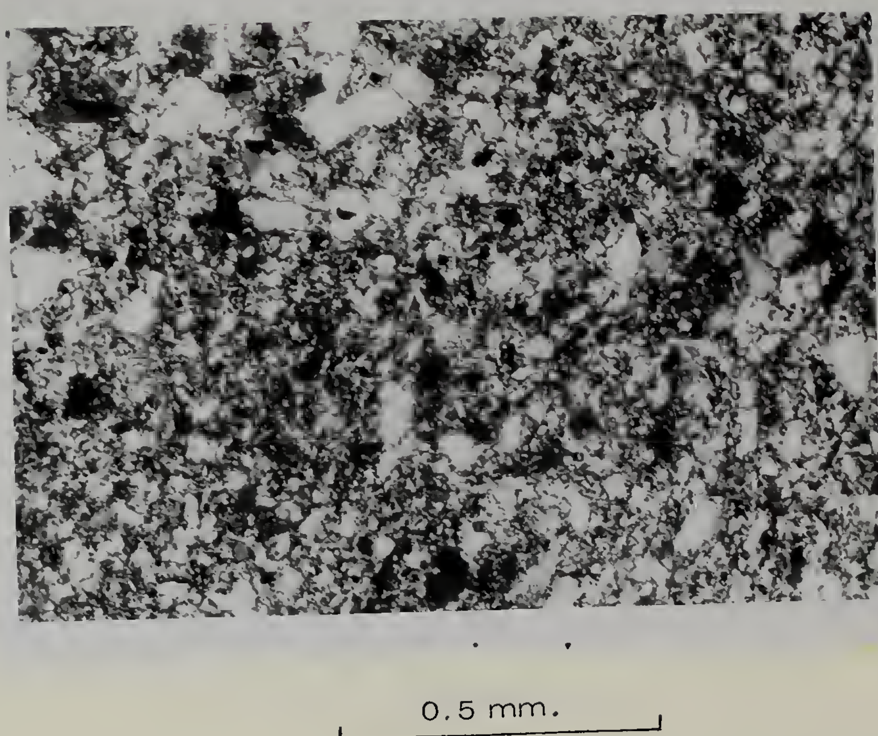
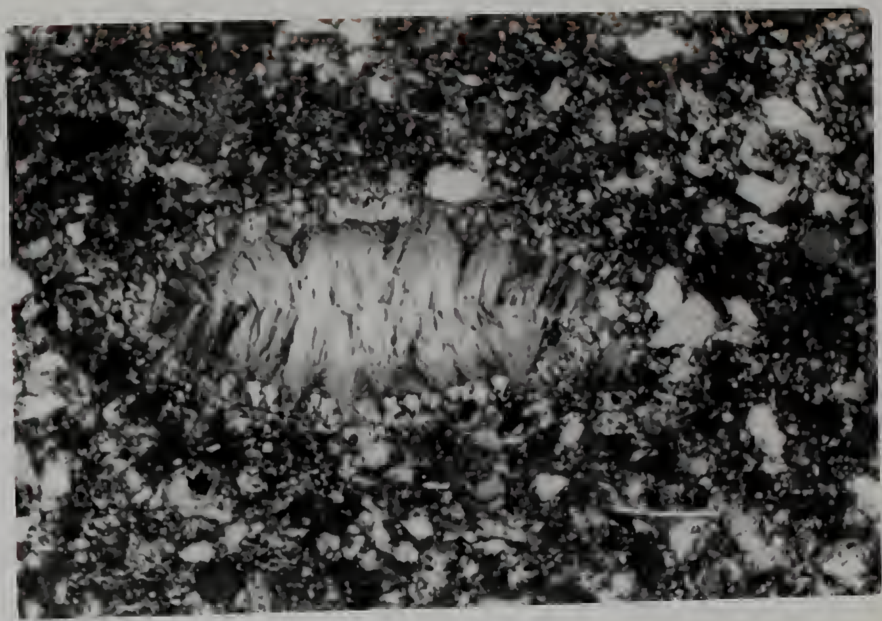


Figure 60.—Photomicrograph of poorly sorted, leached, chalcedonic quartz siltstone, Schoharie-Esopus formations, undivided (upper part), West Bowmans, Carbon Co., Pa. (P22-8). (Polarized light.)



0.5 mm.

Figure 61.—Photomicrograph of ostracode shell, replaced by fine-grained silica with chalcedony filling cavity between valves, Schoharie-Esopus formations, undivided (upper part), West Bowmans, Carbon Co., Pa. (P22-8). (Polarized light.)

crystalline chalcedony, except in fossil cavities where the chalcedony occurs as coarse radiating masses (Fig. 61). Pore space is of two types:

1. Large cavities formed by the leaching out of carbonate shell material;
2. Scattered pores about 0.05 mm. in diameter that probably represent primary calcite grains leached from the rock.

A thin section of the upper, fine grained sandstone from Saylorsburg is composed of approximately 75 per cent quartz sand and silt grains, 20 per cent silica cement, and 5 per cent pore space (Fig. 62). Tourmaline occurs as an accessory mineral. Grain size ranges from 0.025 to 0.25 mm. with a mean of about 0.2 mm. A few scattered coarse grains are about 1.25 mm. in diameter. The silt and fine sand generally occur as single, angular to subangular grains that exhibit moderate to strong undulose extinction, while the coarse sand grains are subrounded and composite with strongly undulose extinction. As in the typical siltstones, grain contacts are sutured and crushed. The silica cement is finely crystalline chalcedony. Pores are grain size and probably represent leached calcite grains.

A dark reddish brown (10R 3/4), hematitic sandy siltstone, six to ten inches thick, was recognized at several exposures of the

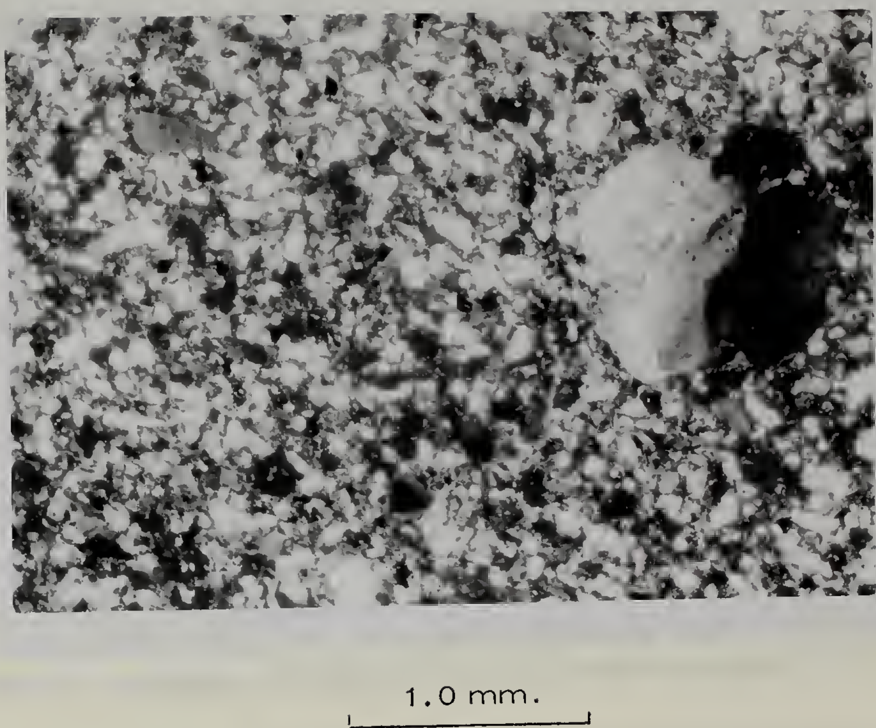


Figure 62.—Photomicrograph of moderately well sorted, fine grained chalcedonic quartz sandstone, Schoharie-Esopus formations, undivided, Saylorsburg, Monroe Co., Pa. (P17-4). Note large, rounded composite quartz grain at right. (Polarized light.)

Schoharie-Esopus. (Also reported by Swartz and Swartz, 1941, and Sevon, 1967, personal communication.) It occurs 10 feet above the base at Little Gap (P19), 25 feet above the base at West Bowmans (P22) (near the top of the lower subdivision), and 7 feet above the base at Stony Mountain School (P24) (Fig. 64). Since only one such bed was observed at each locality, it is likely that a single persistent hematite marker bed exists. The bed may define a time plane.

Locally along Cherry Ridge between Saylorsburg and Kunkletown, the Schoharie-Esopus siltstone has been thoroughly leached to residual white, siliceous clay. These saprolitic clays were formerly mined near Saylorsburg and used in the manufacture of paper and water paints (Leighton, 1941, p. 185). Similar deposits developed from the New Scotland Formation, Shriver Chert, and Onondaga Limestone, about four miles north-northeast of Kunkletown, are presently being worked for cement clay by the Universal Atlas Cement Company (Epstein and Hosterman, 1969).

Contact Relations

The Schoharie-Esopus siltstone disconformably overlies the Ridgeley Sandstone of the Oriskany Group (except at the extreme western end of its outcrop belt) and gradationally underlies the Palmerton Sandstone. Both contacts are well exposed at several localities.

The lower contact with the Ridgeley is always sharp with no indication of intercalation. Because of the abrupt lithologic change, the contact is generally a zone of intense ground water leaching. At Little Gap (P19), a band of white silty clay, 10 feet thick, occurs at the base of the Schoharie-Esopus. Eight miles farther west at West Bowmans (P22) the lower three feet of the siltstone is leached to white, rusty stained clay that rests on a one-inch bed of fine grained quartz sandstone at the top of the Ridgeley. At Stony Mountain School (P24), five miles farther west, the Schoharie-Esopus abruptly succeeds conglomeratic Ridgeley without an intervening clay seam. West of Stony Mountain School, the Ridgeley thins and disappears, and at Millers, five miles distant, the siltstone lies disconformably on the New Scotland Formation (Sevon, 1968).

The contact between the Schoharie-Esopus formations, undivided, and the Palmerton Sandstone is conformable and gradational (Fig. 63). The upper beds of the Schoharie-Esopus are coarser and floating sand grains about 1.0 mm. in diameter are common. These beds are succeeded by several feet of intercalated siltstone (or fine sandstone) and medium-coarse grained sandstone that are included in the Palmerton. The actual contact is defined as the base of the first distinct sandstone bed of Palmerton aspect.

Figure 63.—Contact (at hammer) between Palmerton Sandstone (right) and Schoharie-Esopus formations, undivided, west side of Pa. Rte. 115 in cut through Cherry Ridge, 0.5 mile southeast of Saylorsburg, Monroe Co., Pa. Beds strike N75°E and dip 52°S (overturned). The Palmerton is transitional into the Schoharie-Esopus through 4 feet of interbedded coarse and medium grained sandstone. The upper Schoharie-Esopus consists of thick bedded, very fine to medium grained quartz sandstone.

Distribution and Thickness

The Schoharie-Esopus siltstone is areally restricted to a narrow, sinuous outcrop belt parallel to Blue Mountain in Monroe, Carbon, and eastern Schuylkill counties. Its easternmost exposures are in the vicinity of Saylorsburg, Monroe Co. (P17), while its westernmost occurrence is probably near Millers, Schuylkill Co. (Sevon, 1968). The extent of the Schoharie-Esopus to the north is uncertain. An exploratory gas well, the Graver Estate No. 1 well (P69), drilled in Towamensing Township, Carbon Co. (P69), about 3.3 miles north of Palmerton, passed through 278 feet of "Bowmans-town" before penetrating the Oriskany at 4,960 feet (Lytle et al., 1965). Although the thickness is probably exaggerated by steep dip and other structural complexities, this well provides the only data as to the existence of quartzitic siltstone ("Bomanstown") lithology in the Schoharie-Esopus interval north of the outcrop belt.

The thickness of the Schoharie-Esopus siltstone varies considerably. It increases southwestward from 63 feet at Saylorsburg (P17) to 91 feet at Little Gap (P19), then decreases to 42 feet at West Bowmans (P22) and 22 feet at Stony Mountain School (P24) (Fig. 64). Exposed sections west of Stony Mountain School are incomplete, but local thickening may occur to the southwest (Sevon, 1968) before the unit wedges out east of Schuylkill Haven. North of the outcrop belt

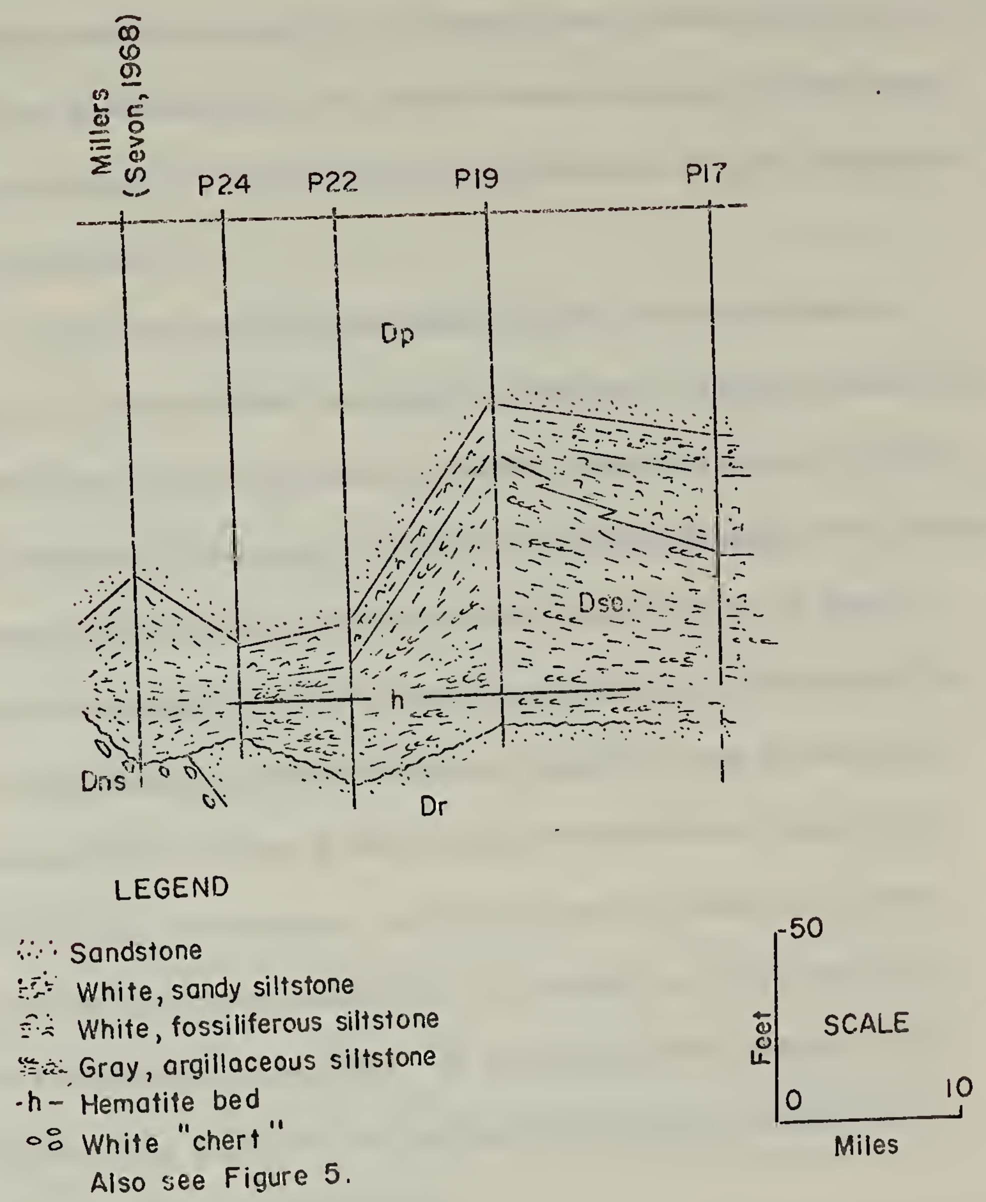


Figure 64.—Stratigraphic sections of Schoharie-Esopus formations, undivided.

the quartzitic siltstones thin rapidly and are replaced by calcareous mudstones (Schoharie Formation) and silty shales (Esopus Formation). This facies change is probably complete a few miles north of the outcrop, as is indicated by the abrupt disappearance of Schoharie-Esopus lithology northward from Cherry Ridge to Godfrey Ridge in eastern Monroe Co.

Where the two informal subdivisions of the Schoharie-Esopus can be recognized, the lower, dark gray, Taonurus-bearing, shaly siltstone is usually thicker than the upper light gray, fossiliferous siltstone. The upper subdivision thins gradually from 32 feet at Saylorsburg (P17) to 17 feet at Little Gap (P19) and 12 feet at West Bowmans (P22), while the lower subdivision is at least 31 feet thick at Saylorsburg, 74 feet thick at Little Gap, and 30 feet thick at West Bowmans. West of the Lehigh, fossiliferous, light gray siltstone typical of the upper subdivision can be traced at least as far as Andreas, eastern Schuylkill Co. (P25), but the lower subdivision is generally concealed. At Stony Mountain School (P24), the only complete exposure of the Schoharie-Esopus west of the Lehigh, separation is not possible.

Variations in thickness of the Schoharie-Esopus along strike appear to be caused by (1) facies changes, (2) local differences in rate of subsidence and deposition, and (3) sedimentary overlap

(Fig. 64). Thinning of the upper fossiliferous siltstone between Saylorsburg and Little Gap is caused in part by facies change into the lower Palmerton Sandstone and upper portion of the lower siltstone. The increased thickness of the lower shaly siltstone at Little Gap is mainly the result of a faster rate of deposition, although some of the increase may occur at the expense of the upper fossiliferous subdivision. Marked thinning of the lower unit between Little Gap and West Bowmans cannot be caused by westward sedimentary overlap on the disconformity at the base of the Schoharie-Esopus, because the hematite bed (an assumed time plane) is actually higher in the section at West Bowmans. West of the Lehigh, however, the Schoharie-Esopus probably wedges out by overlap onto the Auburn Promontory of Swartz (1939).

Fauna and Age

The Schoharie-Esopus formations, undivided, contain a rich brachiopod fauna, particularly in the upper white, quartzose siltstone portion (Table 6). *Eodevonaria arcuata*, *Acrospirifer duodenaria*, and *Mucrospirifer macra* are all typical Schoharie species that also occur in the upper Schoharie in the Delaware Valley and mid-Hudson valley regions, while *Leptocoelia flabellites* is present in the Esopus Formation throughout its outcrop belt. Like

TABLE 6

FAUNA OF THE SCHOHARIE-ESOPUS FORMATIONS, UNDIVIDED, LEHIGH-SCHUYLKILL REGION, PA.

(1 = lower gray siltstone; 2 = upper white siltstone)

Fauna	1	2
Brachiopoda		
Orbiculoidea sp.	x	
Leptaena rhomboidalis (Wilckens)		x
Protoleptostrophia perplana (Conrad)		x
Schellwienella pandora (Billings)		x
Eodevonaria arcuata (Hall)		x
Atrypa reticularis (Linnaeus)		x
Leptocoelia flabellites (Conrad)	x	x
Meristina nasuta (Conrad)		x
Acrospirifer duodenaria (Hall)		x
Mucrospirifer macra (Hall)		x
Cricoconarida		
Tentaculites sp.		x
Incertae sedis		
Taonurus caudagalli (Vanuxem)	x	

the Esopus Formation and Carlisle Center Member of the Schoharie Formation, the lower gray, argillaceous siltstone portion abounds in Taonurus caudagalli.

Faunal and stratigraphic considerations suggest that the Schoharie-Esopus formations, undivided, are mostly Emsian in age, although the lowermost part may be upper Siegenian in age.

Palmerton Sandstone

Definition and Reference Section

The Palmerton Sandstone is a thick, but areally restricted, body of coarse grained to conglomeratic sandstone that occurs only in the Lehigh Valley region. It was named by Swartz and Swartz (1941, p. 1177) for exposures on Stony Ridge in the vicinity of Palmerton, Carbon Co., Pa., where it forms spectacular rock ramparts known locally as the "Devil's Wall" (Fig. 65). The Palmerton bears a striking resemblance to the Ridgeley Sandstone, and until Swartz and Swartz (1938) recognized its higher stratigraphic position, it had been included with the older sandstone and assigned an Oriskany age (Chance, 1882; Hill, 1886; Miller, 1911).

The reference section of the Palmerton Sandstone is in the deep cut of the Pennsylvania Turnpike, Northeast Extension, through Stony Ridge, 0.2 mile south of West Bowmans, Carbon Co., Pa. (P22).

Figure 65.--"The Devil's Wall," a ledge of vertically-dipping Palmerton Sandstone, on Stony Ridge, 0.2 mile south of West Bowmans, Carbon Co., Pa. Craggy, deeply weathered appearance is caused by weathering along well-developed joints. View to north from east side of Northeast Extension, Pennsylvania Turnpike.

Lithology

The Palmerton Sandstone consists of massive, practically unbedded, very light gray (N8), locally moderate red (5R 4/6) mottled, coarse grained to conglomerate quartz sandstone. Most beds are moderately to well sorted. Modal grain size is generally 1 to 2 mm., with some beds, especially conglomeratic ones, being bimodal. Bimodality is not as pronounced as in the Ridgeley, however (Sevon, 1968). In hand specimen, the sand grains appear angular, but this is largely the result of silica overgrowths on originally well-rounded grains. Rare brachiopod and coral molds are the only fossil constituents.

Bedding planes are poorly defined throughout the unit, and stratification is usually marked only by scattered pebble zones or layers of distinctly finer sandstone. Only near the base, just above the contact with the Schoharie-Esopus siltstone, is bedding clearly developed. The most prominent planar features in the Palmerton Sandstone are joints, which dominate the outcrop appearance and aid in the natural disintegration of the rock (Sevon, 1969, p. 119).

Silica comprises over 95 per cent of the sandstone, with clay and hematite making up most of the remaining 5 per cent. Silica occurs as both grains and cement. Although the Palmerton is generally clean, some patches of clay are present in interstices between grains. Hematite appears as a secondary cement throughout the Palmerton outcrop. Its distribution appears to bear a relationship to the occurrence of the hematitic Hazard "paint ore" at the base of the Onondaga Limestone (Sevon, 1969, p. 123).

Thin sections of the Palmerton Sandstone reveal that the grain fraction is composed of monocrystalline quartz, composite (polycrystalline) quartz, and chert (Fig. 66-70). The percentage of each of these components in any rock sample depends on the size of the grains. Very coarse sand and granules (greater than 1.0 mm.) tend to be composite quartz or chert, while fine, medium and coarse sand grains are monocrystalline (Table 7).

TABLE 7

PERCENTAGE OF QUARTZ GRAIN TYPES IN REPRESENTATIVE THIN SECTIONS OF THE PALMERTON SANDSTONE (VISUAL ESTIMATES)

(ff, finer fraction = less than 1.0 mm.; cf, coarser fraction = greater than 1.0 mm.; T = total)

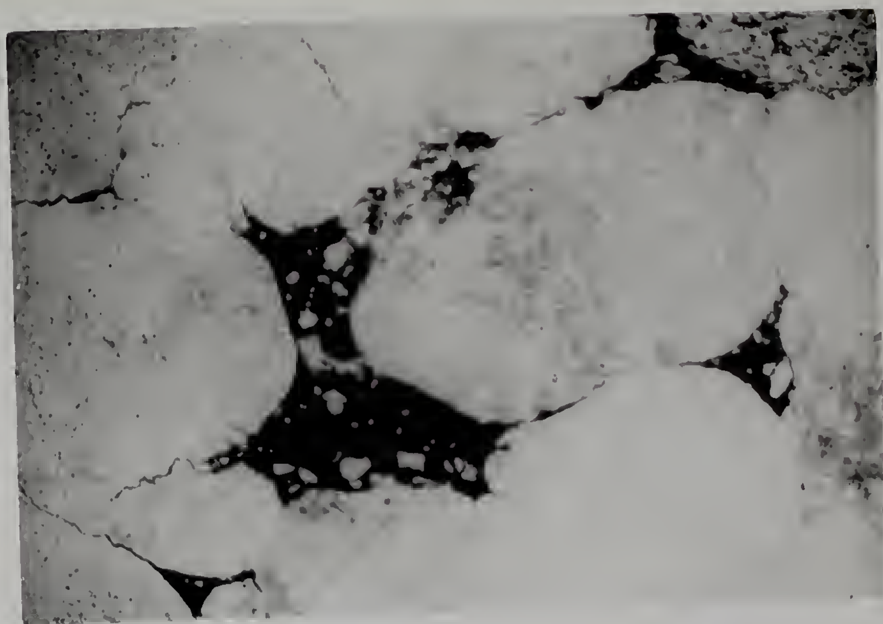
	Thin Section Number								
	P17-12			P22-15			P23		
Grain Fraction	ff	cf	T	ff	cf	T	ff	cf	T
Monocrystalline	90	15	75	75	10	25	-	10	10
Polycrystalline	5	65	20	25	80	60	-	70	70
Chert	5	20	5	0	10	15	-	15	15

1.0 mm.

Figure 66.—Photomicrograph of moderately sorted (bimodal), coarse grained quartz sandstone, Palmerton Sandstone, Saylorsburg, Monroe Co., Pa. (P17-12). Note polycrystalline quartz grains, sutured grain contacts, and quartz overgrowths. (Polarized light.)

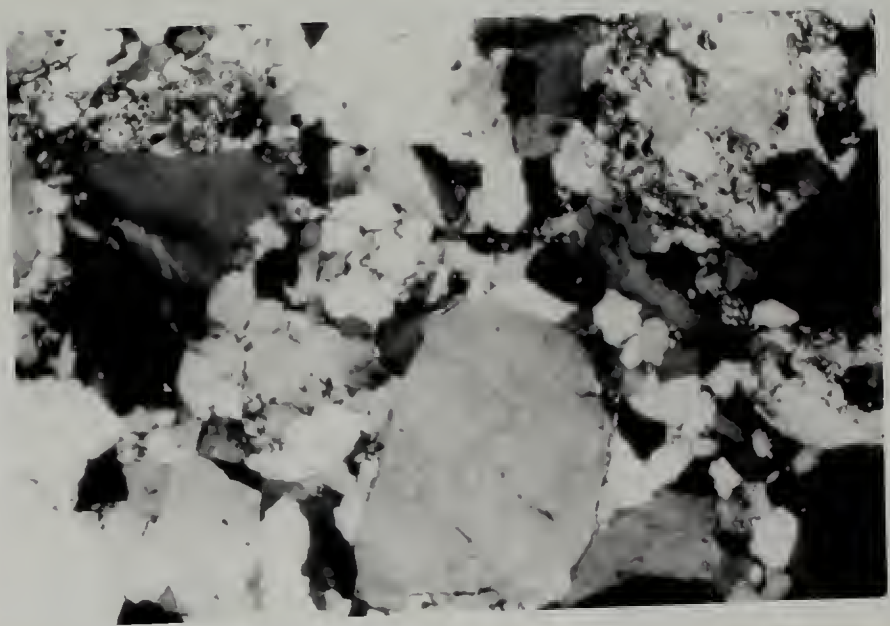
1.0 mm.

Figure 67.—-Photomicrograph of well sorted, coarse grained quartz sandstone, showing strained quartz overgrowth on strained, rounded qúartz grain, Palmerton Sandstone, Bowmanstown, Carbon Co., Pa. (P21-5). (Polarized light.)



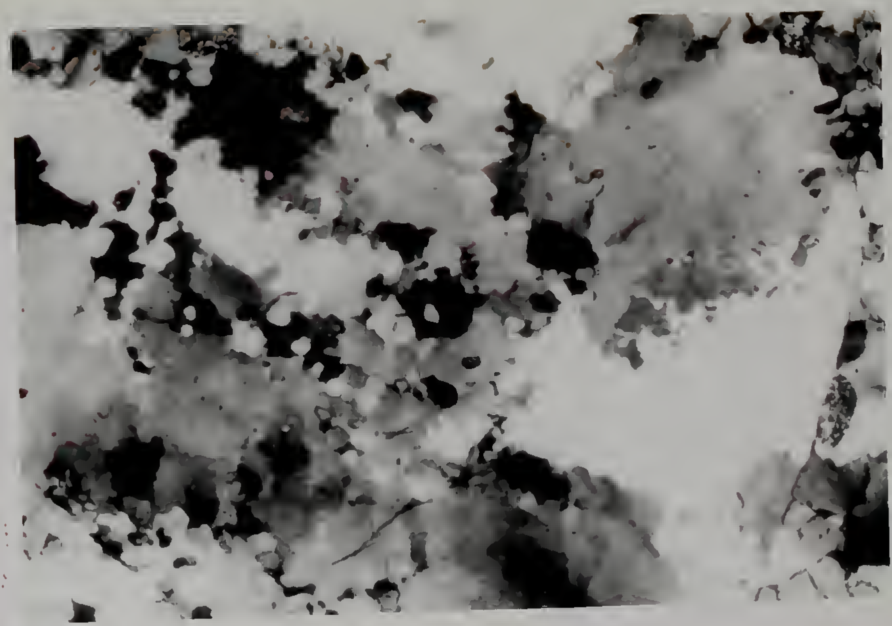
1.0 mm.

Figure 68.—Photomicrograph of moderately well sorted, coarse grained quartz sandstone, cemented by secondary hematite, Palmerton Sandstone, Germans, Carbon Co., Pa. (P23). Note sutured contacts between grains and corrosion of grains by hematite. Quartz grains show closely-spaced deformation lamellae. (Plane light.)



1.0 mm.

Figure 69.—Photomicrograph of moderately sorted (bimodal), pebbly quartz sandstone, Palmerton Sandstone, West Bowmans, Carbon Co., Pa. (P22-15). Note sutured grain contacts, strained quartz grains, and moderate cataclastic texture. (Polarized light.)



1.0 mm.

Figure 70.—Photomicrograph of moderately well-sorted, coarse quartz sandstone, Palmerton Sandstone, Little Gap, Carbon Co., Pa. (P19-20). Note extreme cataclastic texture, with strained quartz grains, stylolitic grain contacts, and abundant crush quartz. (Polarized light.)

The Palmerton is generally cemented by silica (Fig. 66-67), but hematite cement is locally abundant (Fig. 68). It is variably indurated along its outcrop, some portions being extremely resistent to disintegration, while others break down easily into friable sandrock (Sevon, 1969, pp. 124-128). Hematite cemented sandstone occurs mainly in the lower part of the unit.

Most thin sections of the Palmerton Sandstone show a striking cataclastic texture (Fig. 69-70). Quartz grains are intensely strained, sutured grain contacts are the rule, and crush quartz (Fellows, 1943, p. 1414) is common. Undoubtedly, this is a result of the intense deformation that the unit has experienced (Sevon, 1969), p. 129). Since the silica overgrowths are strained in continuity with the quartz grains, it is evident that the deformation that produced the strained and crushed quartz followed primary lithification of the sandstone. Hematite, which locally replaces strained quartz grains and silica overgrowths, is postdeformational.

Contact Relations

In the outcrop belt between Saylorsburg, Monroe Co., and Andreas, Schuylkill Co., the Palmerton Sandstone conformably overlies the Schoharie-Esopus formations, undivided, and abruptly underlies the Onondaga Limestone. West of Andreas and in the subsurface north of the outcrop belt, the relationship of the Palmerton to adjacent units is largely conjectural.

The bottom contact of the Palmerton is placed at the base of the lowest coarse sandstone bed in the interbedded sandstone and siltstone interval that overlies the siltstones of the Schoharie-Esopus. Thickness of the interbedded unit is 7 feet at Little Gap (P19), 4 feet at West Bowmans (P22), and 3 feet at Stony Mountain School (P24). Both siltstone and sandstone beds are generally less than one-foot thick. In the middle quarry at Germans, Carbon Co. (P23), the base of the Palmerton Sandstone contains numerous large, convex-upward brachiopod molds.

The actual contact of the Palmerton Sandstone with the overlying Onondaga Limestone can be observed at only a few localities. It is probably disconformable. In the Pennsylvania Turnpike cut through Stony Ridge, 0.2 mile south of West Bowmans (P22), the Palmerton is carbon stained and deeply weathered at the top and is overlain by silty, grayish red (10R 4/2) shale that represents leached beds of the Hazard "paint ore." In the western-most quarry at Germans (P23), 4.5 miles to the southwest, the upper part of the Palmerton consists of a few feet of coarse grained, friable, pebbly sandstone (with pebbles up to 4 mm. in diameter) followed by a thin bed of finer grained (0.5 to 1.0 mm.) bituminous sandstone. Abruptly overlying the sandstone bed is fossiliferous, varicolored clay at the base of the Onondaga.

Distribution and Thickness

The Palmerton Sandstone occurs only in Monroe, Carbon, and Schuylkill counties, Pa. The eastern limit of its outcrop belt is the east end of Cherry Ridge at Bossardsville, Monroe Co. Its western limit is uncertain, but the sandstone probably pinches out in the vicinity of New Ringgold, Schuylkill Co., 40 miles to the southwest. In the subsurface to the north and northwest, the Palmerton grades laterally into the upper part of the Schoharie Formation and disappears within a few miles of its outcrop.

In Monroe Co., the Palmerton Sandstone appears to extend eastward to the synclinal termination of Cherry Ridge, 0.4 mile south of Bossardsville. Large boulders of coarse grained, iron-stained sandstone mark its occurrence at the crest of the ridge, just south of the Hamilton Stone Company quarry. The Onesquethaw outcrop then swings westward around the nose of the Kemmererville Anticline, and the Palmerton Sandstone is seen no more.

The Palmerton Sandstone can be traced southwestward from Bossardsville by the occurrence of its characteristic bouldery float at or near the crest of Cherry Ridge and its extension, Chestnut Ridge. However, no complete exposure of the unit is known in

Monroe Co. It is more than 85 feet thick along Pa. Rte. 115, 0.5 mile southeast of Saylorsburg (P17), and probably about 100 feet thick in the quarries of the Universal Atlas Cement Company on Chestnut Ridge, 4.0 miles northeast of Kunkletown (Epstein and Epstein, 1967, p. 58; 1969, p. 187) (Fig. 71).

In Carbon Co. the Palmerton is almost continuously exposed along Stony Ridge from Little Gap southwestward to Ashfield, a distance of about 10 miles (Fig. 71). It is 143 feet thick at Little Gap (P19), 139 feet thick in the Alliance Stone Company quarry at Palmerton (P20) (Swartz and Swartz, 1941, p. 1150), and 111 feet thick at West Bowmans (P22) near the Lehigh River. Its subsurface extension to the north is indicated by the 32 feet of Palmerton Sandstone reported in the Graver Estate No. 1 well (P69), 3.3 miles north of Palmerton (Lytle, et al., 1965, p. 40).

Southwest of the Lehigh, the Palmerton is significantly thinner than to the northwest. Thirty-nine feet are exposed at Stony Mountain School (P24), 48 feet in the active quarry of the Refractories Sand Company at Andreas, Schuylkill Co. (P25), and probably less than 50 feet at Millers (Sevon, 1968). No unequivocal Palmerton exposures are known southwest of Millers, although bouldery float of a sandstone that resembles the Palmerton can be traced along strike at least to New Ringgold, 10 miles beyond Millers (Sevon, 1967,

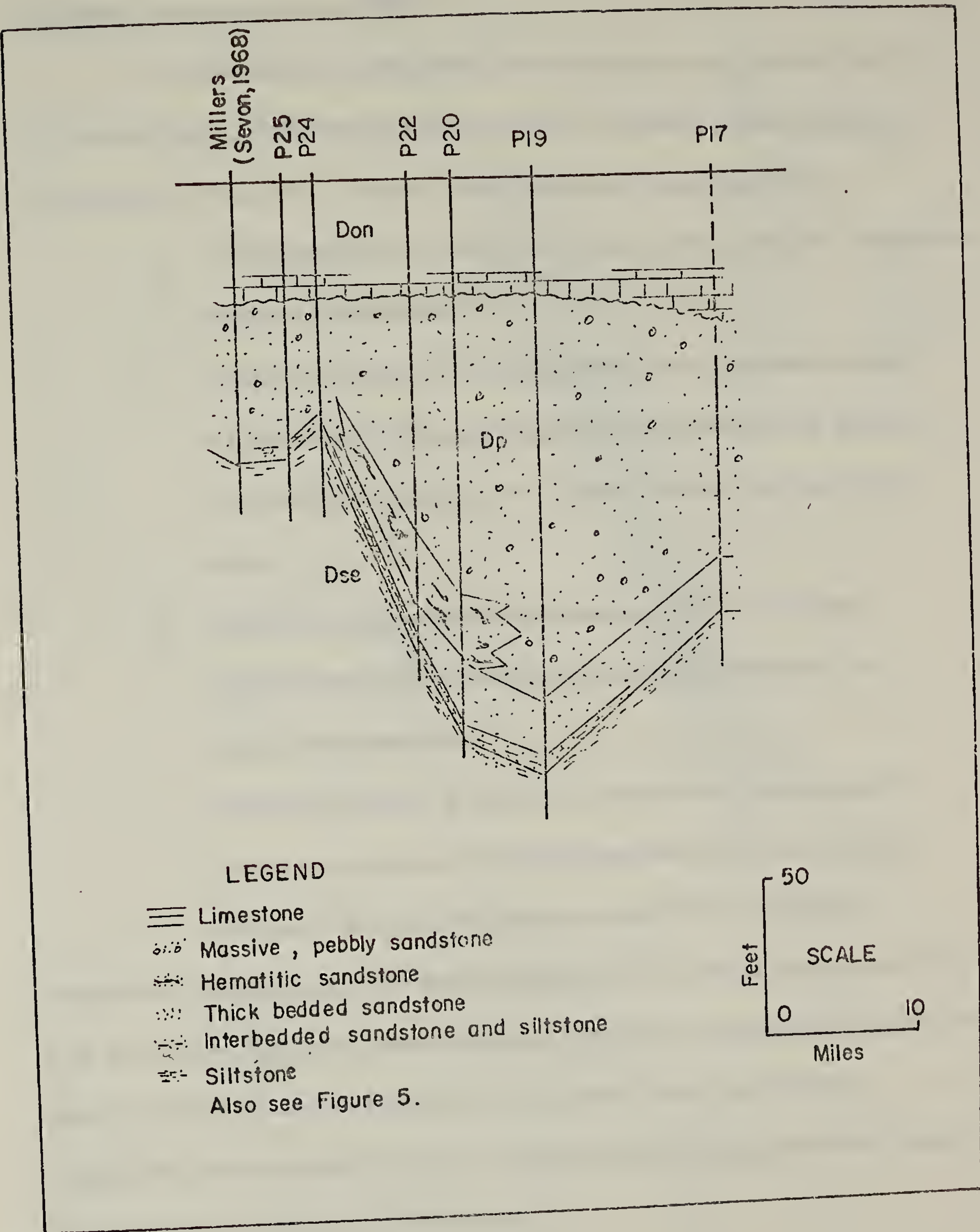


Figure 71.—Stratigraphic sections of Palmerton Sandstone.

personal communication; 1968).

The Palmerton lithosome is interpreted as a narrow bar, 5 to 7 miles wide, that trends about N 75° E, parallel to the present outcrop belt (Fig. 72). Such a configuration is suggested by:

1. The rapidity with which the unit grades into the Schoharie north of Bossardsville;
2. Abrupt thinning of the sandstone from 139 feet in the Aliance Sand Company quarry in Palmerton to 32 feet in the Graver Estate No. 1 well, about 3 miles to the north;
3. The relatively uniform thickness (100 to 150 feet) maintained by the Palmerton from Saylorsburg to West Bowmans; and
4. The coincidence of the abrupt change in thickness of the unit southwest of West Bowmans with a change in strike of the outcrop belt from N 75° E to N 60° E.

Therefore, exposures from Saylorsburg (P17) to West Bowmans (P22) may represent the thick axial portion of the bar, while exposures from Stony Mountain School (P24) to Millers may lie on the thinner southeast (or landward) margin. To the west of West Bowmans, the axis of the bar lies in the subsurface.

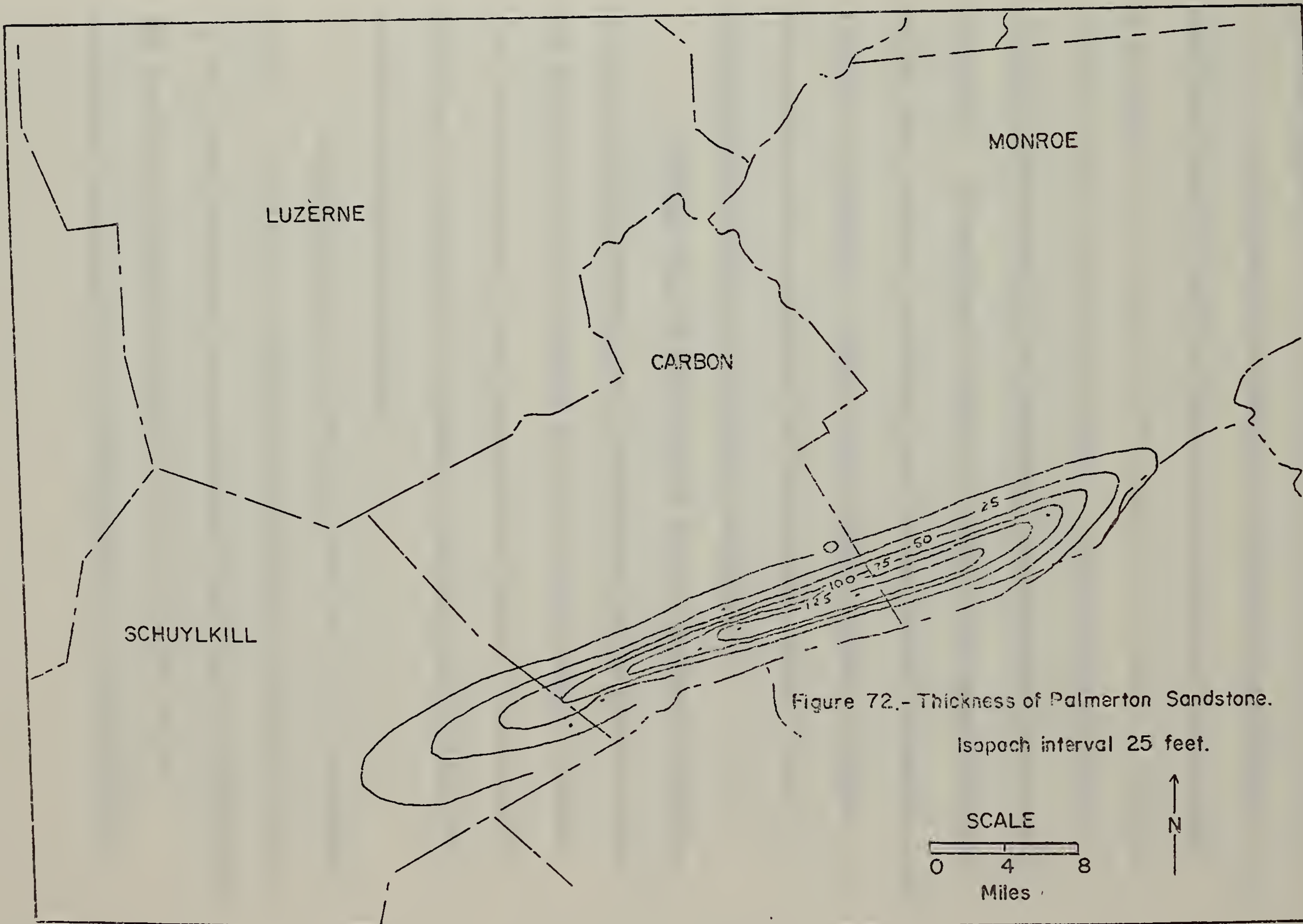


Figure 72.- Thickness of Palmerton Sandstone.
Isopach interval 25 feet.

Fauna and Age

The Palmerton Sandstone is relatively unfossiliferous. Molds and casts of solitary rugose corals and large disarticulated brachiopods occur locally, but the material is too poorly preserved to permit more refined classification. Generally the fossils are widely scattered through the sandstone, the brachiopod valves being convex-up. At Germans, Carbon Co. (P23), many large brachiopod molds were observed in friable, very coarse grained sandstone at the base of the formation. These may be robust Schoharie-Esopus forms which were redeposited by the vigorous currents which accompanied the change to Palmerton deposition.

Although the Palmerton itself does not contain a distinctive fauna, its Onesquethawan age is confirmed by its occurrence above the Schoharie-Esopus siltstone and below the Onondaga Limestone, both of which contain a rich Onesquethawan fauna. A more rigorous definition of the age of the Palmerton, however, must be based on regional stratigraphic relations.

Swartz and Swartz (1941, pp. 1180-1181, pl. 1) and Willard (1939, p. 153; 1953, p. 2201) have considered the Palmerton a facies of the Esopus Formation of the Delaware Valley region. Although both the Swartzes and Willard imply in their early papers that the Palmerton is equivalent to the upper Esopus (i.e., the Schoharie

Formation of present usage), Willard (1953, p. 2309) later clearly states that the Schoharie Formation is absent in the Lehigh Gap region and that the Palmerton is equivalent to the upper Esopus Formation (restricted).

On the other hand, Epstein and Epstein (1969, pp. 144, 157) indicate that the Palmerton is equivalent to both the upper part of the Schoharie Formation and the lower part of the Onondaga Limestone. Supporting this view are the statements of I. C. White (1882, p. 286) that the Onondaga is extremely sandy at outcrops along a country road 0.3 mile south of Hamilton Center, Monroe Co. (P16). The writer examined these exposures, but could not verify White's findings.

That the Palmerton Sandstone is correlative with the upper Schoharie Formation (upper part of the Saugerties-Aquetuck members, undivided) of the Delaware Valley area is suggested by:

1. The arenaceous nature of the upper Schoharie at Stroudsburg and areas to the northeast (Johnsen, 1957);
2. The conformable relationship with the underlying Schoharie-Esopus siltstone, which contains a typical Schoharie fauna (Boucot and Johnson, 1968, pp. B2-B3);
3. The abrupt, disconformable contact with the overlying Onondaga Limestone.

Therefore, the Palmerton is probably entirely upper Emsian (uppermost Lower Devonian) in age.

Onondaga Limestone

Definition and Reference Sections

The Onondaga Limestone in the region between western Monroe and eastern Lebanon counties, Pa., is a varied sequence of argillaceous limestone, siliceous limestone, ferrugenous limestone, and calcareous shale that everywhere underlies the Middle Devonian Marcellus Formation, but disconformably overlies units ranging in age from Late Silurian (Bloomsburg Formation) to upper lower Devonian (Palmerton Sandstone). It represents a transition between the typical cherty Onondaga Limestone of the Delaware Valley and the argillaceous Selinsgrove Limestone of the Susquehanna Valley (Willard, 1939, p. 151). The name Onondaga (Hall, 1839) is extended to these rocks because (1) they are continuous in outcrop with the Onondaga Limestone of the Stroudsburg area, and (2) they contain a profuse fauna which is more closely related environmentally to that of the Onondaga Limestone than that of the Selinsgrove Limestone.

Near the base of the Onondaga Limestone in Carbon Co. is the Hazard "paint ore" Member, an iron-rich limestone that was formerly extensively mined for paint pigments (Chance, 1882; Hill, 1886; Miller, 1911). The Hazard Member was named by Miller (1911) for exposures in underground mines near Hazard, in the western part of what is now the borough of Palmerton. The Tioga Metabentonite Bed occurs at the top of the Onondaga at West Bowmans (P22) and Swatara Gap (P29).

Exposures of the Onondaga Limestone in western Monroe, Carbon, Schuylkill, and Lebanon counties are rare. Those that do exist are generally deeply weathered and provide only incomplete sections. Two reference sections are herein designated as:

1. The cut on the Pennsylvania Turnpike, 0.2 mile south of West Bowmans, Carbon Co. (P22);
2. The cut on the south side of the westbound lane of Interstate Rte. 81, 0.5 miles northwest of Swatara Gap, Lebanon Co. (P29).

The old mines in which the Hazard "paint ore" occurred in an unweathered condition are no longer accessible. The Hazard is completely exposed, but deeply weathered, in the turnpike cut at West Bowmans.

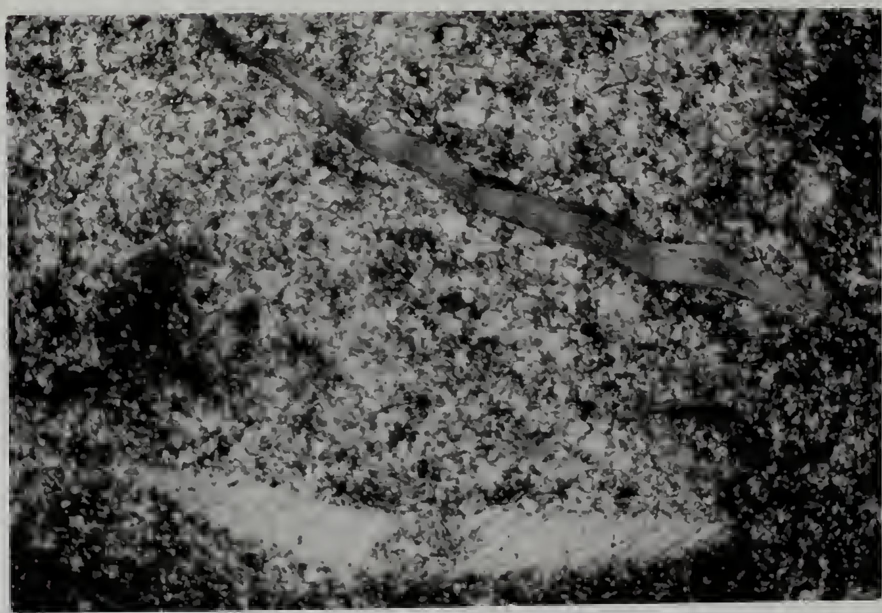
Lithology

In the Lehigh-Schuylkill region, the Onondaga Limestone consists predominantly of argillaceous limestone and calcareous shale. Ferruginous limestone (the Hazard "paint ore" Member) occurs in the Lehigh Gap area between Little Gap and Andreas.

Nodular chert forms a significant component of the upper Onondaga as far as West Bowmans, but is unknown west of there. Metabentonite beds have been found in the upper Onondaga at West Bowmans (P22) and Swatara Gap (P29).

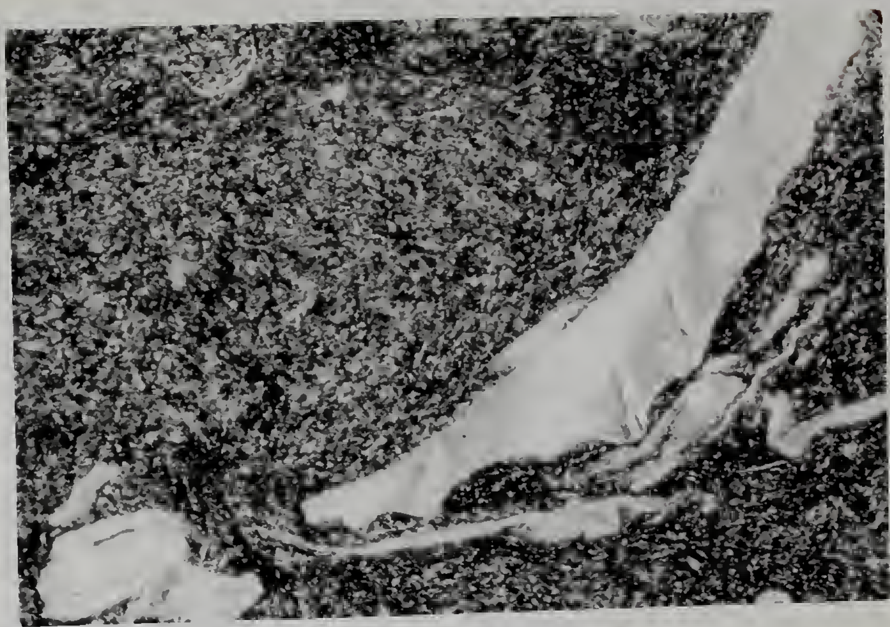
Typically the limestones are medium to thick bedded, medium gray (N5) to medium dark gray (N4), fine grained, argillaceous, variably siliceous, fossiliferous calcilutites and calcisiltites. Where dip of bedding is steep, they readily weather to soft, grayish-orange (10YR 6/6) and dusky yellow (5Y 6/4) clay stone, which often is quite micaceous. In thin section, the limestones are seen to consist of abundant fossil fragments in a burrowed calcareous mud matrix (Fig. 73, 74). The fossils are mostly brachiopod, crinoid, bryozoan and trilobite fragments, some or most of which may be rimmed by silica. The matrix is composed of fine micritic calcite and terrigenous mud (particle size 0.01 mm. or less) with numerous patches of coarser calcite pseudospar (particle size to 0.3 mm.) (Folk, 1965). Nodular, grayish black (N2) chert occurs in the Onondaga Limestone east of the Lehigh Gap area. Generally it comprises only about 10 per cent of the rock.

Limestone samples from Little Gap (P19), Palmerton (P20), and Schuylkill Haven (P26) were digested in cold dilute HCl. They yielded 15 per cent, 20 per cent, and 46 per cent insoluble residue,



1.0 mm.

Figure 73.—Photomicrograph of poorly sorted, burrowed biocalcilulite, with brachiopod (top) and crinoid fragments, Onondaga Limestone, Palmerton, Carbon Co., Pa. (P20). Insoluble residue 20 per cent. (Polarized light.)



1.0 mm.

Figure 74.—Photomicrograph of poorly sorted, intensely burrowed, siliceous biocalcilutite, Onondaga Limestone, Schuylkill Haven, Schuylkill Co., Pa. (P26-13). Large pseudopunctate brachiopod fragment with taleolae is brachial valve of Leptaena. Note thin silica rims around fossil fragments (especially apparent on concave side of Leptaena valve). Insoluble residue of 46 per cent consists of terrigenous quartz silt and argillaceous material, as well as secondary silica. (Plane light.)

respectively. Residues from the first two samples are fine grained, medium dark gray (N4) and highly organic, while that from the third is aggregated, siliceous, medium dark gray (N4) and also highly organic. Insoluble residues of greater than 25 per cent are probably confined to the highly siliceous (and cherty) limestones which form only a minor part of the Onondaga in the Lehigh-Schuylkill area.

In Schuylkill Co., medium gray (N5) and medium dark gray (N4), fossiliferous, calcareous shale occurs as 4 to 12 inch interbeds between argillaceous limestone beds in the lower 20 feet of the Onondaga. Generally this lower shaly unit is poorly exposed, but its presence can be inferred by the abundance of platy brownish-gray weathered, calcareous shale float in covered intervals below the thick limestone beds that characterize the upper Onondaga.

No fresh exposures of the Hazard Member were examined during the present study. At West Bowmans (P22), the only locality where the complete unit crops out, the Hazard is 5 feet thick and consists of fine grained, silty, grayish-red (10R 4/2) weathered, fossiliferous limestone, some beds of which are thoroughly leached to shale and clay. In the old paint ore tunnels where it occurred in an unweathered condition, the Hazard Member has been described as massive, dark blue, pyritic, fossiliferous, dense (S.G. 3.2 to 4.0), ferruginous limestone (Miller, 1911, p. 56). The reddish-gray color seen at West Bowmans develops rapidly upon exposure of the fresh rock by oxidation of iron that was originally present as carbonate (Miller, 1911, p. 56).

The metabentonite beds of the Onondaga Limestone in the Lehigh-Schuylkill region are considered along with the Tioga Metabentonite in a later section.

Contact Relations

Along its outcrop belt from Bossardsville, Monroe Co., to Swatara Gap, Lebanon Co., the Onondaga Limestone overlies units that range in age from upper Lower Devonian (Palmerton Sandstone) to Upper Silurian (Bloomsburg Formation) (Fig. 77). It everywhere underlies black shales of the Middle Devonian Marcellus Formation.

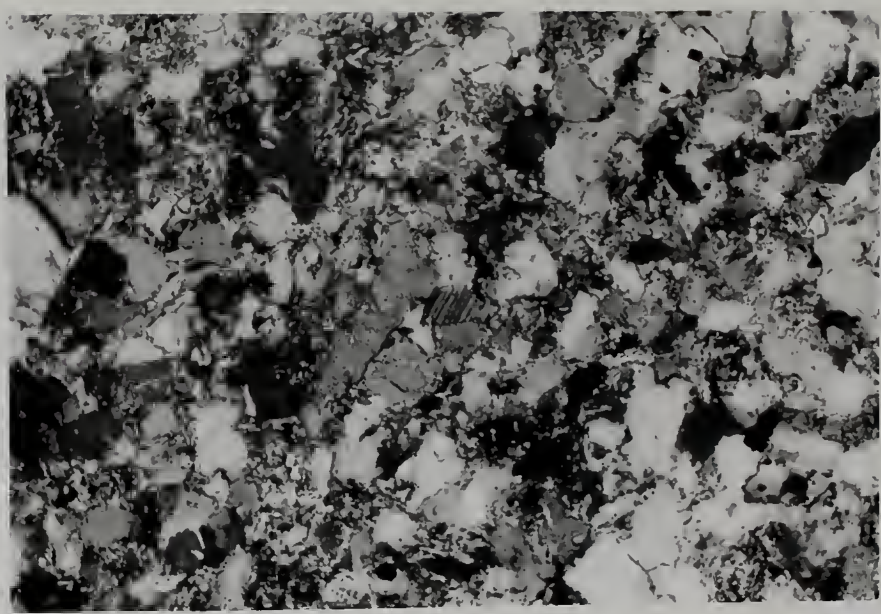
Between Bossardsville and Andreas, the Onondaga abruptly overlies the Palmerton Sandstone. The contact between the two is probably disconformable (p. 165).

In central Schuylkill Co., the Onondaga succeeds the Lower Devonian Ridgeley Sandstone with marked disconformity, the Palmerton Sandstone and Schoharie-Esopus siltstone being absent. The Ridgeley is 5 feet thick, massive, coarse grained to conglomeratic and fossiliferous near Schuylkill Haven (P29), but thins to 3 feet

(Swartz and Swartz, 1941, p. 1132) of pebbly, coarse grained sandstone at Auburn (P27). Farther west the Ridgeley is probably absent, though it may be represented by scattered sandstone float at Moyers (P28), 9 miles west of Auburn. Nowhere can the actual Onondaga-Ridgeley contact be observed, but it is presumed to be abrupt.

In the area between Auburn and Swatara Gap, the Onondaga Limestone disconformably overlies olive-green sandstone and shale of the upper Bloomsburg Formation (Upper Silurian). The most significant exposure showing this relationship is in a deep cut on Interstate Rte. 81 at Swatara Gap (P29). There the Onondaga-Bloomsburg contact is very irregular and is marked by a 6-inch bed of poorly sorted, cobbly polymict conglomerate at the base of the Onondaga, as well as large, calcareous, phosphatic concretions in the limestone above the conglomerate layer (Fig. 75). Olive-green sandstone (Fig. 76), the "Inwood Sandstone" of Cayugan age (Swartz and Swartz, 1931), that occurs beneath the conglomerate persists on strike at least 15 miles northeastward along the north flank of Blue Mountain. Although no fossils have been found in the sandstone, a Silurian age is suggested by its conformable relationship with the red shales and sandstones that comprise the bulk of the Bloomsburg. The "Inwood" bears little resemblance to the Ridgeley Sandstone, with

Figure 75.—Polymict conglomerate at disconformable contact between Onondaga Limestone and Bloomsburg Formation (upper sandstone member), south side of southbound lane of Interstate Rte. 81, 0.5 mile northwest of Swatara Gap, Lebanon Co., Pa. (P29-1). View of upper bedding surface, with sandstone ledges in background.



0.5 mm.

Figure 76.—Photomicrograph of fine grained, moderately sorted, argillaceous sandstone, Bloomsburg Formation (upper sandstone member), Swatara Gap, Lebanon Co., Pa. Grains are mostly fine, angular quartz sand in argillaceous (sericite) matrix. Note plagioclase grain in center. (Polarized light.)

which it is equated by Wood, Trexler and Kehn (1969, pp. 25-26).

The Onondaga-Marcellus contact is abrupt but conformable. At West Bowmans (P22) a 6-inch layer of micaceous metabentonite with thin iron-stone interbeds occurs between leached fossiliferous limestone of the Onondaga and dark gray, fissile, pyritic shale of the Marcellus. There is no interlayering of limestone and shale. At Swatara Gap (P29), the only other exposure of the contact in the area, a metabentonite (?) also is present at the top of the Onondaga. Intercalation of limestone and shale may be represented by beds of tan clay and soft, light gray shale that alternate for three feet below the metabentonite (?).

Distribution and Thickness

In the Lehigh-Schuylkill region, the Onondaga Limestone crops out continuously in a narrow outcrop belt between Monroe and Lebanon counties (Fig. 77). To the northeast, it grades laterally into the massive, cherty Onondaga Limestone of the Stroudsburg area, while in the subsurface to the north and northwest, it grades into more argillaceous limestones that are transitional with the Selinsgrove Limestone Member of the Needmore Formation. West of Swatara Gap, Lebanon Co., the Onondaga pinches out by disconformity (Willard, 1939, p. 148).

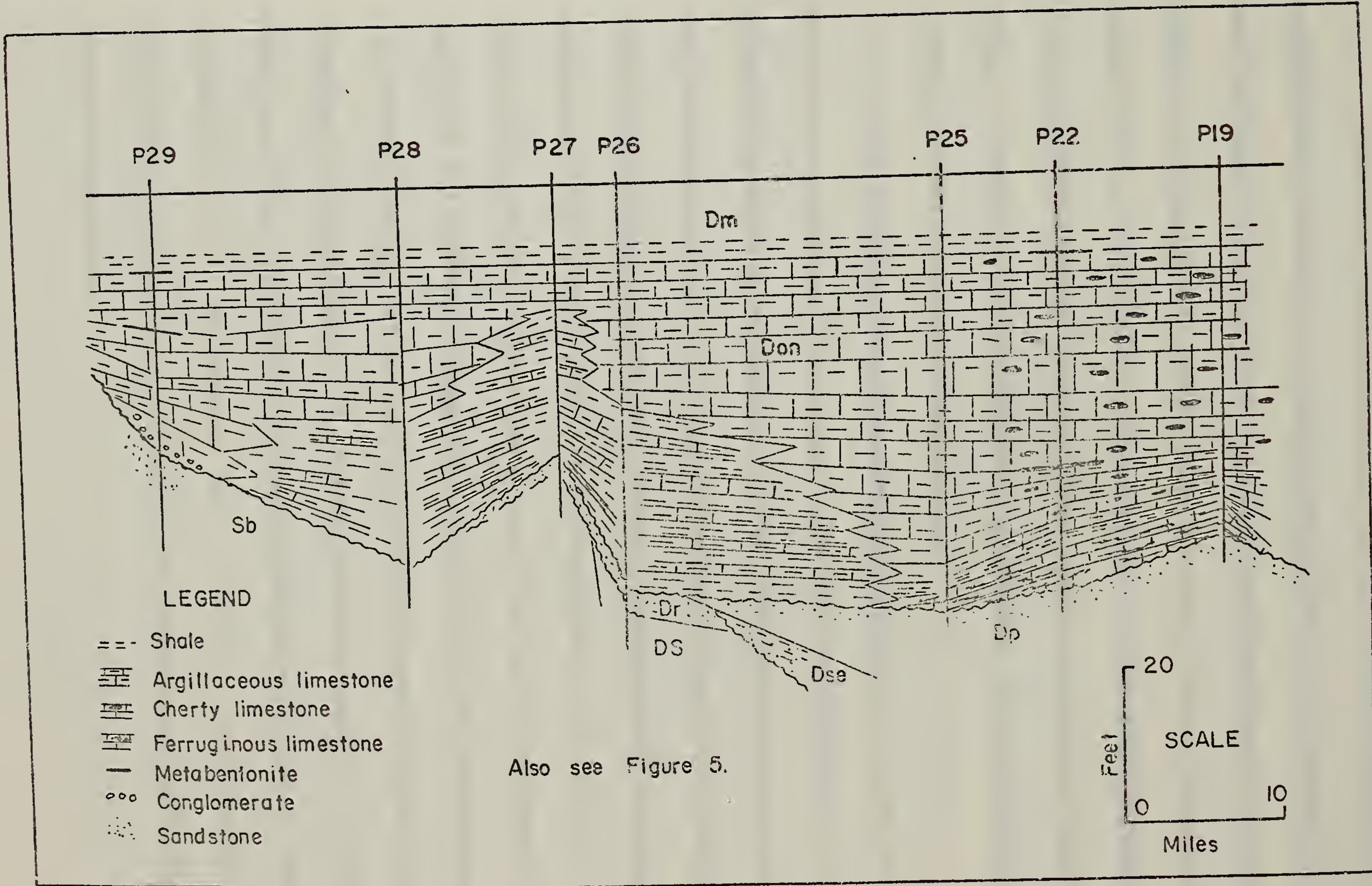


Figure 77.—Stratigraphic sections of Onondaga Limestone, Lehigh-Schuylkill region, Pa.

Thickness of the Onondaga Limestone in south-central and southwestern Monroe Co. is largely conjectural. It is probably at least 100 feet thick at the nose of a minor anticlinal flexure, 0.4 mile south of Hamilton Square, where it is extremely cherty. Epstein and Epstein (1967, p. 58; 1969, p. 187) estimate a thickness of 80 feet in the clay quarries of the Universal Atlas Cement Company on Chestnut Ridge, 4.0 miles north-northeast of Kunkletown. The unit probably continues to thin southwest of Kunkletown.

The Onondaga is quite extensively exposed in Carbon and eastern Schuylkill counties between Little Gap and Andreas. A complete exposure at West Bowmans (P22) shows a thickness of 43 feet, the lower 5 feet of which can be assigned to the Hazard Member. Incomplete sections at Little Gap (P19) and Andreas (P25) indicated thicknesses of at least 32 and 45 feet, respectively. The Hazard Member does not crop out at Little Gap (P19), but it is reported to be present in old mine workings on the west side of the gap (Swartz and Swartz, 1941, p. 1153). In the paint ore mines at Hazard, the Onondaga is 45 to 50 feet thick, and the Hazard probably 5 to 10 feet thick, 2 to 3 feet of which actually was mined as ore (Chance, 1882, pp. 355-356; Swartz and Swartz, 1941, p. 1148). At Andreas (P25) the Hazard is represented by a few feet of reddish brown (10R 4/2) weathered limestone.

The thickness of the Onondaga Limestone in Schuylkill Co. can only be estimated from incomplete exposures. It is probably 30 to 40 feet thick at Schuylkill Haven (P26), about 25 feet thick at Auburn (P27), and 38 feet thick at Moyers (P28). The calcareous shale and limestone unit that persistently occurs at the base of the Onondaga in Schuylkill Co. varies between 15 and 25 feet thick.

Sixteen miles southwest of Moyers, at Swatara Gap (P29), the Onondaga consists of 28 feet of thick bedded, argillaceous limestone. The calcareous shale and limestone unit is missing.

No exposures of the Onondaga Limestone are known between Swatara Gap and the Susquehanna River. It is likely that the Onondaga extends to Indiantown Gap and somewhat beyond. At Indiantown Gap, the Onondaga, if present, is hidden in a long covered interval separating outcrops of the Upper Silurian Bloomsburg red beds from those of the Middle Devonian Montebello Sandstone. Exposure is also poor in Manada Gap, Dauphin Co., the next gap to the west. Although no definite conclusions can be drawn as to just where the Onondaga pinches out west of Swatara Gap, there is little doubt of its absence by unconformity at Susquehanna Gap (Willard, 1939, p. 148).

In western Monroe, Carbon, and eastern Schuylkill counties, the Onondaga thickens rapidly northeastward into the Northeastern

Pennsylvania Basin. It gradually loses its cherty nature in the subsurface and probably contains considerably more argillaceous material (Fletcher and Woodrow, 1970, p. 5). In western Schuylkill and Lebanon counties, the Onondaga gradually thickens northward into a shallow extension of the main northeastern basin. Its subsurface lithology in this area probably more closely resembles the sparingly fossiliferous Selinsgrove Limestone of the central Susquehanna Valley than the richly fossiliferous Onondaga Limestone of the Lehigh-Schuylkill region.

Fauna and Age

The Onondaga Limestone in the Lehigh-Schuylkill region contains a large and varied marine fauna that is dominated by brachiopods. Bryozoans, bivalves, and trilobites are abundant, the latter being especially characteristic of the Hazard "paint ore" Member (Willard and Whitcomb, 1938). Corals, gastropods, and cricoconarids also represent significant faunal elements. (Table 8.)

Most abundant of the brachiopods in the study collections are *Levenia lenticularis*, *Leptaena rhomboidalis*, *Megastrophia (Megastrophia) concava*, *Eodevonaria elymencheri* and other chonetids,[11] and *Coelospira camilla*. *Paraspirifer acuminatus* and *Pentagonia*

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[11] Species noted by Swartz and Swartz (1941) include "*Chonetes*" *hemisphericus*, "*C.*" *setiger*, *Longispina mucronatus*, *Devanochonetes* (?) *lineatus*, and *D.* cf. *D. scitulus*.

TABLE 8

FAUNA OF THE ONONDAGA LIMESTONE, LEHIGH-SCHUYLKILL REGION, PA.

(1 = localities P19, P20, P22, P23, P25; 2 = localities P26, P27, P28, P29)

Fauna	1	2
Coelenterata		
Heterophrentis simplex (Hall)		x
Bryozoa		
Unidentified fenestellids	x	
Fenestrellina sp.		x
Lichenalia sp.		x
Brachiopoda		
Levenia lenticularis (Vanuxem)		x
Leptaena rhomboidalis (Wilckens)	x	x
Strophodonta (Strophodonta) demissa (Conrad)		x
Megastrophia (Megastrophia) concava (Hall)		x
Douvillina (Douvillina) inaequistriata (Conrad)		x
Schellwienella pandora (Billings)		x
Unidentified chonetids	x	x
Eodevonaria elymencheri Boucot and Harper	x	x
Atrypa reticularis (Linnaeus)		x
Coelospira camilla Hall		x
Leptocoelina acutiplicata (Conrad)		x
Athyris spiriferoides (Eaton)		x
Pentagonia unisulcata (Conrad)		x
Kozlowskiellina (Megakozlowskiella) raricosta (Conrad)	x	x
Paraspirifer acuminatus (Conrad)		x
Elita fimbriata (Conrad)		x
Gastropoda		
Palaeozygopleura hamiltoniae (Hall)		x

TABLE 8—Continued

Fauna	1	2
Bivalvia		
Paracyclas lirata (Conrad)		x
Cypricardinia indenta (Conrad)		x
Trilobita		
Odontocephalus selenourus (Eaton)	x	
Phacops pipa Hall		x
Cricoconarida		
Tentaculites bellulus Hall	x	

unisulcata, though common locally, appear to be restricted in geographical occurrence.

Bivalves, namely *Paracyclas lirata* and *Cypricardinia indenta*, are known only from the shalier portions of the formation.

Only two trilobites, *Odontocephalus selenourus* and *Phacops pipa*, are represented in the collections. Willard and Whitcomb (1938) report the occurrence of both these species, aswell as *Cyphaspis minuscula*, *Phaethanides gemmaeus*, *Conoliches eriopsis*, *Acidaspis callicera*, *Phacops cristata*, and *Phacops rana* (? = *Phacops* sp.), in the Hazard Member.

The Onondaga Limestone of the Lehigh-Schuylkill area is believed to have been deposited at about the same time as at least the upper part of the Onondaga Limestone of eastern Pennsylvania, and is, therefore, Eifelian in age.

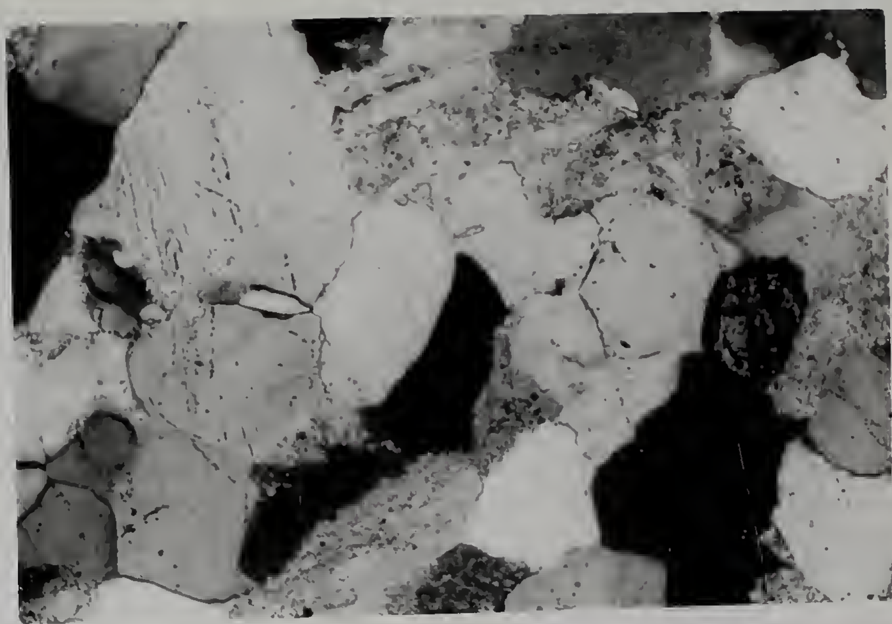
The Onesquethaw Stage in Central Pennsylvania and Areas to the South

At outcrops in the folded Appalachians of central Pennsylvania, the Onesquethaw Stage is represented by shale and argillaceous limestone of the Needmore Formation. Generally the Needmore exhibits a tripartite vertical succession of lithologies (i.e., dark gray, non-calcareous shale, dark gray, calcareous shale, and medium dark gray, argillaceous limestone) that is at least superficially reminiscent of the Esopus-Schoharie-Onondaga interval of eastern Pennsylvania. As shown previously (pp. 41-42; 83; 183), it is possible to trace the three main lithologic subdivisions of the eastern Pennsylvania Onesquethaw into the three subdivisions of the Needmore Formation of central Pennsylvania through deep wells in the intervening subsurface area.

The Onesquethawan rocks of central Pennsylvania apparently always overlie either the Ridgeley Sandstone or Shriver Chert, both of Deerpark age (Fig. 78). The Ridgeley Sandstone is a thick-bedded to massive, medium grained, locally coarse grained to conglomeratic, well sorted, medium light gray (N6), tan to white weathering, highly fossiliferous, calcareous orthoquartzite that is extensively quarried for glass sand. Small-scale cross bedding was observed at several outcrops (Fig. 79) and may be characteristic. Thin sections show that the quartz sand grains of the Ridgeley are generally well rounded and are rimmed by silica overgrowths (primary cement) (Fig. 80). The abundant calcite cement apparently was introduced after primary silicification. (See also Heald, 1965.) The Shriver consists of interbedded limy chert, siliceous limestone, and siliceous shale. Considered together, the Shriver beds are unevenly bedded, dark gray (N3) to medium dark gray (N4), brownish to whitish gray weathering, and sparingly to moderately fossiliferous. When exposed

Figure 78.—Needmore Formation (above) and Ridgeley Sandstone in abandoned sandstone quarry of Lycoming Silica Sand Co. at eastern boundary of Montoursville, Lycoming Co., Pa. (P36). Beds dip north off the flank of the Bald Eagle Mountain Anticline and toward the Allegheny Front.

Figure 79.—Small-scale planar cross bedding in Ridgeley Sandstone, south side of Penn Central Railroad cut, 1.1 miles northwest of Newton Hamilton, Mifflin Co., Pa. (P52). Beds occur in upper 10 feet of Ridgeley and consist of medium grained, supermature, calcareous orthoquartzite (Fig. 80).



0.5 mm.

Figure 80.—Photomicrograph of supermature, calcareous orthoquartzite, Ridgeley Sandstone, Newton Hamilton, Mifflin Co., Pa. (P52). Gráins are mostly monocrystalline quartz with straight extinction. Note silica overgrowths on rounded quartz grains and corrosion of quartz by secondary calcite cement. Heavy mineral grain is zircon. (Polarized light.)

to the elements for a relatively short period of time, the Shriver is leached of its calcareous constituents and breaks down into hackly chert rubble.

Onesquethawan rocks in central Pennsylvania are always succeeded by the Marcellus Formation of Cazenovia age. Typically the Marcellus is a fissile, dark gray (N3) to black (N1), rusty weathering, carbonaceous, non-calcareous to slightly calcareous shale. Silty, grayish black (N2) limestone beds are usually present near the base, and dark gray, argillaceous limestone and calcareous shale (the "Purcell" Member) is relatively persistent in the middle portion. In the central Susquehanna-Juniata Valley region, the Marcellus has been divided into three members (Willard, 1939; Miller, 1961; Conlin and Hoskins, 1962; Dyson, 1963, 1967). In descending order, these are:

Mahanoy Shale Member
Turkey Ridge Sandstone Member
Shamokin Shale Member.[12]

The Mahanoy and Shamokin members are predominantly black to dark gray shale, whereas the Turkey Ridge is a massive, dark gray, fine to medium grained, quartzose sandstone.

A distinctive feature of the Needmore Formation in Pennsylvania, as well as in Maryland, West Virginia, and Virginia, is the

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[12]Hoskins (in Faill and others, 1973) includes the Turkey Ridge and Mahanoy (= Fisher Ridge) in the Mahantango Formation.

occurrence of the Tioga Metabentonite in its uppermost part. Generally the Tioga consists of two beds of brownish-weathering, micaceous siltstone, interbedded with the limestone and shale beds at the top of the Needmore or base of the Marcellus.

Throughout the Valley and Ridge region of central Pennsylvania, the Needmore Formation, together with the lower part of the Marcellus Formation, underlie a valley between low ridges formed by Lower Devonian sandstones and cherts (Ridgeley-Shriver interval) and Middle Devonian sandstones and siltstones (Turkey Ridge Member of Marcellus Formation and Montebello and Sherman Ridge members of Mahantango Formation). Locally, as on the south side of Flint Ridge, about 1.0 mile northeast of Mt. Pleasant Mills, Snyder Co., small sinkholes are developed along the outcrop belt of the limestones at the top of the Needmore. Such solution features are rare, however.

Needmore Formation

Definition and Reference Sections

The Needmore Formation is an extensive argillaceous and argillo-calcareous unit of Onesquethaw age that occurs mainly in the Valley and Ridge Province from east-central Pennsylvania to northern Virginia. As defined in the present paper, it includes all strata between the top of the Ridgeley Sandstone, or Shriver Chert, and the base of the Marcellus Formation, a usage which conforms with that of Dennison (1961) in West Virginia and adjacent states. In central Pennsylvania the designation Needmore Formation is synonymous with Onondaga Group (Willard, 1939, p. 144; Gray et al., 1960) and Onondaga Formation (Willard, 1935; Miller, 1961; Conlin and Hoskins, 1962; Dyson, 1963, 1967). Willard (1939, p. 149) named the Needmore Shale (the lower formation of his Onondaga Group) for exposures along U.S. Rt. 522 between Needmore and Warfordsburg, southern Fulton Co., Pa.

Three members are defined within the Needmore Formation in central Pennsylvania: the Beaverdam Shale Member at the base, an unnamed middle calcareous shale member, and the Selinsgrove Limestone Member at the top. The Beaverdam Shale Member was named by Swain (1958, p. 2867) for exposures of black shale at the base[13] of his "Newton Hamilton formation" (= Needmore Formation) in a cut on the Penn Central Railroad near Beaverdam Run, about 1.0 mile northeast of Newton Hamilton, Mifflin Co., Pa. (P52). It can generally be recognized throughout central and south-central Pennsylvania. The calcareous shale member is the typical "Needmore

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[13] Willard (1939, p. 143) applied the name "Beaver Dam black shale" to black, fissile, fossiliferous shale in the middle of the Needmore at the same locality. This unit is not sufficiently distinct to warrent member status, however.

shale." It is the most persistent and most often exposed of the three members. The Selinsgrove Limestone Member, originally the "Selinsgrove lower limestone," was named by I. C. White (1883, pp. 79-81) for exposures along the Northern Central, now Penn Central, Railroad, 0.25 mile south of Selinsgrove Junction, Northumberland Co., Pa. (P31). Later Willard (1939, p. 146) shortened the name to Selinsgrove Limestone and gave the unit formational rank at the top of the "Onondaga Group." The Selinsgrove gradually becomes more shaly southwest of its type area and cannot be consistently recognized in Bedford, Fulton, and Franklin counties.

In south-central Pennsylvania and nearby Maryland, West Virginia and Virginia, the writer follows Dennison (1961, p. 15) in subdividing the Needmore into three partially intertonguing subfacies: the Beaverdam black shale subfacies, the calcitic shale subfacies, and the calcitic shale and limestone subfacies. These subfacies are roughly equivalent to the three subdivisions of the Needmore Formation in central Pennsylvania, i.e., the Beaverdam Shale Member, the calcareous shale member, and the Selinsgrove Limestone Member, respectively.

Three reference sections for the Needmore Formation in central Pennsylvania and south-central Pennsylvania are herein designated as: (1) the cut on the Penn Central Railroad, 0.25 mile south of Selinsgrove Junction, Northumberland Co. (P31); (2) cuts on the Penn Central Railroad, 1.0 mile northeast and 1.0 mile southwest of Newton Hamilton, Mifflin Co. (P52, P53); and (3) the cut on the east side of Interstate Rte. 70, 1.0 mile northwest of Warfordsburg, Fulton Co. (P63).

Lithology

Throughout most of central Pennsylvania, three lithologic subdivisions can be recognized in the Needmore Formation. In ascending order, these are:

1. Dark gray to grayish black, non-calcareous to slightly calcareous, oolitic shale;
2. Medium dark gray, pale olive weathering, fossiliferous, calcareous shale, with widely spaced interbeds of medium dark gray, very argillaceous limestone; and
3. Medium to thick bedded, medium dark gray to dark gray, fine grained, fossiliferous, argillaceous limestone interbedded with medium dark gray, calcareous shale.

From central Bedford and Fulton counties northward, these units are the Beaverdam Shale Member, the calcareous shale member, and the Selinsgrove Limestone Member, respectively. South of this area, the units correspond to the Beaverdam shale subfacies, the calcitic shale subfacies, and the calcitic shale and limestone subfacies, respectively, of Dennison (1961). The subdivisions are discussed below using only the member terminology.

Beaverdam Shale Member

At the base of the Needmore Formation, from West Virginia northward and northeastward to its outcrop limit in the Susquehanna Valley of central Pennsylvania, is a dark gray (N3) to grayish black (N2), generally slightly calcareous, sparingly fossiliferous shale, that characteristically contains small (1 - 2 mm.), black (N1), phosphatic oolites and larger (3 - 4 inches), hard, calcareous-phosphatic concretions. At Dalmatia, Northumberland Co. (P30), dark gray to grayish black, silty to fine sandy shale at the base of the Needmore has been included in the Beaverdam, but this lithology has not been observed at other localities.

Where the Beaverdam overlies the Ridgeley Sandstone, a thin bed of fine to medium grained, dark gray, rusty weathering, calcareous quartz sandstone is developed at the contact. A thin section of this basal sand (Fig. 81) shows it to be composed of angular to rounded quartz sand grains cemented together by hematite and minor calcite. In some cases, at Flintstone, Allegany Co., Md. (M2), the upper few feet of the Ridgeley is likewise very hematitic. Undoubtedly, the thin basal sand of the Beaverdam represents sediment reworked from the underlying Ridgeley during the marine

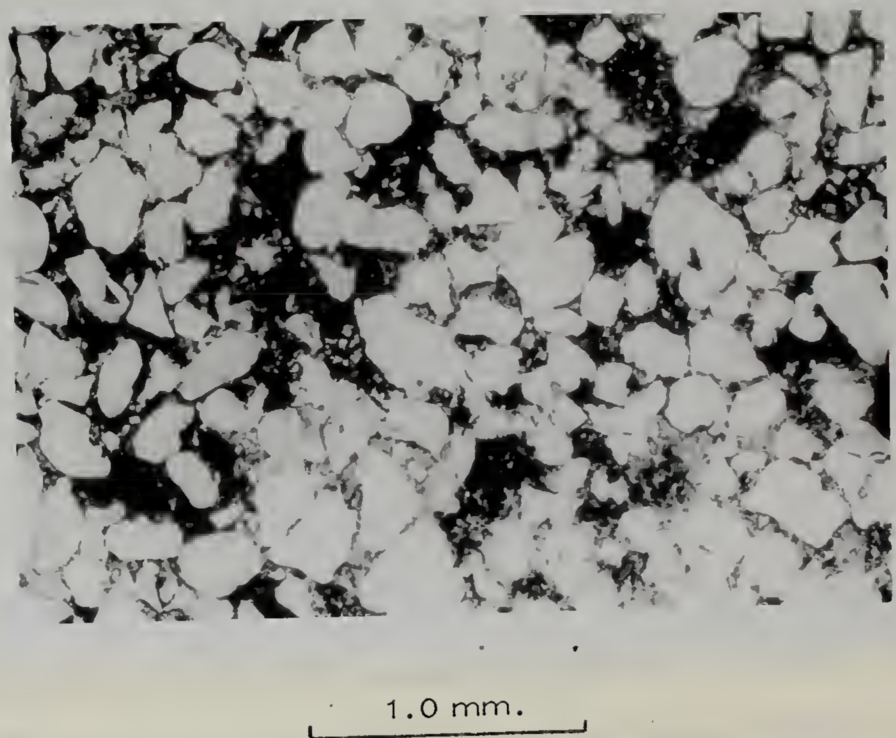
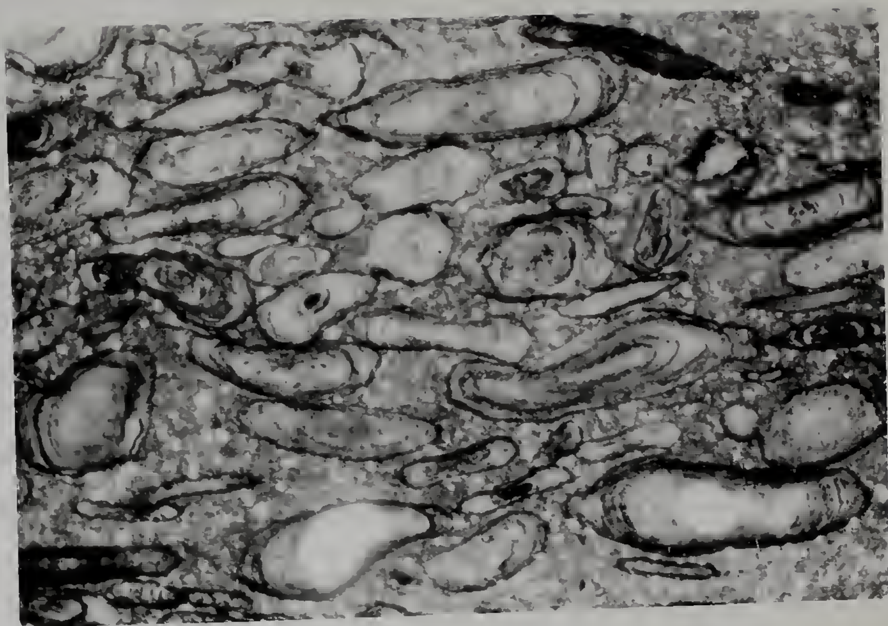


Figure 81.—Photomicrograph of moderately sorted, hematitic, calcareous quartz sandstone, Needmore Formation (basal sand of Beaverdam Shale Member), Newton Hamilton, Mifflin Co., Pa. (P52-1). Angular to rounded quartz sand grains are reworked from underlying Ridgeley Sandstone. Cement is largely hematite with some calcite in lower right. (Plane light.)

transgression that marked the onset of Needmore deposition.

The oolitic beds of the Beaverdam are lenticular, several inches to one foot in thickness, and occur at irregular intervals throughout the member. Particularly striking oolite beds are present at the base of the Beaverdam Member at Warfordsburg, Pa. (P63) and Gainesboro, Va. (V1). In hand specimen the oolites appear as small (1 - 2 mm.), shiny, black, subspherical bodies that in some cases are packed tightly together and in others are floating in a shale matrix. In thin section the oolites are seen to consist of concentric rings of material built up around nuclei of quartz sand and pyrite (Fig. 82). Strain during compaction of the enveloping shale has resulted in flattening in the plane of bedding. Simple chemical tests indicate that the oolites are highly phosphatic. Although they resemble somewhat phosphatic, chamosite ($(Mg, Fe)_3 Fe^{+3}_3 (AlSi_3)_2 O_{10} (OH)_8$) oolites from the Clinton of New York State (Dale, 1953, pp. 53-59, fig. 10), Carter (1969, pp. 8-9) reports that oolites in phosphatic nodules that occur at the top of the Ridgeley Sandstone at the W. L. Newman Phosphate Mine, Juniata Co., Pa., are composed of fluorapatite ($Ca_5F(PO_4)_3$).

Generally the large phosphatic nodules (or concretions) occur toward the base of the Beaverdam, often one foot or less from the actual contact (V1, P30, P64). At Newton Hamilton (P63), limy,



1.0 mm.

Figure 82.—Photomicrograph of phosphatic oolites in silty shale, Needmore Formation (Beaverdam shale subfacies), Warfordsburg, Fulton Co., Pa. (P63-2). Nuclei are quartz (light) and pyrite (dark). Long axis of compressed oolites is parallel to bedding. (Plane light.)

grayish black (N2), phosphatic concretions lie in zones 10 feet, 11-1/2 feet, and 22 feet above the base of the member. A thin section of one of these nodules reveals a nondescript mixture of calcite and phosphatic material (collophane ?), criss-crossed by numerous veins of coarse calcite. Scattered through the matrix are tiny fossil valves, presumably ostracodes. Pyrite is abundant, occurring in irregular masses that constitute about 5 per cent of the section.

Calcareous Shale Member

The calcareous shale member is composed predominantly of medium dark gray (N4), fossiliferous, calcareous shale that weathers pale olive (10Y 6/2), olive gray (5Y 4/1) and light gray (N7) and commonly exhibits a splintery or hacky fracture (Fig. 83). Many horizons are replete with horizontal burrows. Interbedded with the more typical light gray and olive weathering, splintery shales are beds of black (N1) to dark gray (N3), highly bituminous, laminated shale (Fig. 84). Beds and nodules of fine grained, medium dark gray (N4), light gray (N7) weathering, fossiliferous, very argillaceous limestone occur interlayered with the shale, particularly in the upper part where the unit grades into the overlying Selinsgrove Limestone Member. Pyrite, locally in nodules to one inch in diameter, is abundant throughout the member.

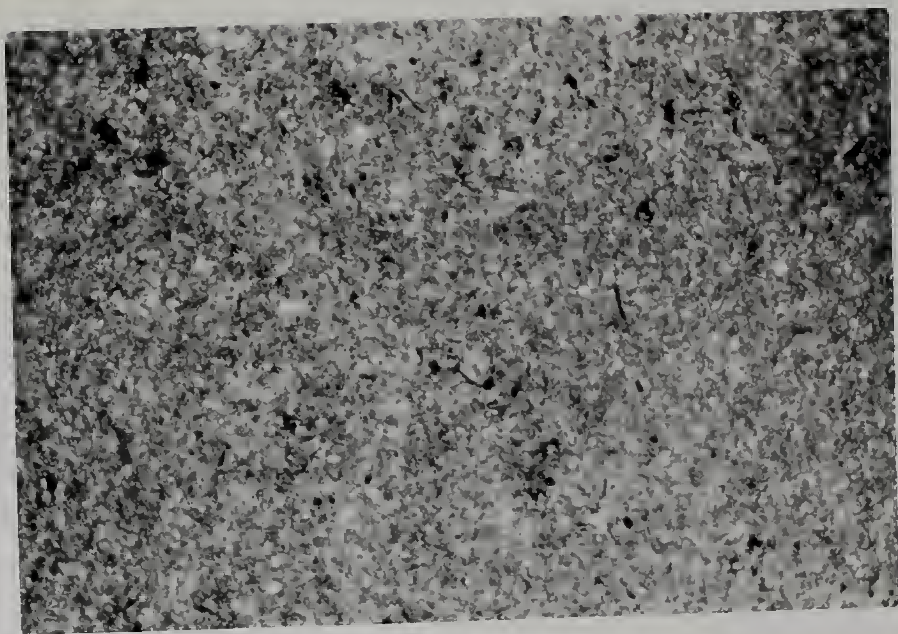
Figure 83.—Calcareous shale member of the Needmore Formation, along Penn Central Railroad, 0.15 mile south of Selinsgrove Junction, Northumberland Co., Pa. Beds are units 3, 4, and 5 of measured section. Hammer rests on limestone nodule. Splintery fracture is typical of the Needmore shales.

Figure 84.—Laminated, bituminous, black shale in calcareous shale member of Needmore Formation, abandoned quarry of Lycoming Silica Sand Co., Montoursville, Lycoming Co., Pa. (P36-13). Note lighter gray shales above and below dark band.

Typical thin sections of shales from the calcareous shale member reveal them to be rather uniformly fine grained and homogeneous (Fig. 85). Argillaceous material and calcite are the dominant constituents, with only rare quartz silt. Pyrite occurs mostly as finely disseminated grains. The calcite grains range up to about 0.02 mm. in size and are intimately mixed with the argillaceous matrix. Silica was rarely observed as a replacement of calcite in fossil valves.

Limestones of the calcareous shale member are usually highly argillaceous biocalcisiltites, containing from 25 to 75 per cent insoluble residue. (Many of these "limestones" are actually marlstones or highly calcareous mudstones.) Although the limestone beds in the uppermost part of the member cannot be distinguished from those in the Selinsgrove Limestone Member, the lower limestones are invariably much more argillaceous and generally more fossiliferous than the Selinsgrove beds. They commonly are thin, lenticular, and packed with fossil valves, particularly Leptocoelina acutiplicata.

Thin sections show the limestones to be composed predominantly of fossil debris in a silty, calcareous mud matrix (Fig. 86, 87). Extensive bioturbation has resulted in concentration of the fossil fragments into irregular swirls. Secondary silica



1.0 mm.

Figure 85.—Photomicrograph of silty, calcareous shale, Needmore Formation (calcareous shale member), Dalmatia, Northumberland Co., Pa. (P30-23). Larger, angular grains are quartz silt, whereas smaller light grains are microcrystalline calcite. Dark patches are pyrite. (Plane light.)

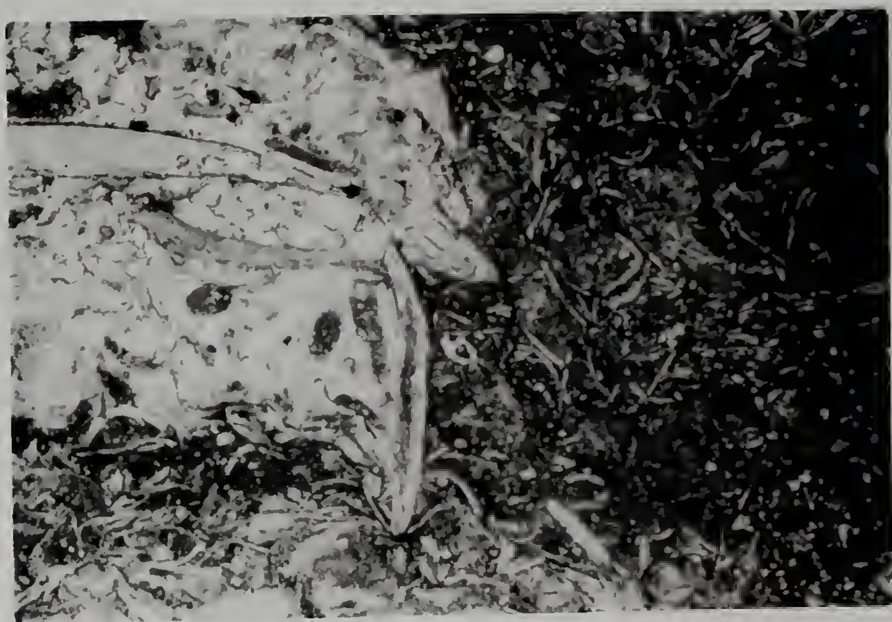


Figure 86.—Photomicrograph of intensely burrowed, silty, very argillaceous biocalcisiltite, Needmore Formation (calcareous shale member), Selinsgrove Junction, Northumberland Co., Pa. (P31-5). Fossils are predominantly brachiopods and ostracodes. Note fragment of silicified wood in upper left. Insoluble residue 43 per cent. (Plane light.)

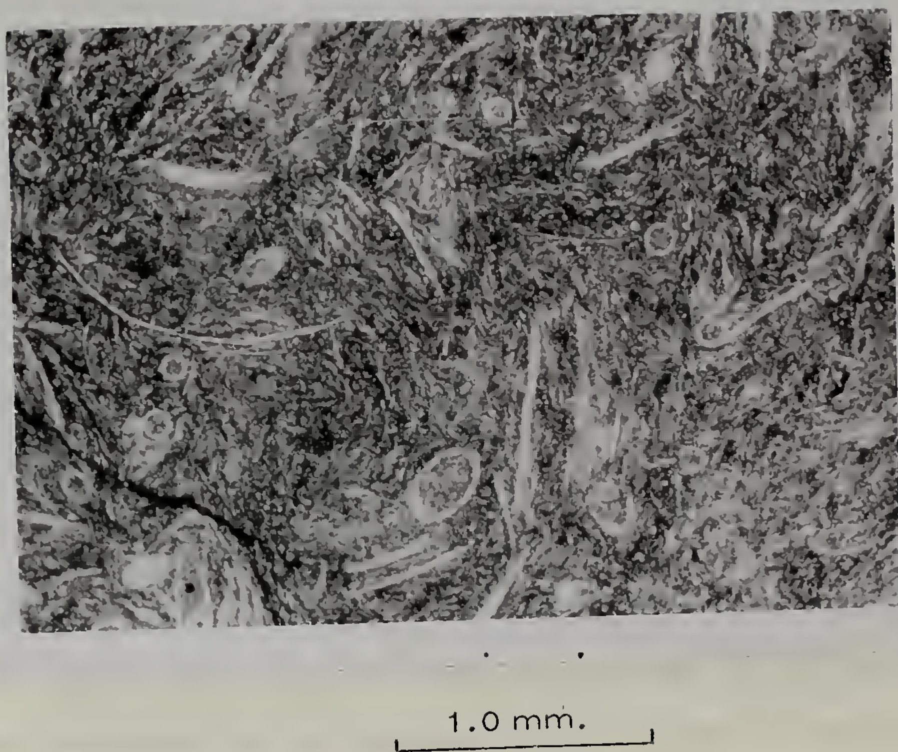


Figure 87.—Photomicrograph of intensely burrowed, argillaceous biocalcisiltite, Needmore Formation (calcareous shale member), Tyrone, Blair Co., Pa. (P61-14). Fossil fragments are mostly styliolines and brachiopods. Insoluble residue 14 per cent. (Plane light.)

forms a thin rind around some fossil fragments and has completely replaced a few ostracode valves. Pyrite is always present and often abundant.

Selinsgrove Limestone Member

The upper part of the Needmore Formation usually consists of fine grained, medium dark gray (N4) to dark gray (N3), fossiliferous limestone (biocalcilutite and biocalcisiltite) with interbeds of medium dark gray, calcareous shale. In relatively fresh exposures, the limestone beds stand out as even, light gray (N7) weathered ribs separated by darker gray weathered shale layers (Fig. 88). Upon prolonged exposure, however, the limestone is leached to olive gray, punky claystone that is often difficult to differentiate from the weathered shale (Fig. 89). As suggested by Fig. 88 and 89, the extent of weathering of the limestone beds is largely a function of bedding dip; i.e., steep dip promotes increased infiltration of vadose water along bedding planes, leading to rapid decomposition. Limestone constitutes about 60 per cent of the Selinsgrove Member in the central Susquehanna-Juniata valley area; but to the north, west, and, especially, southwest, the percentage of limestone rapidly decreases, being only about 20 per cent in northern Bedford Co. (Fig. 90).

Both the limestone and shale beds are normally 2 to 12 inches

Figure 88.—Upper part of Selinsgrove Limestone Member of Needmore Formation, north side of Penn Central Railroad cut, 0.8 mile southwest of Newton Hamilton, Mifflin Co., Pa. (P53). Note regular alternation of thick bedded, light gray-weathering limestone and darker gray, calcareous shale. Contact with overlying Marcellus Formation is approximately marked by uppermost limestone bed below covered interval.

Figure 89.—Olive-gray weathered, fossiliferous, argillaceous limestone and calcareous shale of the Selinsgrove Limestone Member, 1.5 miles north of Thompsontown, Juniata Co., Pa. (P42). Beds are units 9 to 13 of measured section. Contact with calcareous shale member is at right.

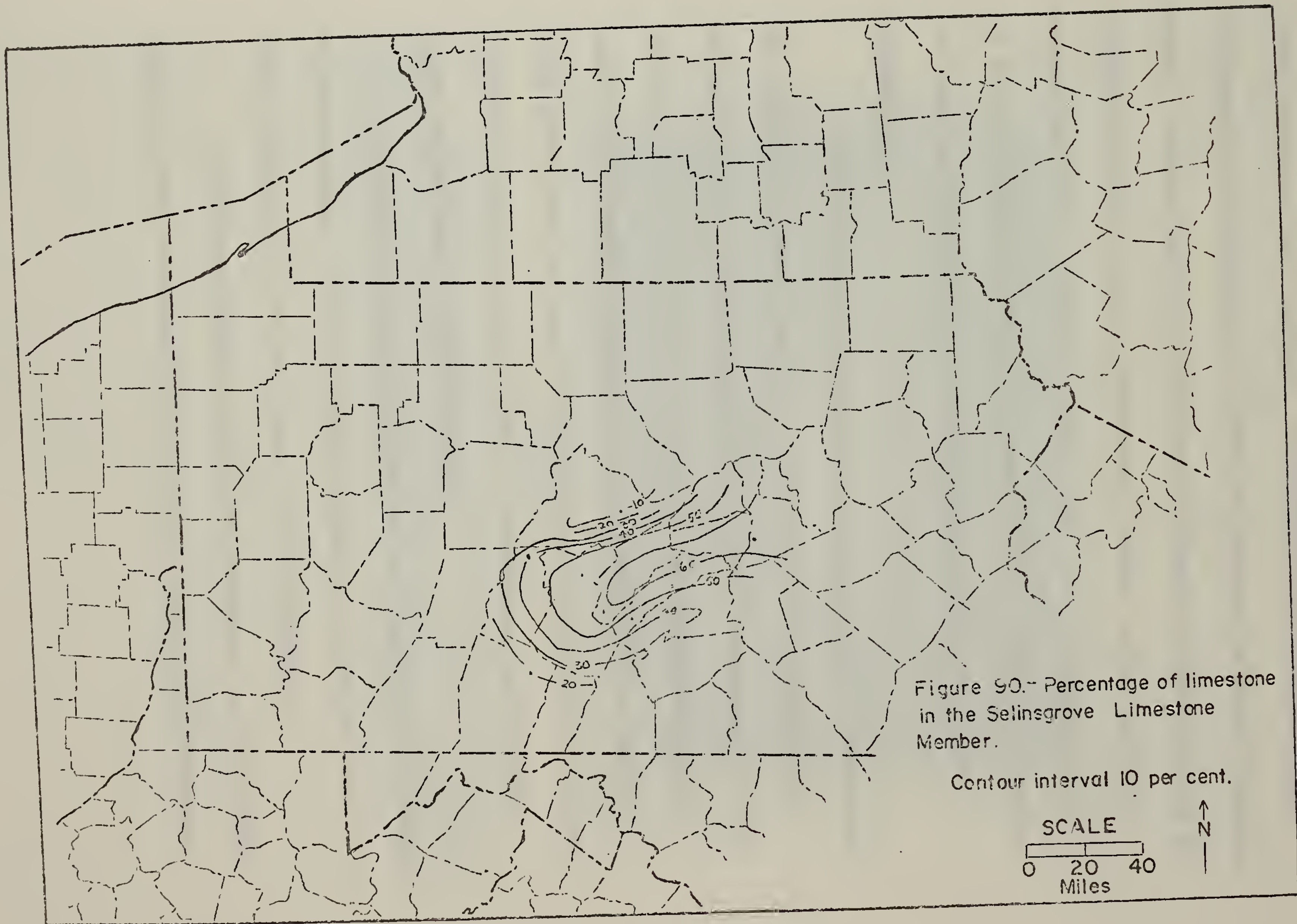


Figure 90.- Percentage of limestone in the Selinsgrove Limestone Member.

thick (medium to thick bedded). Thickness of the limestone beds decreases to the southwest, whereas the converse is true of the shale beds. Laterally nearly all beds can be traced the entire length of an outcrop with little change in thickness. Indeed, in the vicinity of Newton Hamilton, Mifflin Co. (P52, P53), many individual beds can be correlated over a distance of about 2.5 miles. Contacts between the shale and limestone layers are relatively even and appear gradational.

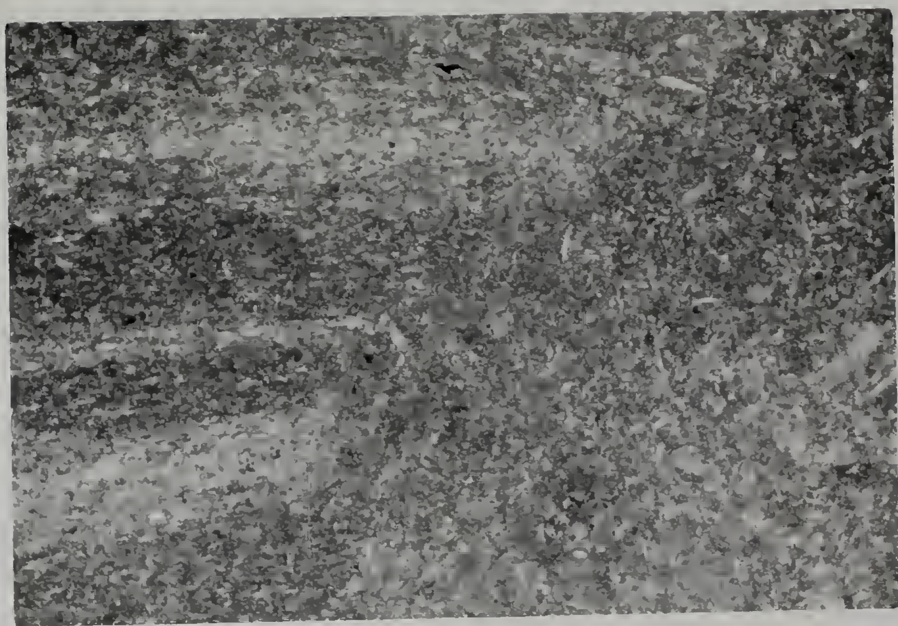
Although many limestone beds exhibit a distinct lamination, the individual laminae being 2 to 5 mm. thick, bioturbation has generally been so intense that the beds appear homogeneous. Well defined burrows are mostly horizontal in both limestone and shale beds, but segmented, vertical burrows, about 2 mm. in diameter, were observed in the upper Selinsgrove at Old Port (P43). Smooth, vertical burrows are also present in limestone equivalent to the upper Selinsgrove at Curtin Gap (P60).

While limestones in the Selinsgrove have been little affected by silicification, small pod-shaped masses of crystalline silica, 1 to 3 mm. wide and 5 to 10 mm. long, are not uncommon.

Photomicrographs of typical thin sections from the Selinsgrove Member are shown in Fig. 91-93. Generally the limestones

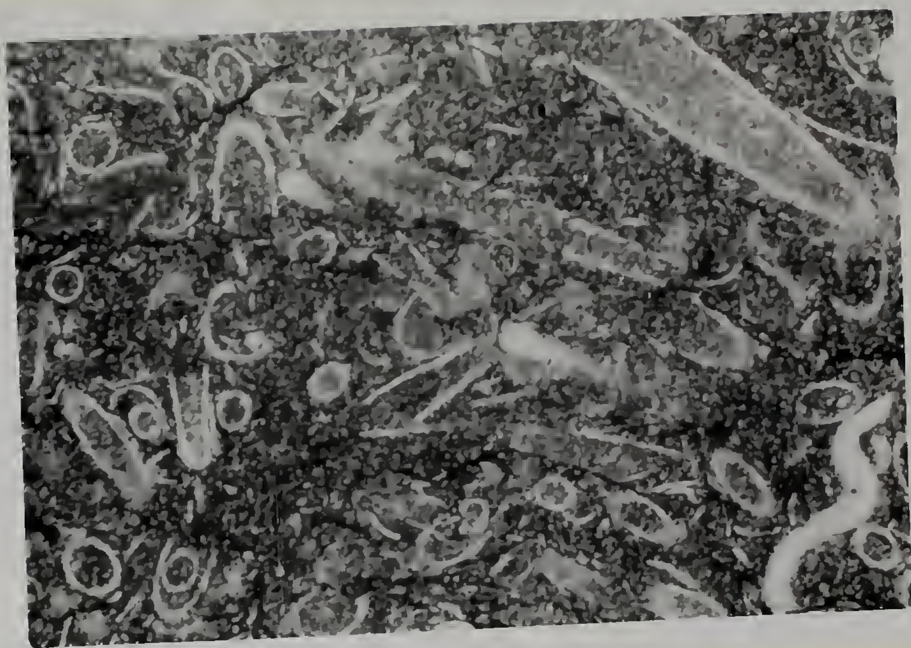
1.0 mm.

Figure 91.—Photomicrograph of intensely burrowed, trilobite-rich, slightly quartzose biocalcisiltite, Needmore Formation (Selinsgrove Limestone Member), Newton Hamilton, Mifflin Co., Pa. (P52-47). Insoluble residue 23 per cent. (Polarized light.)



1.0 mm.

Figure 92.—Photomicrograph of sparsely fossiliferous, laminated calcisiltite, Needmore Formation (Selinsgrove Limestone Member), Newton Hamilton, Mifflin Co., Pa. (P53-11). Comminuted fossil fragments in laminae are mostly styliolines and ostracodes. Note burrow on right.



1.0 mm.

Figure 93.—Photomicrograph of intensely burrowed, argillaceous biocalcisiltite, Needmore Formation (Selinsgrove Limestone Member), Newton Hamilton, Mifflin Co., Pa. (P52-29). Fossils are Styliolina, ostracodes, and trilobites. (Plane light.)

are composed of abundant fossil debris (styliolines, ostracodes, trilobites, and brachiopods) in an argillaceous calcilutite or calcisiltite matrix. Burrows are usually common, but in their absence (Fig. 92), distinct parallel laminations are evident. Pyrite occurs in abundant, irregular masses and scattered grains.

In addition to the typical limestone lithologies described above, two variant limestone types also characterize the member; namely, juvenile-brachiopod coquinites and baritic limestone.

The coquinites are somewhat laminated, medium dark gray (N4) to grayish black (N2), bituminous, highly fossiliferous limestones, composed of myriads of juvenile brachiopods. In hand specimen, many of these coquinite beds appear to be clean sparry limestones, winnowed free of silt and clay matrix. Thin sections reveal, however, that the coarse spar occurs mostly in the cavities between the valves of the individual brachiopods (Fig. 94). The shales associated with these limestones are often as fossiliferous as the limestones themselves. Such beds occur in the upper Selinsgrove, associated with the Tioga Metabentonite at Newton Hamilton (P52, P53), Orbisonia (P58), and Selinsgrove Junction (P31). On the other hand, at Jackson Corner (P56) and Montoursville (P35), identical coquinite beds occur in the middle of the member, and at Tyrone (P61), nearly the entire Selinsgrove Limestone is composed of them.

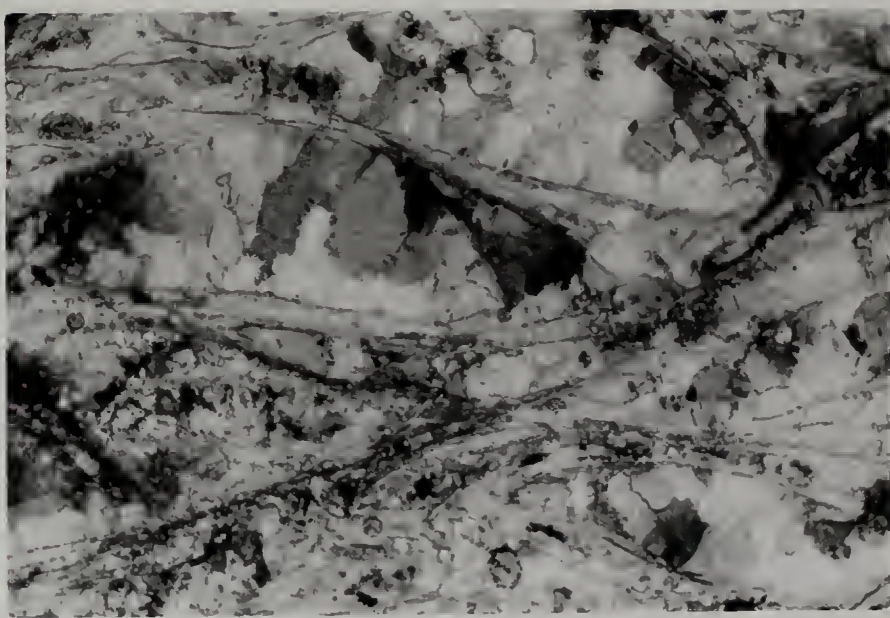


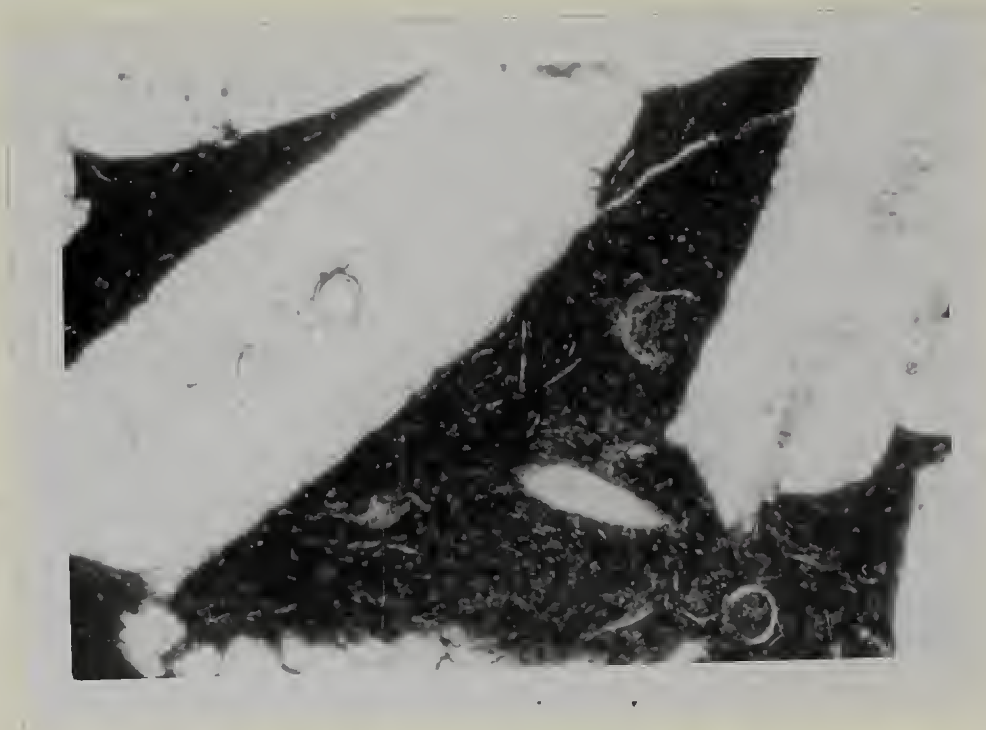
Figure 94.—Photomicrograph of bituminous, sparry juvenile-brachiopod coquinite, Needmore Formation (Selinsgrove Limestone Member), Tyrone, Blair Co., Pa. (P61-24). Valves are aligned roughly parallel to bedding. Note coarse calcite spar in cavities between articulated valves. (Polarized light.)

The coquinites developed at the horizon of the Tioga Metabentonite may represent organisms killed off by the ash fall (Dennison, 1961). Those that occur lower in the Selinsgrove, as at Tyrone, etc., also appear to have had a catastropic origin, and may, in fact, mark an early phase of the Tioga event.

In the lower part of the Selinsgrove Member at Old Port, Juniata Co. (P43), occurs a bed of dark gray (N3), fetid limestone which contains abundant coarse (1/4 - 1/2 inch) subhedral to euhedral barite crystals (Fig. 95). The crystals appear to be aggregated into pods stretched out parallel to fracture cleavage, although the individual crystals probably formed prior to lithification. Small barite crystals (to 1/8 inch in length) also occur in the upper part of the Selinsgrove Limestone at Lewisburg, Union Co. (P35).

Generally the limestones of the Selinsgrove Member contain 8 to 30 per cent insoluble residue, although some beds may contain as little as 4 per cent and others as much as 55 per cent. In color, most of the residues vary from light gray (N7) to dark brownish gray (5YR3/1), the lighter colored residues being derived from the lighter limestones. The darker residues are always moderately to highly organic. Most of the terrigenous fraction is apparently clay, with only a minor amount of quartz silt present.

The shales of the Selinsgrove Limestone Member are



1.0 mm.

Figure 95.—Photomicrograph of euhedral to subhedral barite crystals in poorly sorted, biocalcisiltite, Needmore Formation (Selinsgrove Limestone Member), Old Port, Juniata Co., Pa. (P43-22). Note unaltered Styliolina in center of crystal at left. (Plane light.)

similar to those of the calcareous shale member. Fig. 96-97 represent typical thin sections.

Contact Relations

In central and south-central Pennsylvania, the Needmore Formation overlies the Lower Devonian Ridgeley Sandstone,[14] or Shriver Chert, and underlies the Middle Devonian Marcellus Formation. The lower contact is always abrupt and disconformable, while the upper contact is gradational.

Relationship of the Needmore to underlying units is shown in Fig. 98. Over most of central Pennsylvania, the Needmore Formation abruptly overlies the Ridgeley Sandstone. In the area of thickest Needmore development that centers in Northumberland and Union counties, however, the formation succeeds the Shriver Chert with the Ridgeley absent or represented only by a thin unit of quartz sand at the top of the Shriver. Such a thin sand is present in the G. Krick No. 1 well, Northumberland Co. (P83) (Wood, Trexler, and Kehn, 1969, p. 19). Along a country road, 1.5 miles south of Sunbury and 1.7 miles west-southwest of Lantz, Northumberland Co., 1.0 feet of highly fossiliferous, quartz sandstone occurs at the top of the Shriver. The absence of the Ridgeley in this area is

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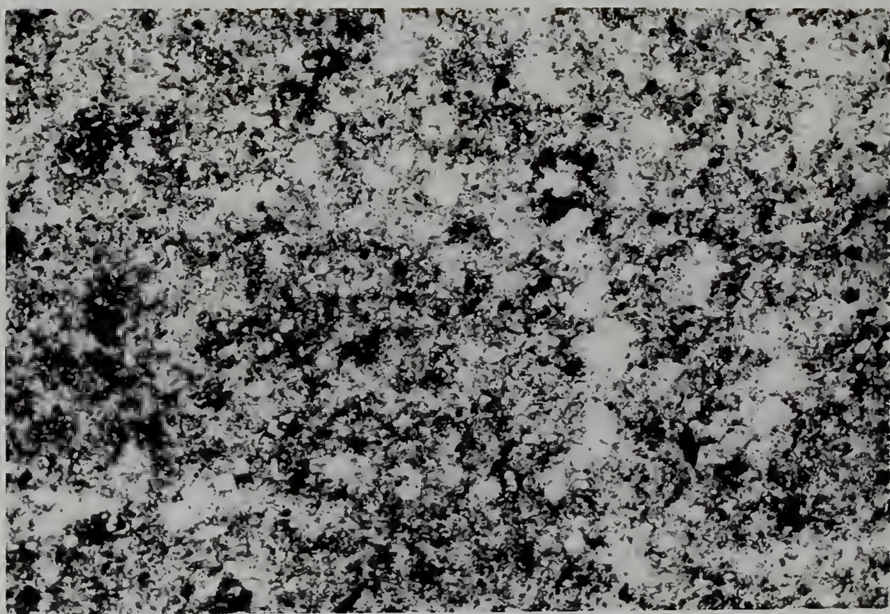
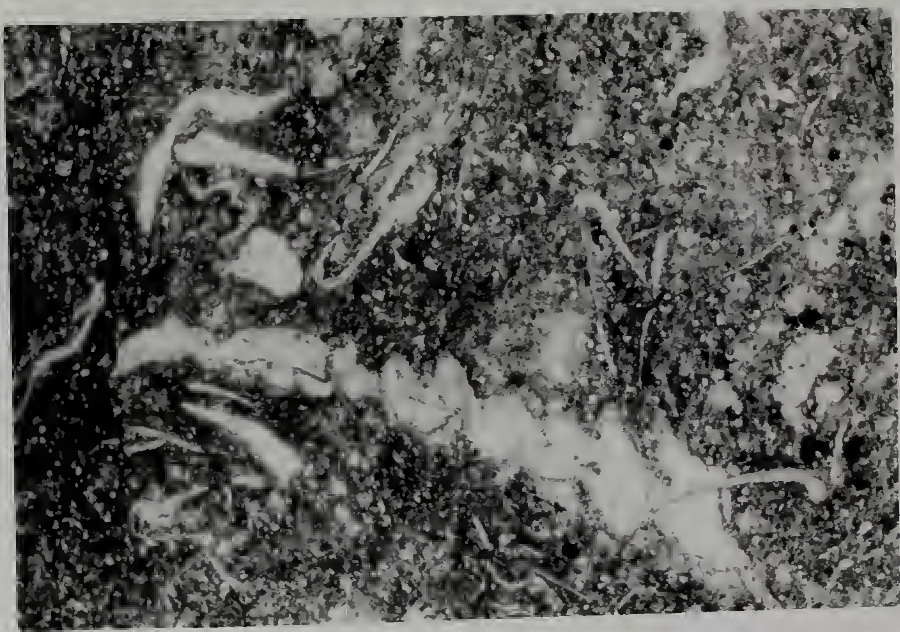
[14] It is possible that the Needmore overlies older formations as it onlaps the Harrisburg Promontory in the subsurface of Perry and Dauphin counties.



0.5 mm.

Figure 96.—Photomicrograph of bituminous, sparsely fossiliferous, calcareous shale, Needmore Formation (Selinsgrove Limestone Member), Newton Hamilton, Mifflin Co., Pa. (P52-44). Light areas are mostly microcrystalline calcite and silt-size clastic calcite grains. (Plane light.)



1.0 mm.

Figure 97.—Photomicrograph of bituminous, highly fossiliferous, calcareous shale, Needmore Formation (Selinsgrove Limestone Member), Newton Hamilton, Mifflin Co., Pa. (P52-62). Fossils are brachiopods, trilobites, and styliolines. Small light grains are clastic calcite silt. (Plane light.)

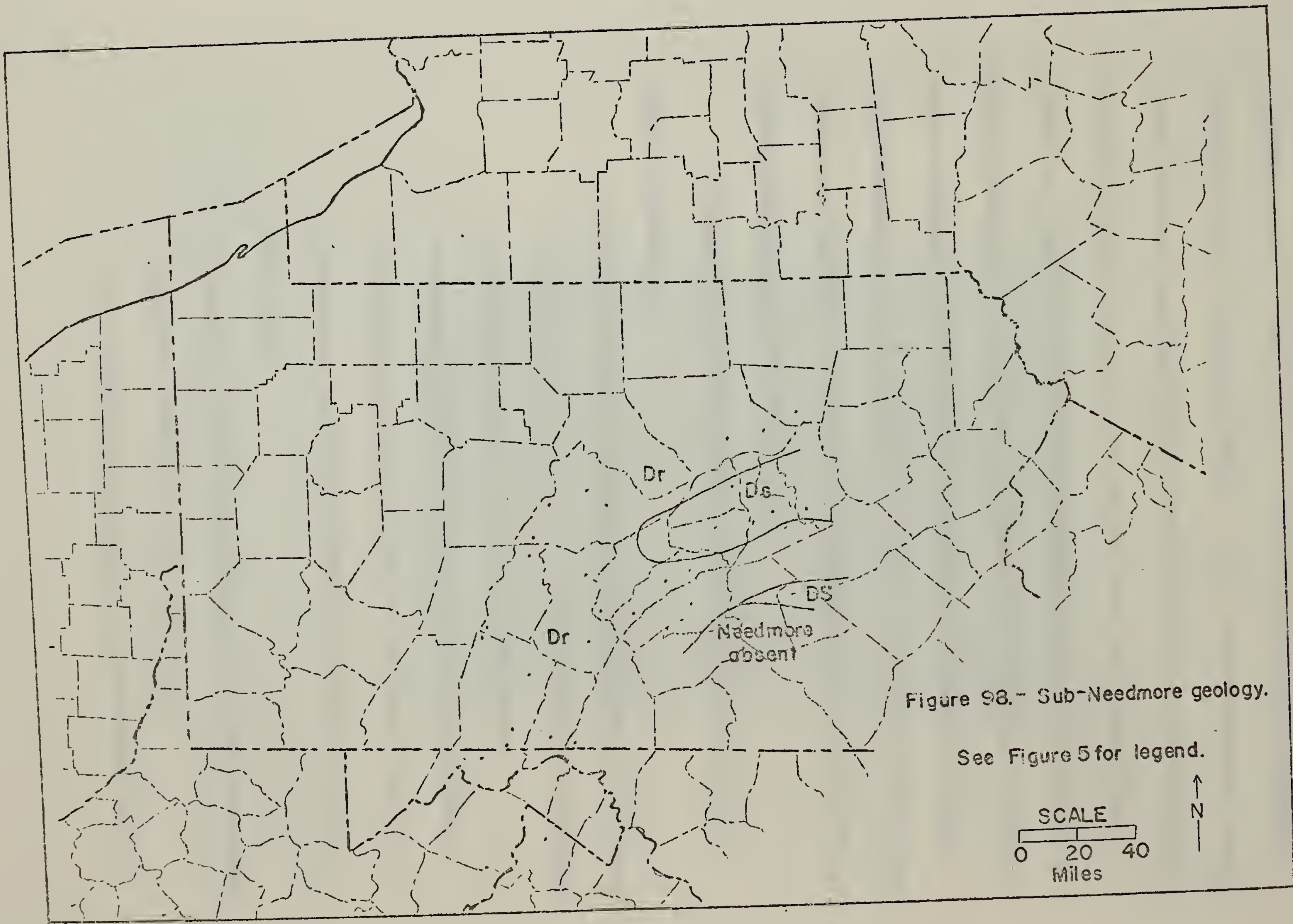


Figure 98.- Sub-Needmore geology.

See Figure 5 for legend.

undoubtedly due to lateral facies change of the Ridgeley sandstone into Shriver chert (Cleaves, 1939, p. 115). Reconnaissance investigations along an unnamed Shriver ridge that bounds the north side of the Middle Creek Valley between Selinsgrove and Beavertown, Snyder Co., have shown numerous localities where sand beds are interlayered with the Shriver. Occurrence of highly fossiliferous, cherty limestone above Ridgeley Sandstone on Tuscarora Creek, 1.5 miles west (Conlin and Hoskins, 1962, p. 23) and 0.4 mile east of Old Port, Juniata Co. (P43), also indicates lateral facies change of the upper Ridgeley into the Shriver.

The disconformable nature of the Needmore-Oriskany contact is shown by:

1. Abrupt change from quartz sand (Ridgeley or siliceous limestone (Shriver) in the upper Oriskany to dark gray shale (Beaverdam) in the basal Needmore;
2. Reworked Ridgeley sand grains in a carbonaceous-hematitic-calcareous matrix in the lower foot of the Beaverdam shale (P30, P36, P52, P63, etc.) (Fig. 99, 100);
3. Phosphatic nodules and oolites in the basal Beaverdam (P30, P35, P36, P52, P63, P64, V1);
4. Poorly-sorted quartz pebble conglomerate at the top

Figure 99.—Disconformable contact of Needmore Formation (Beaverdam Shale Member), above, and Ridgeley Sandstone, abandoned quarry of the Lycoming Silica Sand Co., Montoursville, Lycoming Co., Pa. (P36). A one-inch rusty weathering, calcareous bed containing reworked Ridgeley sand grains is at base of Needmore (visible behind head of hammer).

Figure 100.—Disconformable contact (at hammer) between Needmore Formation (Beaverdam Shale Member) and Ridgeley Sandstone, south side of Penn Central Railroad cut, 1.1 miles northeast of Newton Hamilton, Mifflin Co., Pa. (P52). Basal 6-inches of Needmore is grayish black, carbonaceous, calcareous, quartz sandstone that represents Ridgeley sand reworked by advancing Needmore sea (Fig. 81).

of the Ridgeley at Warren Point, Fulton Co. (P64) (Rowe, 1900; Stose and Swartz, 1912);

5. Siliceous limonite ore beds at the Oriskany-Needmore contact in Perry Co. (Claypole, 1885, pp. 64, 101) and limonitic chert at the same horizon in parts of Blair and Huntingdon counties (Swartz and Swain, 1941, pp. 403-405).

Although the above evidence for a disconformity between the Needmore and Oriskany has been compiled entirely from outcrop data in the Susquehanna Valley and areas to the west, contact relations in the subsurface east of the Susquehanna (see Wood, Trexler, and Kehn, 1969, p. 19) and west of the Allegheny Front in Clearfield and Indiana counties (see Lytle, et al., 1961, pl. 7) are probably similar.

Generally the contact of the Needmore Formation and the Marcellus Formation is marked by a change from medium dark gray, argillaceous limestones typical of the Selinsgrove Limestone Member into grayish-black, carbonaceous, silty limestones and interlayering of these beds with black, silty, carbonaceous shales of Marcellus aspect. At some localities (e.g., P31, P45, P60) the contact can satisfactorily be placed at the top of the last continuous bed of medium dark gray to dark gray, argillaceous limestone (Fig. 101). (Limestones in the basal Marcellus tend to be lenticular, grayish-black,

Figure 101.—Gradational contact (at hammer) between Needmore Formation (Selinsgrove Limestone Member) (below) and Marcellus Formation, cut on Penn Central Railroad, 0.25 mile south of Selinsgrove Junction, Northumberland Co., Pa. (P31). Limestone beds above hammer are dark gray, bituminous, and silty and tend to have blocky fracture. Upper bed (B) of Tioga Metabentonite occurs in Marcellus Formation at end of hammer handle.

laminated and silty.) At some more westerly outcrops (P61, P53), however, where the bituminous, "juvenile-brachiopod" facies of the Selinsgrove is well developed, the coquinitic limestones are often interbedded with laminated Marcellus-like limestones, as well as with medium dark gray Selinsgrove-like limestones. Therefore, the contact is arbitrarily placed at the base of the first thick, black shale bed, a position which includes most of the fossiliferous limestones in the Needmore (Fig. 102).

The Needmore-Marcellus contact is gradational in the subsurface east of the Susquehanna and northwest of the Allegheny Front (see Wood, Trexler, and Kehn, 1969, p. 19; Lytle, et al., 1961, pl. 7; Glover, 1970, p. 115). Some limestone beds which would be included in the Marcellus at outcrops are probably placed at the top of the Needmore (or "Onondaga") in the subsurface.

The individual beds of the Tioga Metabentonite usually occur in the Needmore-Marcellus transition interval. It is important to note that the top of the Needmore Formation does not necessarily coincide with the top of the Onesquethaw Stage, which by definition is placed at the middle coarse mica zone of the Tioga Metabentonite (Dennison, 1969, p. 13).

Distribution and Thickness

With local exceptions, the Needmore Formation crops out

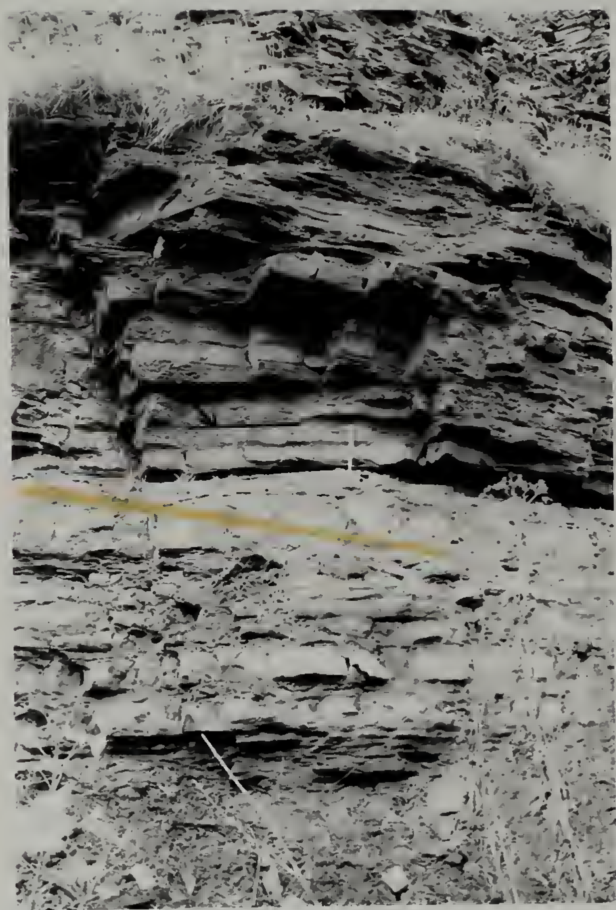


Figure 102.—Contact (as marked) between Needmore Formation (Selinsgrove Limestone Member) (below) and Marcellus Formation, north side of Penn Central Railroad cut, 0.8 mile southwest of Newton Hamilton, Mifflin Co., Pa. (P53). Tioga Meta-bentonite beds marked by hammer (A) and by grassy area near top (B).

throughout the folded Appalachians of Pennsylvania and states immediately to the south. It is also known in the subsurface of the Anthracite region, where it grades eastward into the Esopus, Schoharie, and Onondaga interval, and in the subsurface north and west of the Allegheny Front, where it is laterally replaced by the Onondaga Limestone and "Huntersville Chert."

In Pennsylvania the Needmore Formation attains its greatest thickness in two lobes that extend southwestward from the Northeastern Basin (Fig. 103). One lobe is centered in Montour and Union counties and may, in fact, be spurious, as its existence is postulated only on a measurement of about 200 feet for a poorly exposed section at Lewisburg, Union Co. (P35). Another lobe extends from Columbia and Northumberland counties southwestward into Snyder and Juniata counties. The Needmore is 265 feet thick in the Knarr No. 1 well, Columbia Co. (P82) (Lytle, et al., 1961, p. 84) and about 169-175 feet thick in wells in eastern Northumberland County (Fettke, 1956, p. 100; Wood, Trexler, and Kehn, 1969, p. 19). Thicknesses at outcrops farther west are not entirely reliable, but a thickened lobe of the Needmore undoubtedly extends southwest from Selinsgrove Junction (P31) (135+ feet) to Old Port (P43) (161 feet) and East Waterford (P45) (154 feet).

South and southeast of the areas of its thickest development,

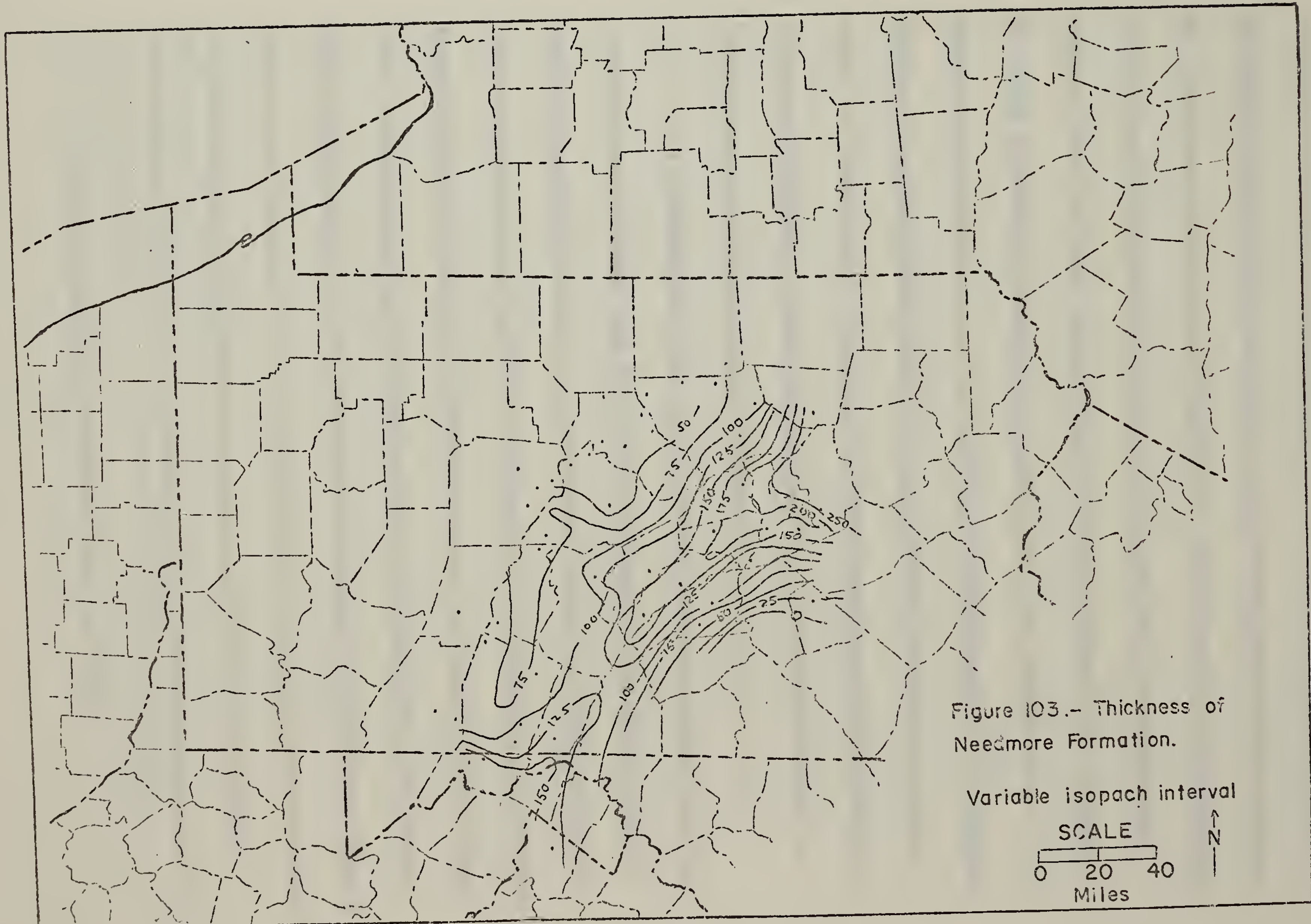


Figure 103.– Thickness of Needmore Formation.

Variable isopach interval

the Needmore thins progressively at a rate of about 6 feet per mile. At Falling Spring (P51), its southernmost measured outcrop in Perry Co., the Needmore is only 67 feet thick. Southeast of Falling Spring, the unit can be traced only as far as Sterretts Gap, 5 miles distant (Dyson, 1967, p. 26). East of Sterretts Gap in Perry Co., as well as in the subsurface of northern Dauphin Co., the Needmore is absent by disconformity on the "Harrisburg Promontory."[15] Between Dalmatia and the Onesquethaw outcrop belt east of the Susquehanna River in Lebanon Co., the lower two shaly members of the Needmore pinch out completely, while the Selinsgrove Limestone Member is continuous with the Onondaga Limestone.

The Needmore thins north and west of the thickened lobes but at a generally slower rate than to the southeast. It is about 110 feet thick at Newton Hamilton in southwestern Mifflin Co. (P52, P53) and about 125 feet thick in northern Huntingdon Co. (Jackson Corner-Martin Gap) (P56, P57). Along the Allegheny Front the Needmore is 115 feet thick at Montoursville (P36), 33 feet at Curtin Gap (P60), and 70 feet thick at Tyrone (P61). The minimal development at Curtin Gap reflects proximity to the southern end of the platform-basin element that existed in north-central Pennsylvania and south-central New York during Onesquethaw time (p. 15). Continued thinning of the Needmore and its

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[15] Cape Cumberland of Willard (1939, p. 195).

equivalents (the Onondaga Limestone and "Huntersville Chert") north and west of the Allegheny Front in central Pennsylvania is controlied by this same paleogeographic element.

In south-central Pennsylvania and adjacent Maryland and West Virginia, the Needmore varies between 100 and 170 feet thick, being thickest in the vicinity of Cumberland, Md., and thinning to the east and north. It appears to be about 165 feet thick on Cash Valley Road, LaVale (M3), about 2 miles southwest of Cumberland, but the exposure is very poor. On the old Williams Road, about 2 miles southeast of Cumberland, a faulted section of the Needmore is reported to show a stratigraphic thickness of 157 feet (Prosser, Kindle, and Swartz, 1913, p. 55). Farther east, the unit thins to 140 feet at Flintstone, Md. (M2), about 100 feet at Warfordsburg, Fulton Co. (P63), and 120 feet at Warren Point, Franklin Co. (P64). The Needmore ("Onondaga") is reported to be 100 to 125 feet thick in gas fields in southeastern Bedford Co., Pa. (Lytle, et al., 1963, 1964, 1965). In the subsurface west of Cumberland, the Needmore Formation changes laterally into the Huntersville Chert (Dennison, 1961).

Beaverdam Shale Member

At outcrops where it can be recognized in central and south-central Pennsylvania, the Beaverdam Shale Member is 10 to

25 feet thick (Fig. 104). It is thickest in the extreme eastern and southwestern parts of the outcrop area. The Beaverdam is absent in Centre Co., the thin Needmore interval there being assigned wholly to the calcareous shale member.

Although thickening of the Beaverdam Shale Member east of the Susquehanna is suggested by the subsurface information available, outcrop data from the North Branch valley is far from conclusive. Over 60 feet of non-calcareous shale (Beaverdam ?) have been reported from the lower Needmore in deep wells in eastern Northumberland Co. (Wood, Trexler, and Kehn, 1969, p. 19). At outcrops east of Danville, Montour Co. (P32, P33), the lower Needmore consists of deeply leached, olive, light tan and rusty weathering, sparingly fossiliferous shale that little resembles the typical Beaverdam. The exposures are so incomplete and deeply weathered, however, that no firm conclusions can be made concerning their member assignment.

The Beaverdam Member is interpreted as the equivalent of the upper Esopus-lower Schoharie (Carlisle Center) interval of northeastern Pennsylvania. East of the Susquehanna it thickens rapidly into the Northeastern Basin. It is probably included in the 110 feet of Esopus in the Bennett No. 1 well, Sullivan Co., Pa. (P81). In the area west of the Susquehanna, the Beaverdam accumulated under

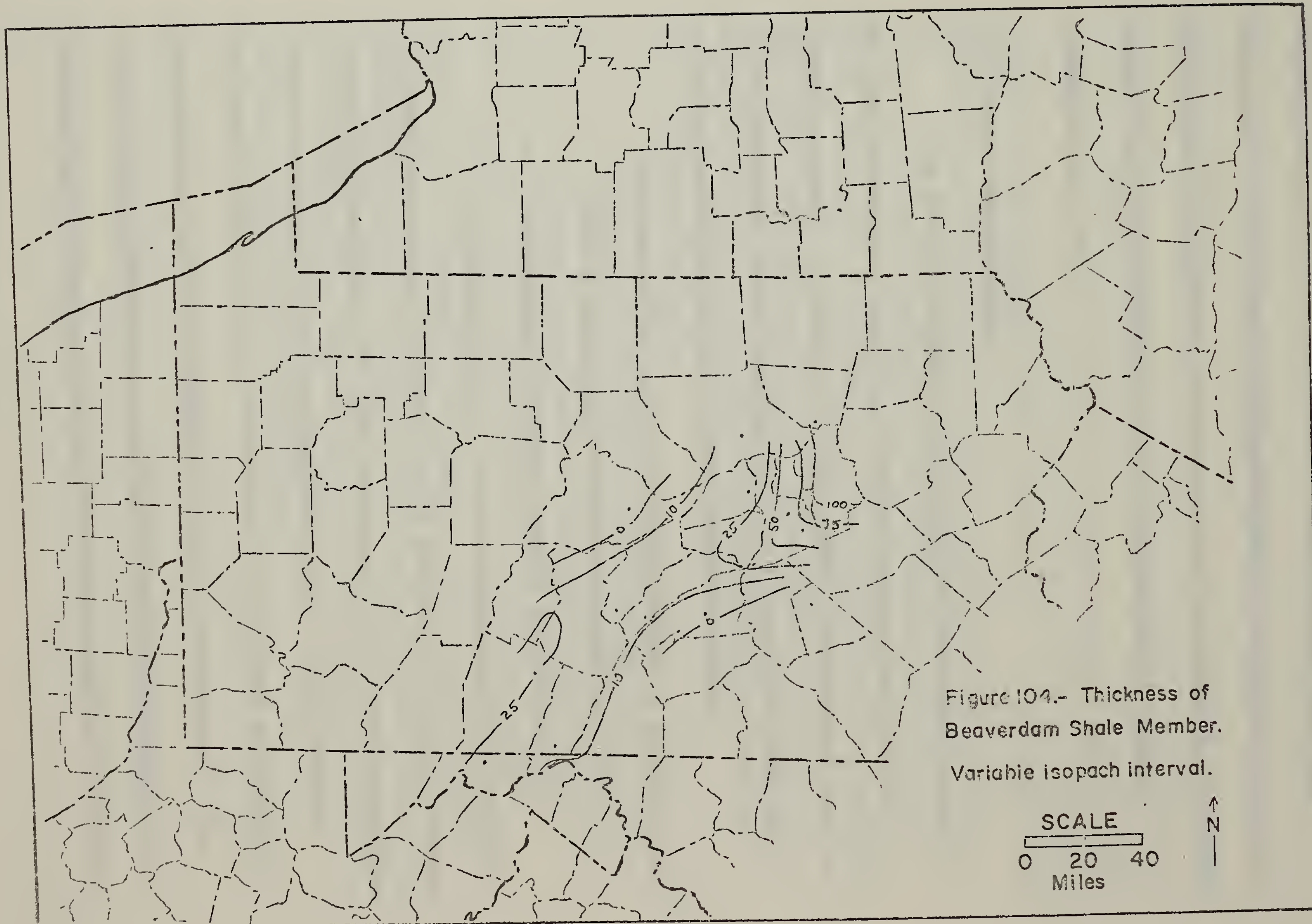

Figure 104.- Thickness of Beaverdam Shale Member. Variable isopach interval.

starved-basin conditions that followed rapid post-Oriskany submergence. That the base of the Beaverdam is everywhere essentially synchronous is suggested by the similarity of the Needmore-Oriskany contact from the Susquehanna Valley southwestward at least to Frederick Co., Va.

Calcareous Shale Member

The middle member of the Needmore Formation is areally the most extensive of the three members and also the most frequently exposed. Although it is most typically developed at outcrops in the Ridge and Valley Province, it is also known from deep wells in the Anthracite Region and eastern Allegheny Plateau.

Thickness of the calcareous shale member is controlled by:

1. Rate of deposition of argillaceous sediment, and
2. Southwestward facies change of the Selinsgrove Limestone Member into the calcareous shale member.

Its maximum outcrop thickness, 140 to 150 feet, in Union and Montour counties is associated with rapid thickening of the entire Onesquethaw interval eastward into the Northeastern Basin. In this area the calcareous shale member is believed to be the lateral equivalent of the Schoharie and lower Onondaga of eastern Pennsylvania. The member thins southwestward into Snyder and Juniata counties, but thickens again in southern Juniata and Fulton counties as it gradually replaces the lower beds of the Selinsgrove Member (Fig. 105). Thinning of the calcareous shale member onto the basin margin to the southeast is well shown at outcrops in Juniata and Perry counties. In wells in eastern Northumberland Co., abrupt decrease in the thickness of the member reflects the greater thickness of beds assigned to the Beaverdam Shale Member (Fig. 104). To the north and northwest it thins against the north-central platform, but calcareous shale still constitutes a major portion of the "Onondaga" as far north as Potter and Cameron counties (Fettke, 1961, pp. 308-309, 334). West of the Allegheny Front, in Clearfield, Cambria, and Somerset counties, the calcareous shale member grades laterally into the Huntersville Chert.

In south-central Pennsylvania and adjacent areas, the calcareous shale member is represented by the calcitic shale subfacies and lower part of the calcitic shale and limestone subfacies of Dennison (1961). Based on the definition of the various members in central Pennsylvania, nearly all of the Needmore Formation in south-central Pennsylvania, exclusive of the Beaverdam Shale, would be included in the calcareous shale member.

Selinsgrove Limestone Member

The argillaceous, non-cherty Selinsgrove Limestone is characteristic of the upper portion of the Needmore Formation

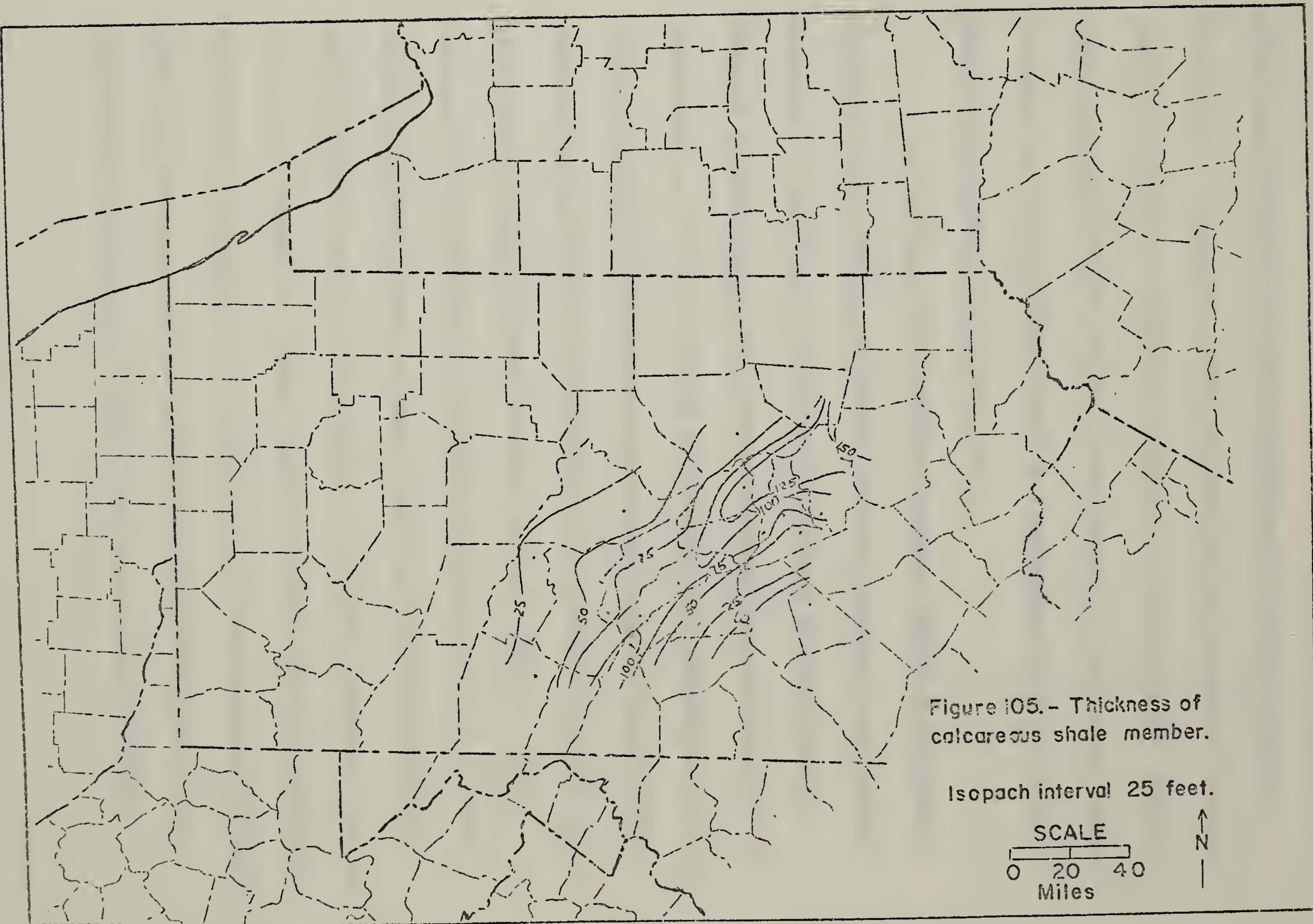

Figure 105. - Thickness of calcareous shale member.

Isopach interval 25 feet.

throughout the folded Appalachians from the central Susquehanna Valley southwestward to northern Bedford and Fulton counties (Fig. 106). To the east, north and west the Selinsgrove is laterally continuous with the Onondaga Limestone. In south-central Pennsylvania, Maryland, West Virginia, and Virginia, it is represented by the upper part of the calcitic shale and limestone subfacies of the Needmore Formation (Dennison, 1961).

The Selinsgrove Limestone Member attains its greatest thickness, 60 to 70 feet, in Northumberland, Snyder, and Juniata counties in a belt that is essentially coincident with the area of thickest development of the entire Needmore Formation west of the Susquehanna. To the northeast of this area, the Selinsgrove thickens toward the center of the Northeastern Basin, and to the southwest it thins as the lower beds of the Selinsgrove are replaced by the upper beds of the calcareous shale member (Willard, 1939, p. 147). Southeast and northwest of the Northumberland-Juniata axis, the Selinsgrove thins toward the basin margin and the north-central platform-basin element, respectively. Along the Allegheny Front at Curtin Gap, Centre Co. (P60), near the southern end of the platform-basin area, the horizon of the Selinsgrove is represented by 33 feet of dark gray, fossiliferous, calcareous shale with widely separated interbeds of argillaceous limestone (calcareous shale member).

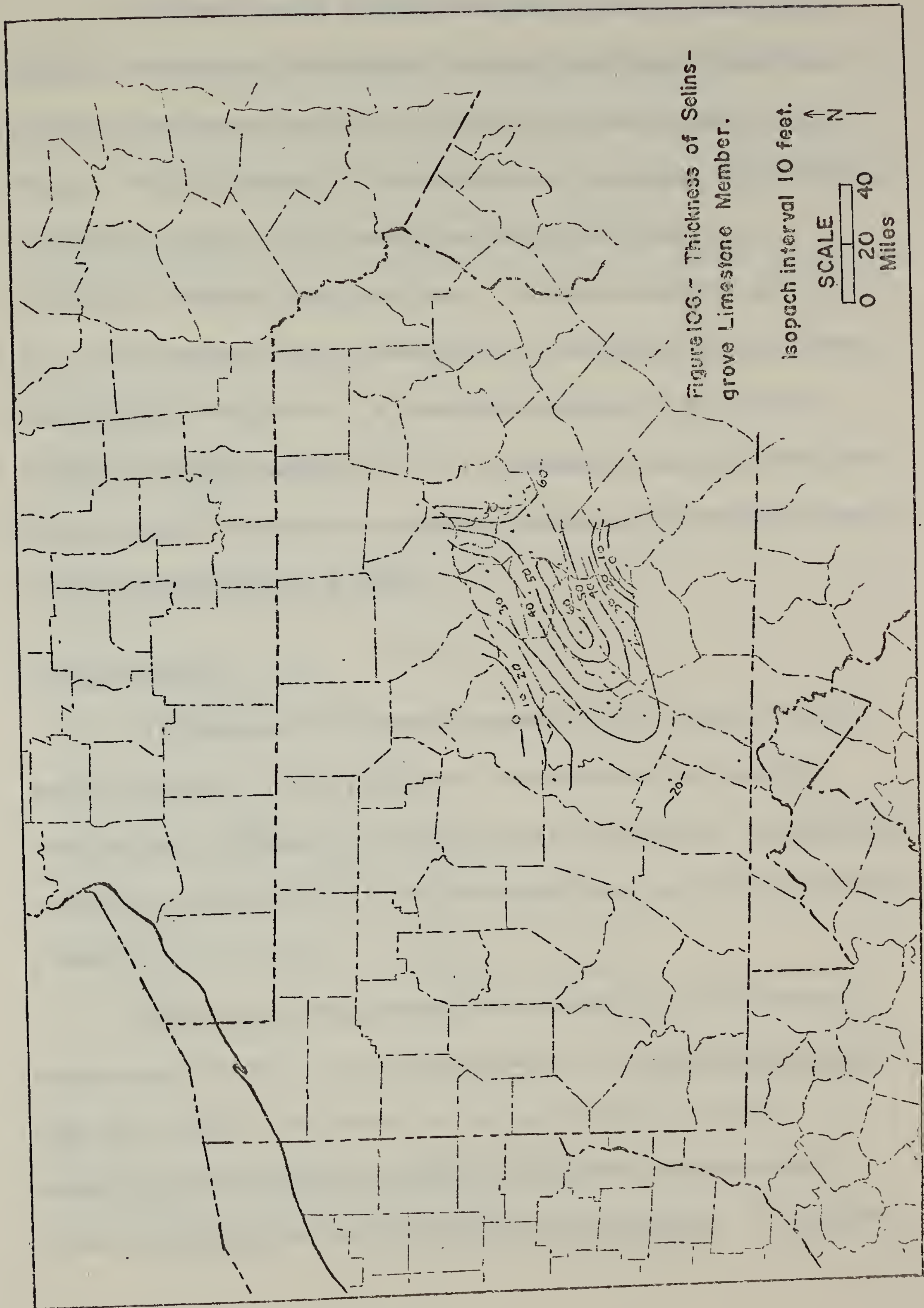

Figure 106.- Thickness of Selinsgrove Limestone Member.

Isopach interval 10 feet.

In south-central Pennsylvania and bordering areas, argillaceous limestone of Selinsgrove lithology constitutes a significant portion of the upper Needmore (calcitic shale and limestone subfacies). Even at relatively fresh exposures, however, the limestone/limestone + shale ratio is much less than 50 per cent, e.g., Flintstone, Allegany Co., Md. (M2). At more weathered outcrops, e.g., near Warren Point, Franklin Co., Pa. (P64), limestone beds can hardly be recognized. A limestone maximum that occurs in Grant and Hardy counties, W. Va., is probably a separate lithosome from the type Selinsgrove and does not extend northward into Pennsylvania (Dennison, 1961, p. 23).

Fauna and Age

The Needmore Formation abounds in the remains marine, shelly organisms. Most prominent constituents of the fauna are brachiopods, trilobites, ostracodes, and cricoconarids. Cephalopods, gastropods, bivalves, and corals are significant, but minor, elements (Table 9).

Although the Beaverdam Shale Member is usually barren, scattered specimens of Orbiculoidea media and Leptocoelina acutiplicata occur rarely. According to Dennison (1961, p. 41), the Beaverdam shale subfacies in West Virginia and adjacent areas contains Styliolina sp. and Tentaculites gracilistriatus. The present

TABLE 9

FAUNA OF THE NEEDMORE FORMATION, CENTRAL PENNSYLVANIA AND ADJACENT AREAS

(1 = Beaverdam Shale Member, and Beaverdam shale subfacies; 2 = calcareous shale member, and calcitic shale subfacies; 3 = Selinsgrove Limestone Member, and calcitic shale and limestone subfacies)

Fauna	1	2	3
Coelenterata			
Trachypora (?) sp.		×	×
Heterophrentis simplex (Hall)		×	
"Heterophrentis" sp. A.			×
Brachiopoda			
Orbiculoidea media (Hall)	×	×	×
Levenea lenticularis (Vanuxem)		×	×
Levenea sp.		×	×
Schellwienella pandora (Billings)		×	
Unidentified chonetids		×	
Anoplia nucleata (Hall)		×	
Eodevonaria sp.		×	
Truncalosia truncata (Hall)			
Atrypa reticularis (Linnaeus)		×	×
Coelospira camilla Hall		×	
Leptocoelina acutiplicata (Conrad)	×	×	×
Small juvenile brachiopods (Meristella sp., Ambocoelia sp., etc.)			×
Ambocoelia umbonata (Conrad)		×	×
Kozlowskiellina (Megakozlowskiella) raricosta (Conrad)		×	
Amphigenia elongata (Vanuxem)			×
Gastropoda			
Unidentified gastropods		×	
Bembexia sp.		×	
Platyceras (Platystoma) turbinatum Hall		×	×
Platyceras (Platystoma) cochleatum Hall		×	
Palaeozygopleura hamiltoniae (Hall)		×	

TABLE 9—Continued

Fauna	1	2	3
Bivalvia			
Unidentified bivalves		x	x
Nuculoidea sp.		x	
Praecardium cf. *P. multiradiatum* (Hall)		x	
Cephalopoda			
Michelinoceras subulatum (Hall)		x	x
Agoniatites (?) sp.		x	
Trilobita			
Phacops cristata Hall		x	x
P. pipa Hall and Clarke		x	x
P. sp.		x	x
Odontocephalus selenourus (Eaton)			x
O. aegeria Hall		x	x
Ostracoda			
Unidentified ostracodes		x	x
Bollia ungula Jones		x	x
Favulella favulosa (Jones)		x	x
Cricoconarida			
Tentaculites gracilistriatus Hall			x
Styliolina fissurella (Hall)		x	x
Echinodermata			
Large crinoid columnals		x	x

writer did not observe these forms in the Pennsylvania rocks.

Of the several subdivisions of the Needmore Formation, the calcareous shale member, and equivalent strata of the calcitic shale and calcitic shale and limestone subfacies contain the greatest concentration of fossils. The most characteristic form is Leptocoelina acutiplicata,[16] which has been widely cited as the index fossil to Onesquethawan rocks in the central Appalachians (Willard, 1939, p. 154; Dennison, 1961, p. 40; Miller, 1961, p. 26; Conlin and Hoskins, 1962, p. 25; Dyson, 1963, p. 16). Other brachiopods, especially Orbiculoidea media, Levenea sp., and Ambocoelia umbonata, are also very abundant. Gastropods, particularly Platyceras (Platystoma) cochleatum appear to be most characteristic of dark gray to black, pyritic, intensely burrowed shales that are locally developed in the middle to upper parts of the calcareous shale member, or calcitic shale subfacies. The cephalopod Michelinoceras subulatum is also commonly found in these gastropod-rich strata. Agoniatites (?) sp., a questionable ammonoid, has an extremely limited stratigraphic distribution at two widely separated localities, occurring in 2 feet of medium dark gray shale about 32 feet above the base of the calcareous shale member at Newton Hamilton (P52-18) and about 27 feet above

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[16] This brachiopod is referred to as Anoplotheca acutiplicata in the works mentioned.

the base of the calcitic shale subfacies at Warfordsburg (P63-4). It is quite probable that these two occurrences of Agoniatites (?) sp. are time equivalent. Of the trilobites, the phacopid forms, i.e., Phacops pipa, P. cristata, and P. sp., are most common in the shalier phases of the formation. Cricoconarids, especially styliolines, and ostracodes constitute much of the skeletal material in the argillaceous limestones of the calcareous shale member and its lateral equivalents. Although pelmatozoans are a relatively rare component of the Needmore fauna, a concentration of large crinoid columnals (comparable in size to those of the Edgecliff Member of the Onondaga Limestone) is present near the top of the calcitic shale subfacies at Gainesboro, Va. (V1).

The Selinsgrove Limestone Member generally contains fewer fossils than the calcareous shale member. Equivalent strata in the calcitic shale and limestone subfacies of south-central Pennsylvania and adjacent states are richly fossiliferous, however. Ambocoelia umbonata is somewhat more abundant than Leptocoelina acutiplicata in the Selinsgrove Member. The floods of juvenile brachiopods that occur in the bituminous coquinite beds have not been identified as to species, but they probably belong mostly to the genera Meristella and Ambocoelia (Swartz and Swain, 1941, p. 405; Woodward, 1943, p. 283). The tooth-brimmed trilobites Odontocephalus aegeria and

O. selenourus are the most diagnostic elements of the Selinsgrove fauna. Of the two similar species, the former is probably more common (Kindle, 1912, p. 109). Although in general, gastropods are not abundant in the Selinsgrove, a zone where numerous *Platyceras (Platystoma) turbinatum* are recrystallized to coarsely crystalline calcite is present at the top of the member near Newton Hamilton (P52, P53). Ostracodes and cricoconarids form the bulk of the skeletal material in the limestone beds.

The lower part of the Needmore Formation is Emsian (upper lower Devonian) in age and the upper part is Eifelian (lower middle Devonian) in age (Oliver and others, 1969).

Tioga Metabentonite

Definition and Reference Section

At the top of the Onesquethaw Stage throughout the Appalachian and northern Interior regions occurs the Tioga Metabentonite, a micaceous siltstone of volcanic origin (Dennison, 1961). A distinctive bed at this horizon was first observed by James Hall during the early investigations of the Devonian System in New York State. Near the top of the Corniferous Limestone in the vicinity of Waterloo, Seneca Co., he described a "seam of clay, about four inches thick . . . exceedingly fine, like the softest talc, [having] a laminated structure and yellowish color." (Hall, 1842, p. 163.) Lincoln (1895, pp. 91-92) and later Luther (1909, p. 14) also described the bed in the same area, both using it to correlate quarry sections between Waterloo and Canoga.

The usefulness of the Tioga as a subsurface marker horizon was recognized early in the history of deep sand exploration in Pennsylvania and New York. Fettke (1931, p. 8), in studying well cuttings from the Tioga Gas Field, Tioga Co., Pa., reported the occurrence of a brown shale in the Onondaga Limestone. Later he described numerous occurrences of this brown shale in the subsurface of western Pennsylvania and traced it southwestward across the state to the Summit Gas Field, Fayette Co. (Fettke, 1940, 1941). Nearly two decades after his original discovery, Fettke first postulated the volcanic nature of the bed and named it the Tioga Bentonite (Ebright, Fettke, and Ingham, 1949, p. 10). Flowers (1952) reported a meta-bentonite at the top of the Huntersville chert and Needmore shale in the subsurface of West Virginia. Fettke (1952) recognized this to be the Tioga.

Outcrop studies of the Tioga Metabentonite in this century lagged considerably behind subsurface studies and were inaugurated only two decades ago. Oliver (1954, p. 629) reported the Tioga in outcrops in central and eastern New York. In his zonation of the Onondaga Limestone, the metabentonite is Zone H and marks the boundary between the Moorehouse and Seneca members. Subsequent work of Dennison (1961, 1969) and Dennison and Textoris (1967, 1971) has resulted in tracing of the Tioga Metabentonite throughout the Appalachian region, where it is now known at over 125 outcrop occurrences and in several hundred wells. Most of these occurrences represent the middle coarse mica zone of Dennison and Textoris (1971a).

The reference section for the Tioga Metabentonite in central Pennsylvania is herein designated as the cut on the Penn Central Railroad, 0.3 mile south of Selinsgrove Junction, Northumberland Co. (P31).

Lithology

At outcrops in central Pennsylvania, the Tioga middle coarse mica zone usually appears as one or more micaceous siltstone beds, 2 to 8 inches thick, that weather yellowish-brown and commonly exhibit a blocky fracture (Fig. 107). The individual beds may be graded from coarse to fine upward, as near the gaging station on Tuscarora Creek, southwest of Old Port, Juniata Co. (P44). Thin beds of black calcareous shale or argillaceous limestone which contain floods of tiny juvenile brachiopods often directly underlie the metabentonite layers.

Hand specimens of the Tioga exhibit abundant bleached biotite and altered feldspar in a whitish groundmass. Pyrite is evident only in fresh samples, but its former presence in weathered samples is

Figure 107.--Tioga Metabentonite, cut on Interstate 80, Curtin Gap, Centre Co., Pa. (P60). Thick bed at hammer is probably Bed B of the middle coarse mica zone. Metabentonite beds are enclosed in dark gray to grayish black shales of Marcellus Formation.

indicated by their yellowish-brown coloration. Exposed surfaces of the metabentonite are usually coated by tiny gypsum rosettes.

In thin section the Tioga is seen to be composed predominantly of biotite, orthoclase, plagioclase (probably andesine), quartz, pyrite, and undifferentiated matrix (Fig. 108, 109). Biotite constitutes 20 to 40 per cent of the specimens examined. The biotite crystals are commonly subhedral to euhedral, average about 0.50 mm. in maximum diameter, and usually have their long axes aligned parallel to bedding. Biotite is partially altered to chlorite (Fig. 109). Highly sericitized feldspar makes up about 30 per cent of the typical metabentonite. The grains vary in size from 0.1 to 0.25 mm. and often have rounded, corroded edges (Fig. 109). Quartz, which composes about 1 to 5 per cent of average specimens, occurs as angular shards up to 0.25 mm. in maximum length. As shown clearly in Fig. 109, pyrite is extremely abundant as tiny grains about 0.01 mm. in diameter that are scattered through the matrix and also appear to rim many of the crystalline components. The pyrite is authigenic and may be related to sulfur released by the decay of organisms that were killed by the ash fall (Dennison and Textoris, 1967). The matrix is composed of glass dust that has devitrified mainly to illite (sericite), but also partly to microcrystalline quartz and montmorillonite (Dennison and Textoris,

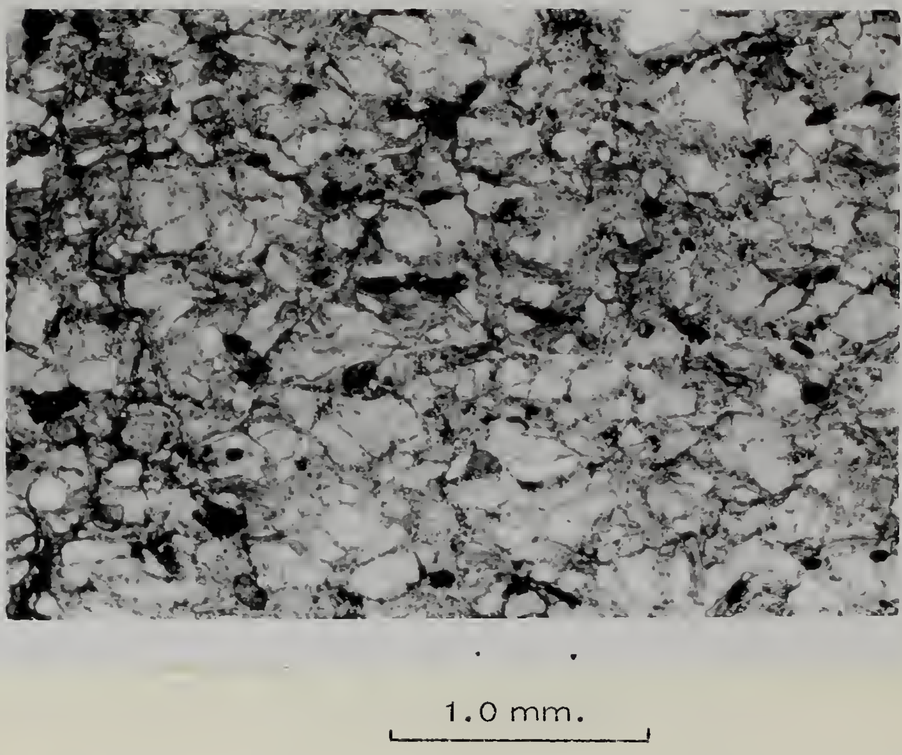


Figure 108.—Photomicrograph of Tioga Metabentonite (middle coarse mica zone, Bed B), Newton Hamilton, Mifflin Co., Pa. (P53-32). Orthoclase, andesine, biotite, and quartz grains occur in a sericite (altered volcanic glass) matrix. Black grains are pyrite. (Plane light.)

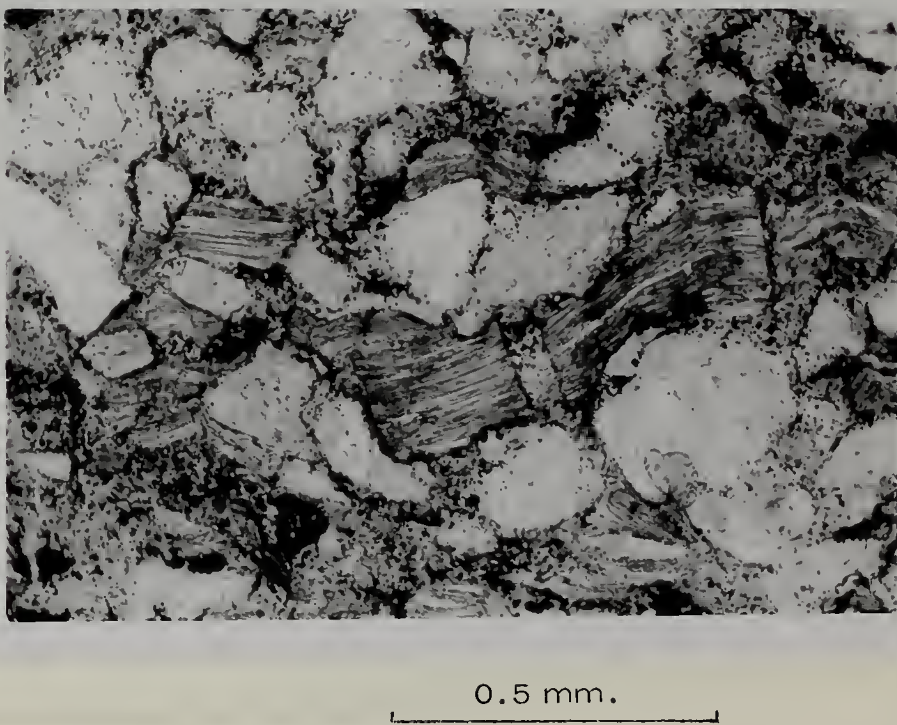


Figure 109.—Photomicrograph of portion of same slide (enlarged) shown in Fig. 108, showing feldspar partially altered to sericite and biotite partially altered to chlorite. Note abundant disseminated pyrite. (Plane light.)

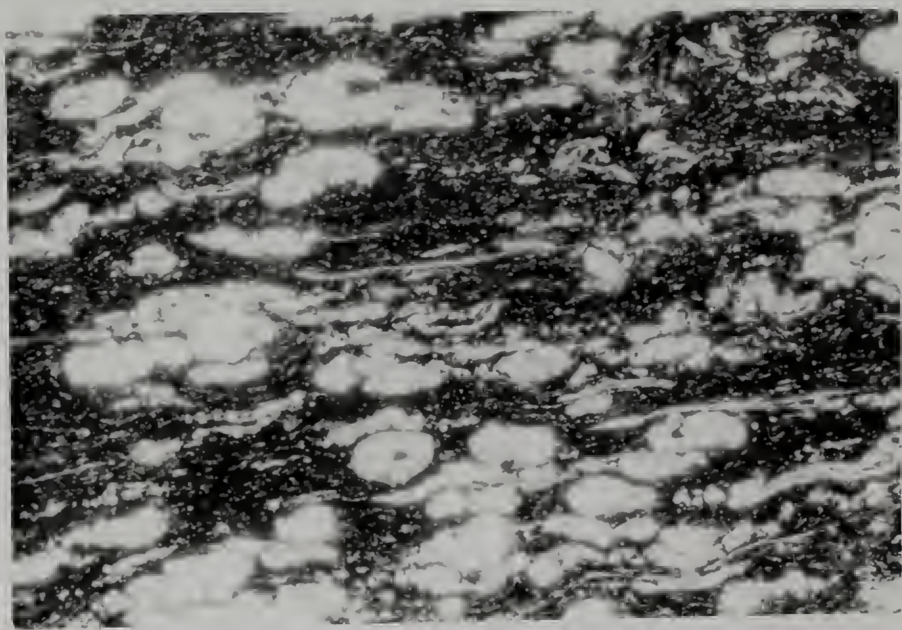
1967, 1971b). In the samples examined for the present study, matrix constitutes 30 to 50 per cent of the metabentonite.

The coquinites which occur in direct contact with the metabentonite beds of the middle coarse mica zone are generally finer grained than those which occur elsewhere in the upper Needmore and lower Marcellus. Maximum diameter of the styliolines and juvenile brachiopods in these beds rarely exceeds 1.0 mm. (Fig. 110). These beds are somewhat micaceous and weather to the yellowish-brown color typical of the metabentonite beds.

Stratigraphic Relations

Although the Tioga Metabentonite varies somewhat in stratigraphic position, it generally occurs in the transition interval between the Onondaga Limestone (and its equivalents) and the Marcellus Formation (and its equivalents).

The relationship of the Tioga to immediately underlying rock units is shown in Fig. 111. In northwestern Pennsylvania and adjacent New York and extreme eastern Pennsylvania, the Tioga overlies typical Onondaga cherty limestone. Throughout the rest of Pennsylvania, however, the Tioga rests on dark gray, calcareous shale (Needmore-Marcellus) or interbedded argillaceous limestone and calcareous shale (Selinsgrove-Onondaga). The area of thickest shale development beneath the Tioga occurs in Clinton, Centre,



1.0 mm.

Figure 110.—Photomicrograph of bituminous, laminated, highly fossiliferous, metabentonitic shale associated with Bed B of middle coarse mica zone, Tioga Metabentonite, Selinsgrove Junction, Northumberland Co., Pa. (P31-57). Fossils are mostly cricoconarids (with cavities filled with quartz and calcite) and juvenile brachiopods. (Plane light.)

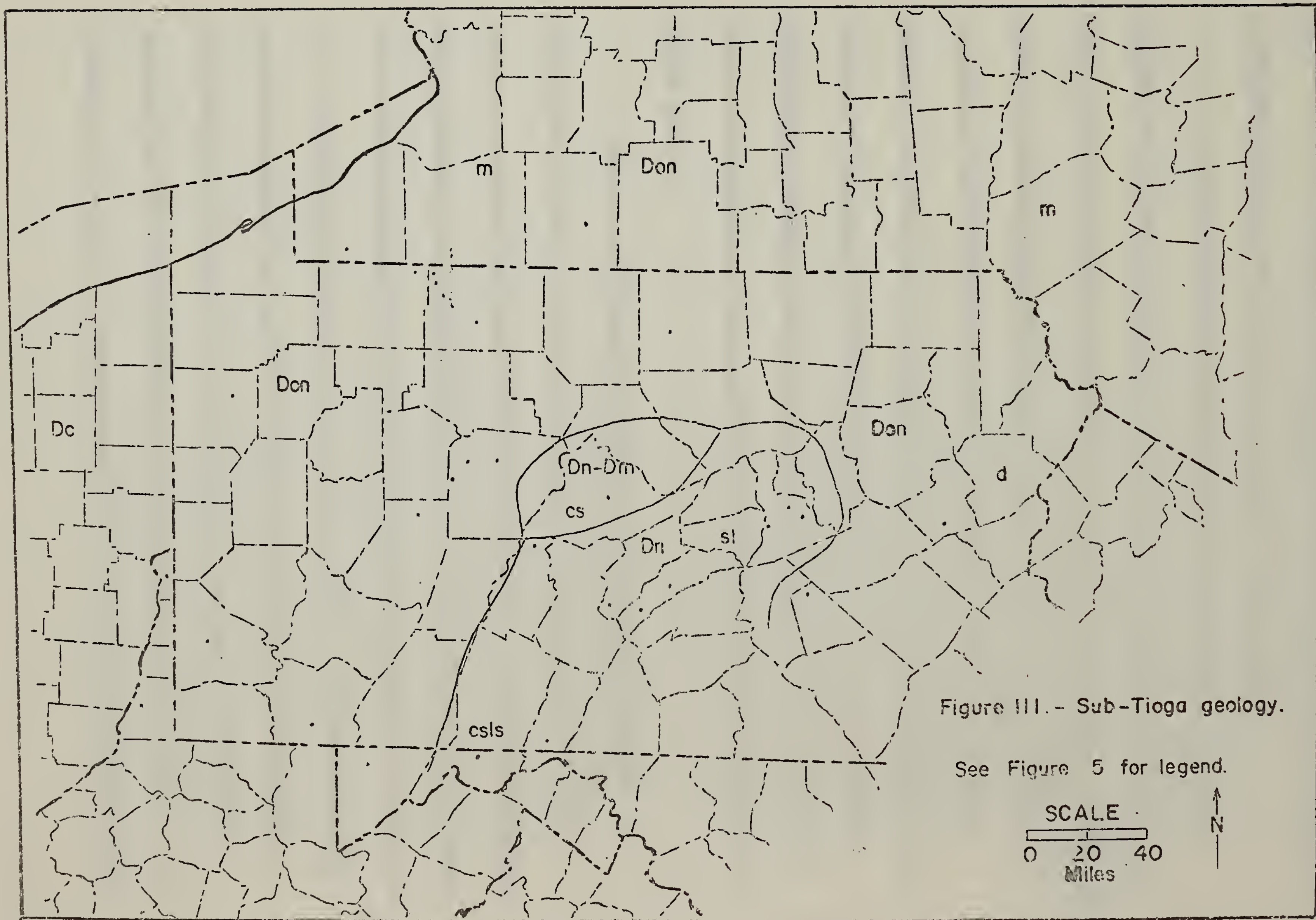


Figure III. - Sub-Tioga geology.

See Figure 5 for legend.

Clearfield, and Indiana counties, an area relatively far removed from carbonate banks in New York and eastern Pennsylvania.

Typically the lowest bed of the Tioga (A) occurs above several inches of grayish black (N2), bituminous, calcareous shale which contains a flood of very small. juvenile brachiopods. Limestone beds immediately below the dark shale, as well as those within the metabentonite interval, also often contain myriads of these tiny fossils. As observed by Dennison (1961, p. 39), the coquinites may represent organisms killed by the volcanism. The occurrence of coquinites throughout the Selinsgrove Member at Tyrone and in the lower Selinsgrove at Montoursville may indicate early phases of the Tioga event.

Rocks overlying the Tioga consist predominantly of limestones in New York and northwestern Pennsylvania and black shales in central and southwestern Pennsylvania. Along the outcrop belt in western and central New York, the Tioga Metabentonite forms the boundary between the Moorehouse (below) and Seneca members of the Onondaga Limestone (Oliver, 1954, p. 629). The stratigraphic distance between the top of the Tioga and the base of the Marcellus Formation decreases from west to east as the Seneca limestone grades into the Union Springs black shale (Oliver, 1954; 1956). The "Seneca" limestone is also present above the Tioga in the subsurface of the southern tier counties and adjacent Pennsylvania (Fig. 112). The "Seneca" has its maximum thickness, 40 feet, in northwestern McKean Co., Pa. (Fettke, 1961, pp. 197-198). It apparently thins rapidly to the southeast of this area, however, for in southern McKean Co., black shale of the Marcellus is reported above the Tioga (Fettke, 1961, pp. 217, 236).

A significant thickness of limestone may also overlie the Tioga in northeastern Pennsylvania and southeastern New York. Rickard (1969, pl. 11, 12) records up to 20 feet of limestone above the "Tioga" in western Greene and Ulster counties, N.Y. About 54 feet of medium gray, silty, cherty limestone occur above a meta-bentonite (Tioga ?) in the Richards No. 1 well, Lackawanna Co., Pa. (Kehn, Glick, and Culbertson, 1966, p. 76). A metabentonite is also present 30, 26, and 7 feet below the top of the Onondaga Limestone at East Stroudsburg, West Bowmans, and Swatara Gap, respectively. These metabentonites may be older than the single bed known in New York and northwestern Pennsylvania.

In Virginia and West Virginia, the middle coarse mica zone of the Tioga Metabentonite lies at the contact of the Millboro (Marcellus) black shale and the Needmore shale, Huntersville chert, or Onondaga limestone (Dennison, 1961; Dennison and Textoris, 1971b, p. 64). Further southwest, at Little War Gap, Hawkins Co.,

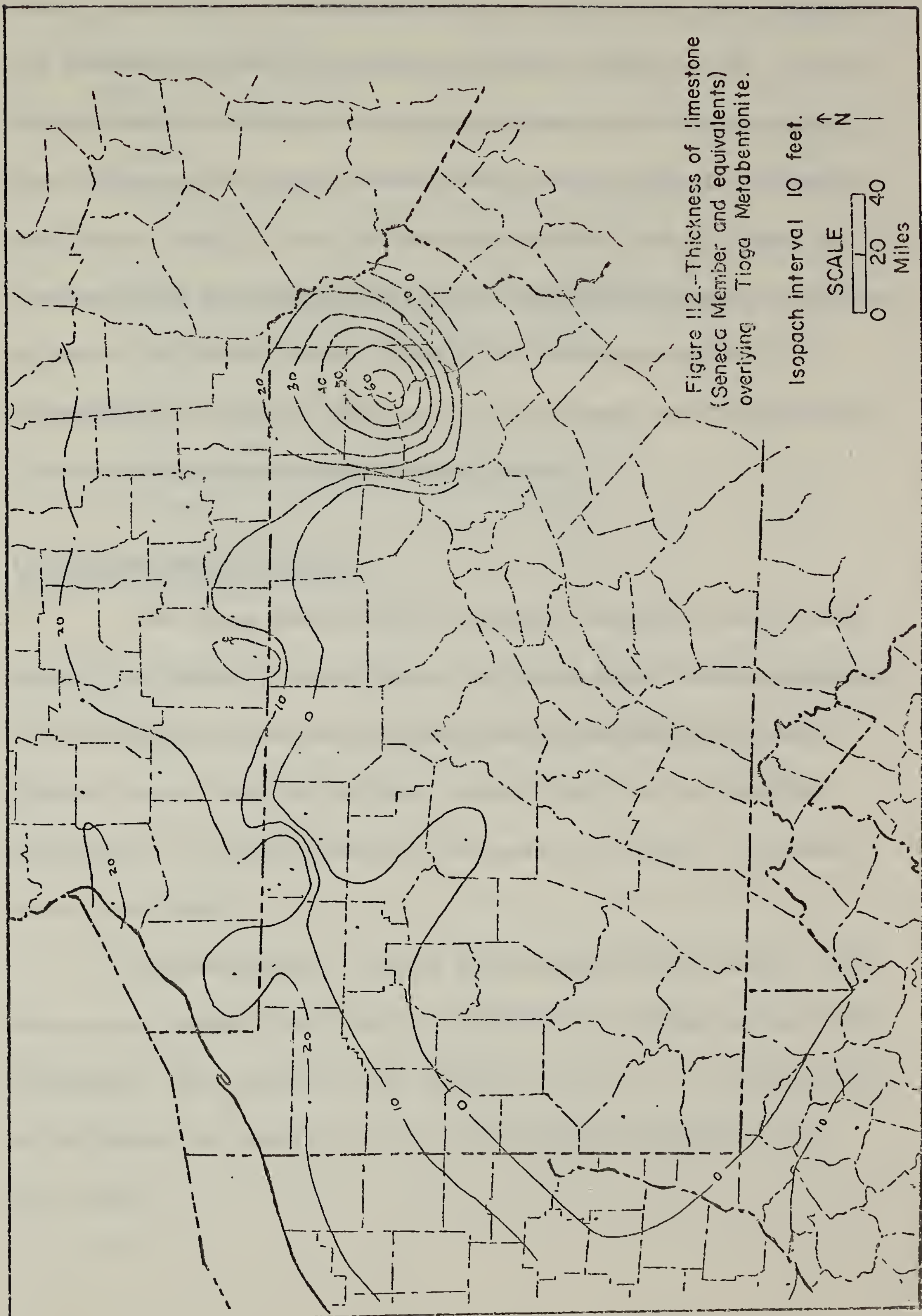


Figure 112.--Thickness of limestone (Seneca Member and equivalents) overlying Tioga Metabentonite.

Tenn., four Tioga Metabentonite layers occur in the basal 27 feet of the Chattanooga Shale (Dennison and Boucot, 1969, p. 18). In the Illinois Basin, the Tioga has been encountered in numerous wells near the top of the Grand Tower/Jeffersonville Limestone (Meents and Swann, 1965, p. 10; Collinson and others, 1967, p. 954). A metabentonite that can be traced from carbonates through anhydrites to salt in the Detroit River Group of the Michigan Basin (E. J. Balthusaitis, in Sloss, 1969, p. 777) is probably the Tioga middle coarse zone (Dennison and Textoris, 1971b).

Distribution and Thickness

The Tioga Metabentonite has been recognized over a vast area in the eastern United States. Its areal extent encompasses over 300,000 square miles and is approximately bounded by the Appalachian Great Valley on the east, central New York and northern Michigan on the north, central Tennessee on the south, and eastern Iowa on the west.

In northwestern Virginia and adjacent West Virginia, near the source volcano, the Tioga is a thick pile of tuffaceous sediments (Dennison, 1961; Dennison and Textoris, 1971b). The Tioga interval at Williamsville, Bath Co., Va., is as follows (Dennison, 1971, pp. 47-48):

	Feet
Millboro Formation	
Black, platy shale.	—
Brownish-black, very slightly tuffaceous (?) shale.	100
Brownish-black, somewhat tuffaceous shale, with three thin metabentonite beds in lower 14 feet.	84
Middle coarse mica zone of Tioga Metabentonite (three metabentonite beds 0.6, 0.10 and 0.20 feet thick, in descending order)	3
Needmore Formation	
Platy, calcitic shale with tuffaceous beds. Contains Styliolina and Tentaculites (a).	23
Interbedded calcitic shale and limestone, with some brownish-gray tuffaceous shale.	50
Interbedded calcitic shale and limestone with no tuffaceous influence.	—

The thickest section of Tioga tuffaceous beds is at Seven Fountains, Shenandoah Co., Va., on the east flank of the Massanutten Syncline, where the Tioga influence extends through 203 feet of sediments (Dennison and Textoris, 1971b).

The Tioga interval thins northward through West Virginia and Maryland into Pennsylvania. Generally only the middle coarse mica zone can be recognized in central Pennsylvania, although thin metabentonite streaks do occur both above and below the main beds. The two beds (A and B) present at most outcrops are both believed to be part of the middle coarse mica zone. Dennison (1967, personal communication) suggests that the upper bed (B, of this report) is the one that extends into New York.

The relationship of the several metabentonite beds reported from the Richards No. 1 well, Lackawanna Co., with the Tioga beds of central Pennsylvania is uncertain. Metabentonites apparently occur at the following horizons in the Richards well (Kehn, Glick, and Culbertson, 1966, p. 76):

7,464 feet (54 feet below top of Onondaga)
7,512 - 7,517 feet
7,521 - 7,725 feet

The metabentonite at 7,464 feet may represent the entire middle coarse mica zone (beds A and B), or it may be an older ash layer. The two lower metabentonitic intervals may represent horizons that are absent at outcrops, but they are more likely cavings from the higher bed.

Measured thicknesses of the Tioga interval (i.e., the middle coarse mica zone) in central Pennsylvania range from 9 feet at more southerly exposures to 5 feet at northerly ones (Fig. 113). No complete exposures are known south of Newton Hamilton, where the middle zone is 9 feet thick. Dennison (1961, p. 37) shows a thickness of 3 to 4 feet for the Tioga interval in south-central Pennsylvania. The thick Tioga sections at Newton Hamilton are a result of more rapid sediment deposition in this area during latest Onesquethaw time. (That is, more limestone and shale were

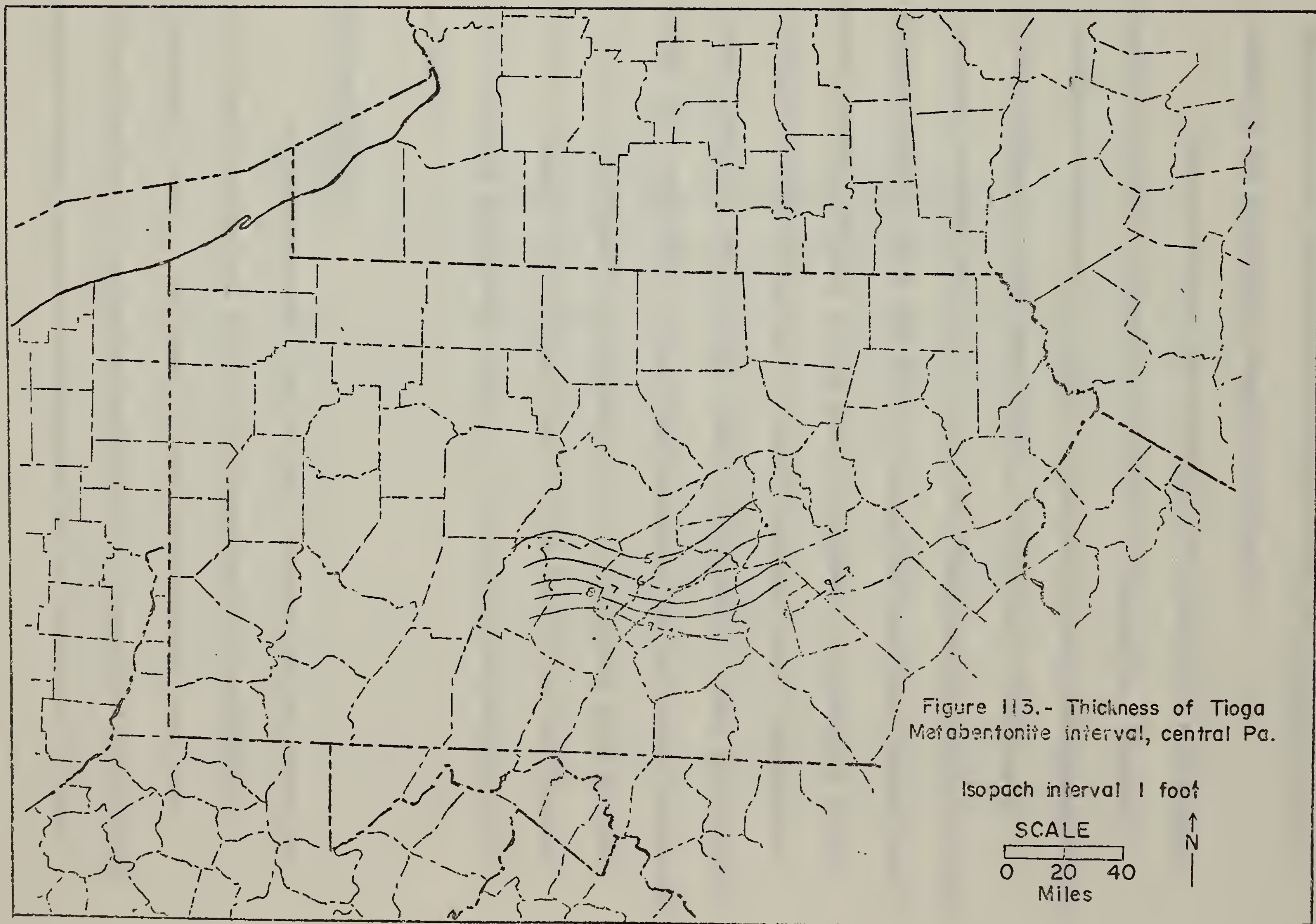


Figure 113.- Thickness of Tioga Metabentonite interval, central Pa.

Isopach interval 1 foot

deposited during the interludes between volcanic eruptions represented by the individual metabentonite beds.)

Table 10 shows the thickness of the various metabentonite beds at outcrops in eastern and central Pennsylvania. Marked variation in thickness is evident. Apparently Bed A disappears north of the Allegheny Front, while Bed B, the coarser of the two at outcrops, extends into New York. The Tioga (Bed B) is often reported to be between 1 and 3 feet thick in subsurface sections (Fettke, 1961), but it probably always is less than a foot thick. At outcrops in New York, the single Tioga bed is usually between 3 and 8 inches thick (Hall, 1842, p. 163; Lincoln, 1895, p. 91; Oliver, 1954, pp. 629-631; 1956, pp. 1465-1466). The Tioga Metabentonite bed that is recognized in the mid-continent region (Bed B ?) is 1 to 4 inches thick in most wells, although in the Illinois Basin it may locally be 6 to 8 inches thick (Meents and Swann, 1965, p. 10; Collinson and others, 1967, p. 954).

Age and Origin

By definition the Tioga middle coarse mica zone marks the top of the Onesquethaw Stage in the northeastern United States (Dennison, 1961, p. 10; 1969, p. 13). Rb-Sr (whole rock) age determinations on weathered samples of the Tioga from Virginia and adjacent states show an average age of 302 million years (Fullagar

TABLE 10

THICKNESS (IN INCHES) AND TENTATIVE CORRELATION OF METABENTONITE BEDS IN TIOGA INTERVAL

(See Appendix for location of numbered sections.)

	P11	P13	P22	P29	P31	P43	P44		P56	P58	P60	P61	P63	M2
				1										
								2						
B			6	5	4		8	4	2		7	2	6	12
								2						
							2			4	0.5			
										2				
								3.5						
A					4	3	6.5	2	9	6		2		
								1						
									0.5					
	12	18	12	19										

and Bottine, 1969b). Because of the weathered condition of the samples, however, this can only be considered a minimum age. Interpolation from some recent time scale charts indicates that the Tioga Metabentonite actually was deposited about 365 to 380 years ago (Kulp, 1961, p. 1111; Friend and House, 1964, p. 236).

The Tioga Metabentonite records a related series of major volcanic events in lower Middle Devonian time. Culmination of volcanic activity resulted in the wind-blown distribution of the middle coarse mica zone over much of what is now eastern United States (Dennison and Textoris, 1971b). Detailed stratigraphic and petrologic studies by Dennison (1961; 1971a; 1971b) and Dennison and Textoris (1971a; 1971b) indicated that the source volcano was in the latitude of central Virginia. Felsic rocks interstratified with the Tioga interval near Monterey, Highland Co., Va., originally believed to be flows associated with the Tioga volcanoes (Dennison and Textoris, 1967) are now known to be Eocene intrusives (Fullagar and Bottino, 1969a; Dennison, 1971b). Granodiorite plutons located in the Piedmont Belt of Fluvanna County, Virginia, are of the correct general age (300 to 500 million years) and composition (Smith, Milici, and Greenberg, 1964, p. 21) to represent the Tioga magma (Dennison, 1969; Dennison and Textoris, 1971b).

As suggested by Dennison and Johnson (1971), volcanism in

Virginia during Middle Devonian time may have been related to the 38th parallel fracture zone, a structural lineament that extends from Virginia, across West Virginia, into the highly faulted mineral districts of Kentucky, Illinois, and Missouri (Zartman and others, 1967, pp. 865-867; Heyl and others, 1965; Snyder and Gerdemann, 1965). The wide range in age of intrusives along this line suggests that it marks a deep fault zone along which movement has been periodically renewed through Paleozoic and Mesozoic time (Zartman and others, 1967, p. 848). Evidence for late Pre-Cambrian, Devonian, Triassic, Jurassic and Eocene igneous activity at the east end of the 38th parallel lineament has been summarized by Dennison and Johnson (1971, pp. 504-506).

The Onesquethaw Stage in the Subsurface of North-Central and Western Pennsylvania

In the Allegheny Plateau region, north and west of the Allegheny Front, Onesquethawan rocks are buried beneath thousands of feet of younger Devonian, Mississippian, and Pennsylvanian rocks. Since the plateau area is a major deep gas province, however, much information on subsurface conditions is available from drill cuttings and gamma-ray neutron logs. No drill cuttings were examined during the present study, but most available published sample and radio-activity logs were utilized. Detailed well sample descriptions by

Martens (1939; 1945), Fettke (1940; 1941; 1961), Ebright, Fettke and Ingham (1949), and Wagner (1958a; 1958b) were found especially useful. Although some minor reinterpretations have been made, most of the data have been incorporated without change.

Subsurface Onesquethawan rocks consist predominantly of argillaceous limestone with minor glauconitic, calcareous shale in north-central Pennsylvania and adjacent New York, cherty limestone and limy chert in northwestern and western Pennsylvania, and chert with minor argillaceous limestone in southwestern Pennsylvania. (See Fig. 3; Jones and Cate, 1957, pl. 4; Oliver and others, 1971, pl. 4.) As discussed below, the Huntersville Chert, Onondaga (and Columbus) Limestone, and Bois Blanc Formation of outcrop areas are present in the subsurface. In Cameron, Elk, Clearfield, and Indiana counties, thick beds of gray, calcareous shale in the lower part of the Onesquethaw interval (Fettke, 1961, pp. 308-309, 481; Lytle and others, 1961b, pl. 7) are undoubtedly extensions of the Needmore lithosome of central Pennsylvania. The Tioga Metabentonite has been recognized in numerous wells throughout western Pennsylvania.

Except in the areas noted below, Onesquethawan rocks generally overlie the Oriskany (Ridgeley) Sandstone. (See Fig. 5.) Over a broad belt that extends from Potter and McKean counties southwestward to Armstrong, Clarion and Venango counties, the Ridgeley is absent or only sporatically developed (Fettke, 1950; Jones and Cate, 1957, p. 3, pl. 3; Kelley and others, 1970, p. 57) and the Onesquethaw usually overlies limestones of Helderbergian age (Jones and Cate, 1957, pl. 1). In parts of Erie, Crawford, and Warren counties, rocks that lie subjacent to the Onesquethaw are limestones and dolomites of the Helderberg and Bass Islands groups (Cate, 1961, pl. 1, 2). The Oriskany Sandstone that underlies the "Onondaga" Limestone in northwestern Pennsylvania may actually represent a younger sand, perhaps the Springvale of Onesquethaw age, that has its source to the northwest (Summerson and Swann, 1970), as suggested by Kelley and others (1970a, pp. 57-58).

Onesquethawan rocks are overlain by black shales of Marcellus aspect in portions of western Pennsylvania and adjacent areas. The change from black shale to limestone may coincide with the position of the Tioga Metabentonite. More often, however, the Tioga occurs below the lithologic change. Limestone that lies immediately above the Tioga is probably in stratal continuity with the Seneca Limestone of New York, the Delaware Limestone of Ohio, and the Dundee Limestone of Michigan (Oliver and others, 1967; Sanford, 1967).

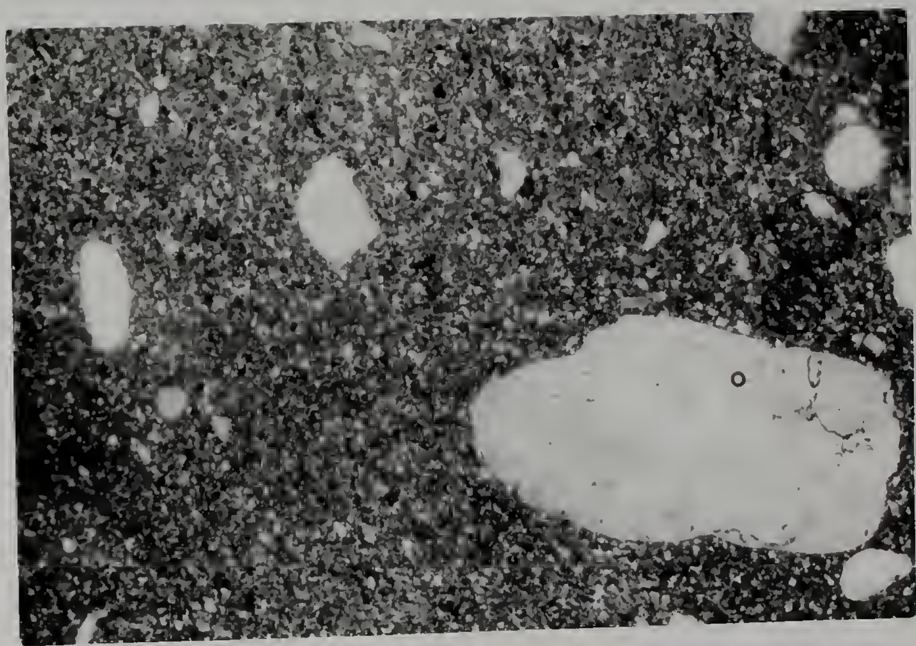
The subsurface Onesquethawan sequence ranges in thickness from less than 10 feet in some areas in north-central Pennsylvania to almost 300 feet in extreme northwestern and southwestern Pennsylvania. The area of thinnest development is in the north-central part of the state, where over a large area in Tioga, Potter, Cameron, Clinton, and adjacent counties the interval is less than 50 feet thick. Westward and southwestward from this area of minimum thickness, the Onesquethaw thickens to about 260 feet in Erie Co. and about the same in southern Washington Co. The Onesquethaw interval is somewhat thinner, about 200 feet thick, along the Pennsylvania-Ohio boundary in Mercer, Lawrence, and Beaver counties. Onesquethawan rocks exceed 300 feet in thickness between Lake and Carroll counties, Ohio (Oliver and others, 1967; 1971).

Huntersville Chert

At its type locality, near Huntersville, Pocahontas Co., W.Va., the Huntersville Chert consists of gray to black, irregularly bedded, sandy chert that contains occasional streaks of green phosphatic sandstone (Price, 1929, pp. 232, 237). Commonly present are brecciated zones that contain blocks of cherty material, chips of black, silicified shale and fragments of yellow clay shale (Woodward, 1943, p. 260). Although chert is only rarely present at Onesquethawan outcrops north of Pocahontas Co., W.Va., Huntersville-type lithology constitutes a major portion of the subsurface Onesquethaw in West

Virginia, western Maryland, and southwestern Pennsylvania.

In southwestern Pennsylvania, the Huntersville is mostly dark gray, slightly calcareous, sometimes glauconitic chert with interbeds of dark gray glauconitic shale and siltstone (Martens, 1939; Fettke, 1940). Dolomite is fairly common and occurs as rhombs scattered through the chert and siltstone (Martens, 1939, pp. 28, 69, 72, 79, 81). In the A. T. McBurney No. 1 well, Washington Co. (P308), the Huntersville contains considerable cherty limestone in the lower part (Martens, 1939, p. 62). Limestone also constitutes a large portion of the interval here included with the Huntersville in deep wells in Beaver, Lawrence, Allegheny, and Butler counties, where the chert grades laterally into the Bois Blanc Formation and Onondaga Limestone. In the subsurface of Clearfield Co., just west of the Allegheny Front, the Huntersville contains significant admixtures of dark gray to black, siliceous and calcareous shale (Lytle, Bergsten, Cate, and others, 1961, pl. 7; Edmunds, 1968, p. 16, pl. 2; Glover, 1970, p. 115; Edmunds and Berg, 1971, pl. 2), a reflection of an intertonguing relationship with the Needmore Formation. The only representative of the Huntersville present in outcrops east of the Front is a thin zone of ferrugenous chert that lies at the base of the Needmore Formation in Blair and Huntington counties (Fig. 114; Swartz and Swain, 1941, pp. 403-405).



1.0 mm.

Figure 114.—Photomicrograph of sandy, calcareous chert ("Huntersville"), Needmore Formation (basal part), Frankstown, Huntingdon Co., Pa. (P59). Large grains are subangular to subrounded quartz. Ground-mass is composed of microcrystalline chert, with abundant disseminated grains of hematite and calcite. (Polarized light.)

As shown in Fig. 115, the Huntersville reaches its maximum thickness of over 250 feet in central Washington Co. Part of this total interval, however, consists of cherty limestone, rather than bedded chert. East of Washington and Greene counties, the thickness of the Huntersville decreases, but the percentage of chert increases. (See Fig. 3; Jones and Cate, 1957, pl. 4.) Decrease in thickness to the east and north of Fayette and Westmoreland counties is a result of both depositional thinning and facies changes. (See plates 3, 4, and 5.) Chert is absent in central Pennsylvania east of a sinuous southwest-to-northeast line that extends from eastern Somerset Co. on the south to eastern Potter Co. on the north.

At outcrops in West Virginia, the Huntersville Chert contains a typical Onesquethawan fauna (Woodward, 1943, p. 274). Although Emsian elements seem to predominate (Woodward, 1943, pp. 275, 276-278; Boucot and Johnson, 1968, pp. B2-B3), stratigraphic considerations indicate that the Huntersville ranges in age from Emsian to Eifelian both at outcrops and in the subsurface.

Bois Blanc Formation

The Bois Blanc Formation was named by Ehlers (1945, p. 80) for exposures on Bois Blanc Island in the Mackinac Straits region of northern Michigan. In the type area the formation consists

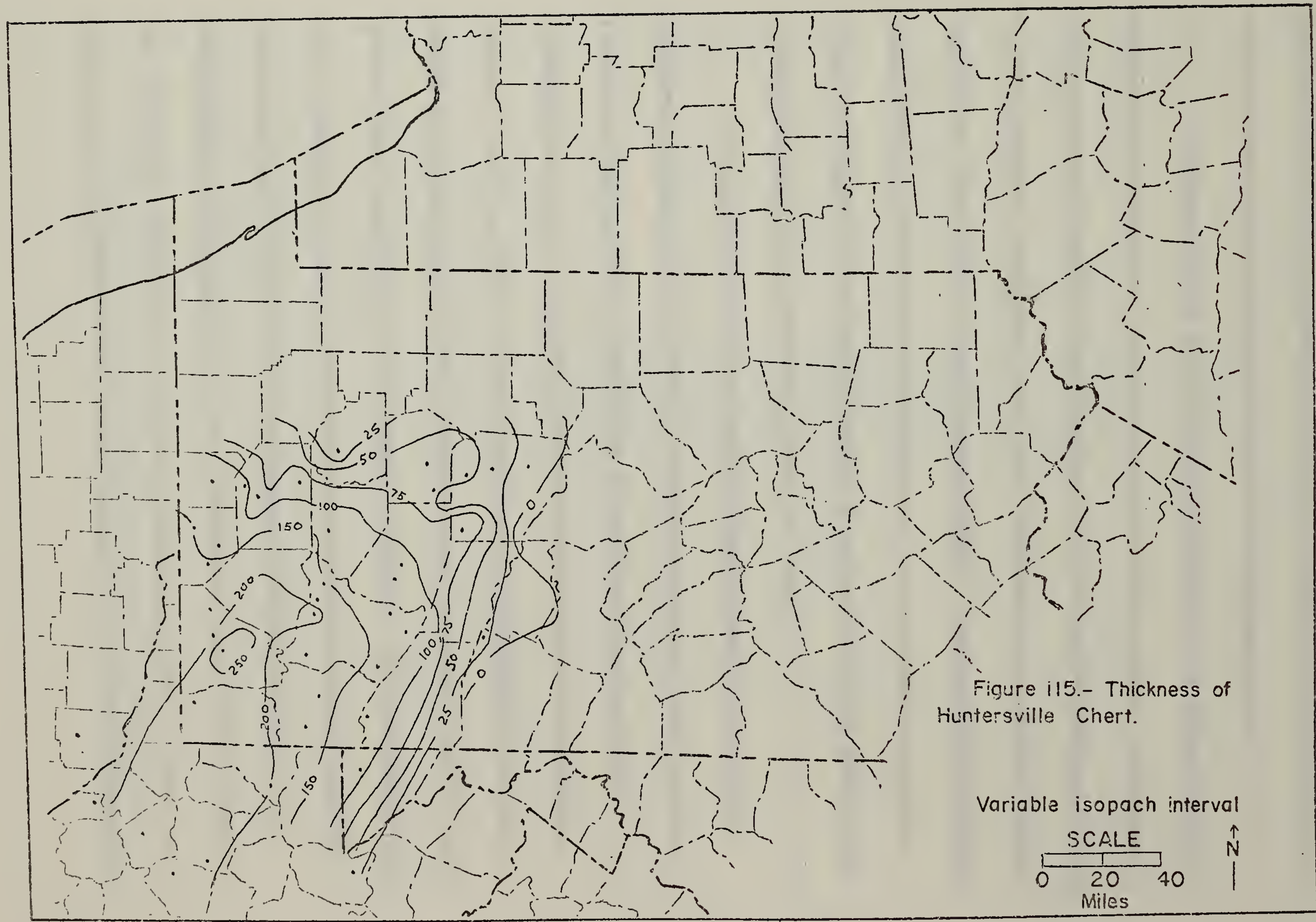


Figure 115.- Thickness of Huntersville Chert.

predominantly of fossiliferous limestone, dolomite, and chert, the dolomite and chert being most abundant in the lower part.

Presence of the Bois Blanc Formation in the subsurface of southwestern New York and northwestern Pennsylvania, at the base of a sequence of cherty limestone and chert formerly assigned wholely to the Onondaga Limestone, has been indicated by Dow (1962), Oliver and others (1967; 1971), and Rickard (1969). The area of Bois Blanc occurrence in northwestern Pennsylvania is connected through the Chatham Sag of southwestern Ontario with the main Bois Blanc area in the Michigan Basin (Sanford, 1967, p. 978).

The Bois Blanc Formation in western New York and the Niagara Peninsula of Ontario is a medium dark gray, fine grained limestone that contains little chert in New York outcrops but considerable chert in Ontario outcrops where sections are thicker (Oliver, 1967, p. A5). In the subsurface of northwestern Pennsylvania and adjacent New York, the Bois Blanc is predominantly light gray, finely crystalline, very cherty limestone. Considerable light gray, slightly calcareous bedded chert occurs in the lower part of the formation in eastern Erie and western Warren counties, Pa., and southern Chautauqua Co., N.Y. (Wagner, 1958; Fettke, 1961, pp. 75, 613). Southward, along the Pennsylvania-Ohio border, the Bois Blanc is predominantly cherty limestone. Dolomite increases in abundance westward into Ohio. From Cuyahoga and Wayne counties to its western pinch-out in Erie Co., Ohio, the formation consists of brown to brownish-gray, somewhat sandy, finely crystalline dolomite, with considerable white, grayish brown, or bluish gray chert (Dow, 1962, pp. 8-9; Janssens, 1968, pp. 8-9). The lower portion of the Bois Blanc is typically rich in quartz sand and glauconite in eastern Ohio (Dow, 1962, pp. 8-9, 32) and portions of northwestern Pennsylvania (Fettke, 1961, pp. 75-76).

Separation of the Bois Blanc from the overlying Onondaga Limestone is quite difficult in the subsurface, since the two formations have very similar lithologies. Sample descriptions from wells in Erie and Warren counties, Pa., and Chautauqua Co., N.Y. (Wagner, 1958; Fettke, 1961, pp. 32, 613) indicate that the lower 50 to 100 feet of the "Onondaga" contains considerably more chert than the upper part.[17] On neutron logs from the Pierce Field, Erie Co., Pa. (Kelley and McGlade, 1969), the lower 80 to 90 feet of the "Onondaga Limestone" has distinctly greater porosity than higher beds (Fig. 116). This lower, very cherty, more porous zone represents the Bois Blanc.

Thickness of the Bois Blanc Formation in northwestern Pennsylvania and adjacent Ohio and New York is shown in Fig. 117.

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[17]Dow (1962, p. 9) recognized a similar "chert-break" between the Bois Blanc and Onondaga/Columbus in northeastern Ohio.

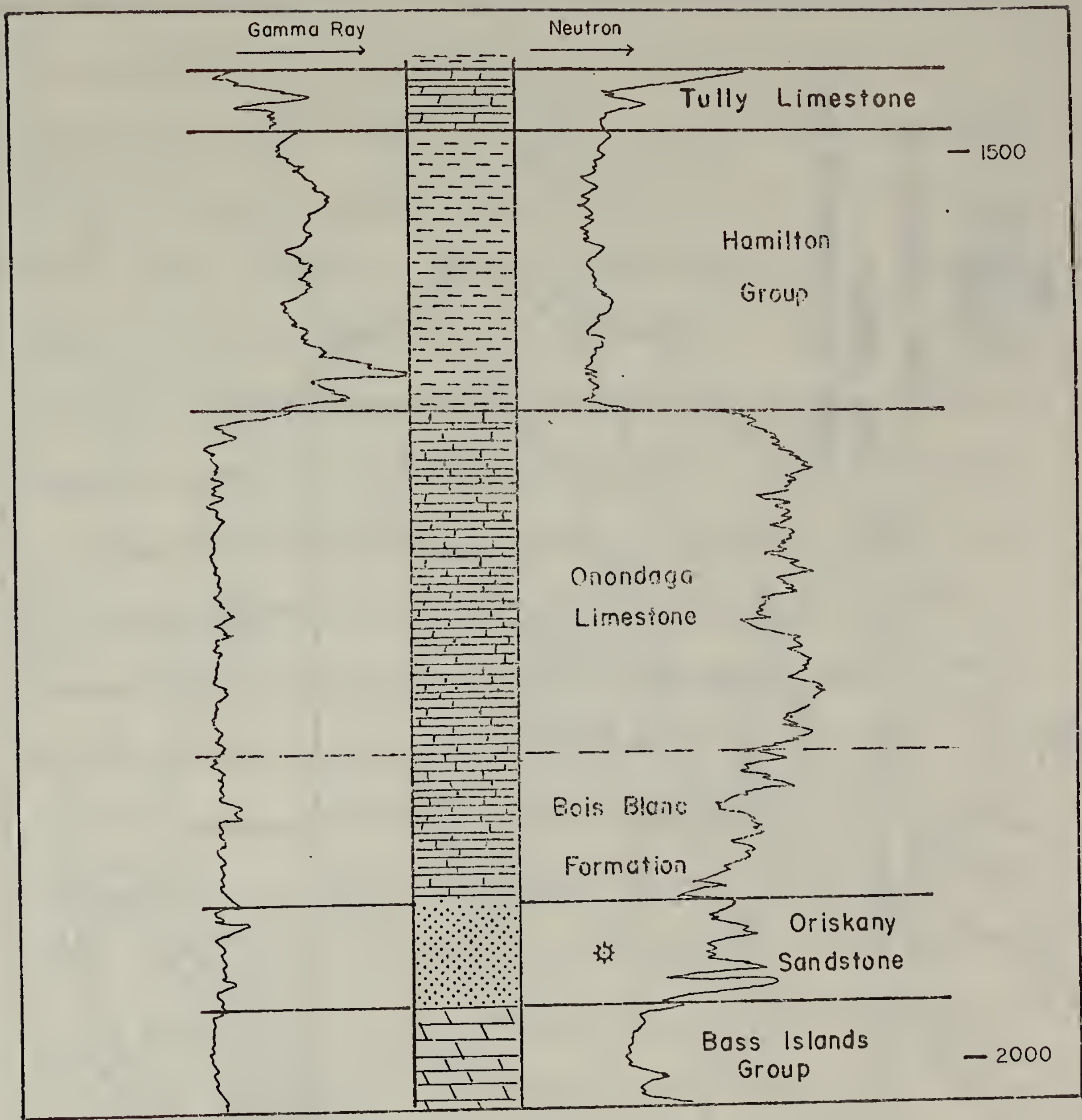

Figure 116.—Gamma ray-neutron log of Osterberg No. 1 well (Caymen Corp.) combined with generalized lithology log of Pennsylvania Block A No. 1 well (New York State Natural Gas Corp.), Pierce Field, Erie Co., Pa. (Slightly modified from Kelley and McGlade, 1969, pl. 1.)

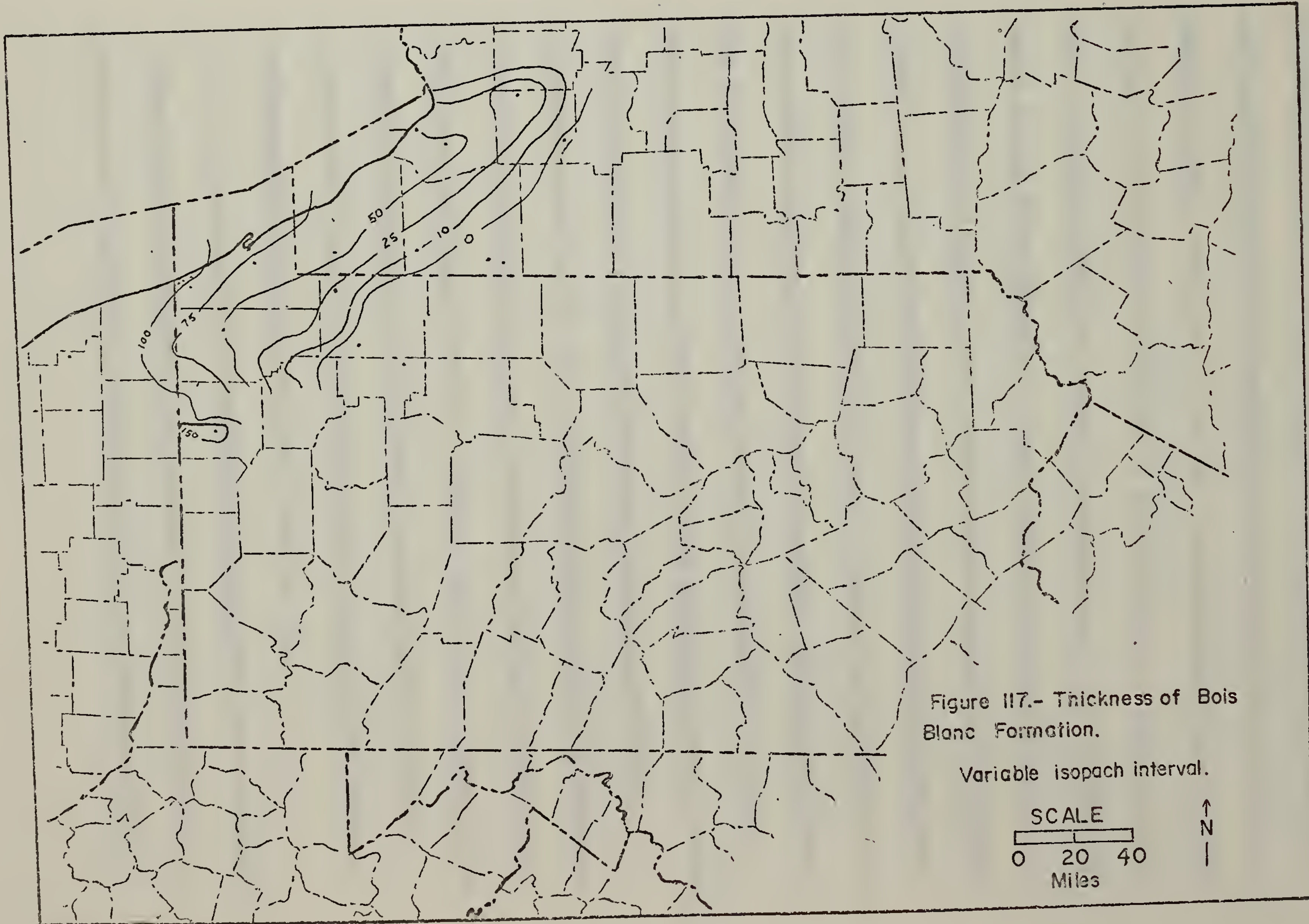

Figure 117.- Thickness of Bois Blanc Formation.

Variable isopach interval.

In western Erie Co., Pa., about 110 feet of light gray, fine grained, very cherty limestone are assigned to the formation (Dow, 1962, pl. 1; see also Feltke, 1961, pp. 7, 19, 32). The Bois Blanc thins to about 85 feet in the Goodwill-Curley No. 1 well, Erie Co. (P195), about 57 feet in the Kyle Morse No. 1 well, Chautauqua Co., N.Y. (Y65), and about 32 feet in the Spetz No. 1 well, Warren Co., Pa. (P181). Identification of the Bois Blanc further east is uncertain, but Rickard (1969, pl. 12) shows the formation extending as far east as the Nunn No. 2 well, eastern McKean Co. (P161). The writer believes that the Bois Blanc does not extend this far to the east. Although the extent of the Bois Blanc to the southeast of Erie Co. is uncertain, marked thinning of the Onesquethaw interval in this direction makes it unlikely that the formation extends much farther than the approximate 0-isopach shown in Fig. 117. The Bois Blanc maintains a thickness of about 70-100 feet in western Crawford and Mercer counties (see Kelley and McGlade, 1969; Dow, 1962, p. 50, pl. 1). Farther to the south and southwest, the Bois Blanc Formation grades into the Huntersville Chert. In northeastern Ohio, the Bois Blanc reaches thicknesses of about 150 feet (Dow, 1962, pl. 1).

The Bois Blanc Formation in the subsurface of northwestern Pennsylvania is presumed to be equivalent in age to strata of the same name in Michigan, Ontario, and New York which contain an

Emsian (upper Lower Devonian) fauna (Boucot and Johnson, 1968; see also Ehlers, 1945, pp. 106-109).

Onondaga Limestone

In the common parlance of the well driller and "wildcatter" of the western Pennsylvania plateau region, the "Onondaga Limestone" includes all limy and cherty strata between the top of the Oriskany Sandstone and base of the Marcellus black shale. As used in the present paper, the Onondaga consists of cherty and argillaceous limestone, with minor bedded chert, which lies between the top of the Bois Blanc (or Huntersville) and the base of the Marcellus. Like the type Onondaga Limestone of outcrop areas in New York, the subsurface Onondaga contains both Onesquethaw and Cazenovia-age rocks. Where the Tioga Metabentonite is present (and reported), separation of the Seneca-Delaware limestone equivalents from the underlying Onesquethawan limestone is an easy matter. Although it is likely that the Tioga is always present, the metabentonite is often not reported, or else it is reported through an indefinite interval because of cavings. Rigorous definition of the Cazenovia-age limestones is not possible under these conditions.

The bulk of the Onondaga Limestone in northwestern Pennsylvania and adjacent New York is composed of fine grained, light gray, fossiliferous limestone that abounds in light brownish-gray chert (Fettke, 1961, pp. 6-7, 19, 31-32, 612-613, etc.). In Mercer Co., Pa., and areas to the south and southeast, the Onondaga becomes increasingly cherty, glauconitic and dolomitic (Fettke, 1941, p. 22; Dow, 1962, pp. 47-49) as it grades into the upper part of the Huntersville Chert. East and southeast of Warren Co., Pa., the formation becomes more argillaceous and less cherty. Thick shale beds are interlayered with the limestone in the Pennsylvania State Game Lands, Warrant 3653, No. 1 well, Elk Co. (P157) and the A. Pardee Estate No. 1 well, Cameron Co. (P143) and in parts of the East Fork-Wharton Gas Field, Potter Co. (Fettke, 1961, pp. 308, 481; Ebright, Fettke, and Ingham, 1949, p. 37).

At the top of the Onondaga throughout much of western Pennsylvania occurs a relatively thin but remarkably persistent unit of non-cherty, dark gray, argillaceous limestone. This unit is 20 to 40 feet thick across the northern tier counties of Pennsylvania from Erie to Tioga counties, but considerably thicker farther east where it represents the entire Onondaga interval. To the south, argillaceous, non-cherty limestone overlies the Huntersville Chert in the Reed-Deemer Gas Pool and adjacent parts of Clearfield and Indiana counties (Lytle and others, 1961b, pl. 7; Glover, 1970, p. 112). The same relations prevail in southwestern Pennsylvania

(Martens, 1939, p. 79). Argillaceous limestone also occurs above cherty Onondaga/Columbus Limestone in the subsurface of eastern Ohio (Fettke, 1961, p. 625; Dow, 1962, p. 31) and above the Huntersville Chert in the subsurface of West Virginia (Woodward, 1959, p. 18). Generally this upper argillaceous limestone occurs in close association with the Tioga Metabentonite (in wells in which the Tioga is reported) and is probably in part equivalent to the Seneca Member of the Onondaga Limestone of New York and the Delaware Limestone of Ohio (Woodward, 1959, p. 18).

Fig. 118 shows the thickness of the Onondaga Limestone in western Pennsylvania and adjacent areas. Maximum development of the Onondaga is in northern Erie Co., Pa., where the formation attains a thickness of 175 feet. To the east, southeast, and south of Erie Co., the Onondaga thins progressively and is in fact less than 25 feet thick over a broad area that lies southeast of an irregular line extending from central Steuben Co., N.Y., to central Beaver Co., Pa. In the border counties of New York and Pennsylvania, this marked decrease in thickness is a result mainly of depositional thinning of the Onondaga over a broad area that subsided faster than depositional build-up, whereas to the southeast and south thinning of the Onondaga is caused by facies change into the upper part of the Huntersville Chert. (See plates 2 and 5.)

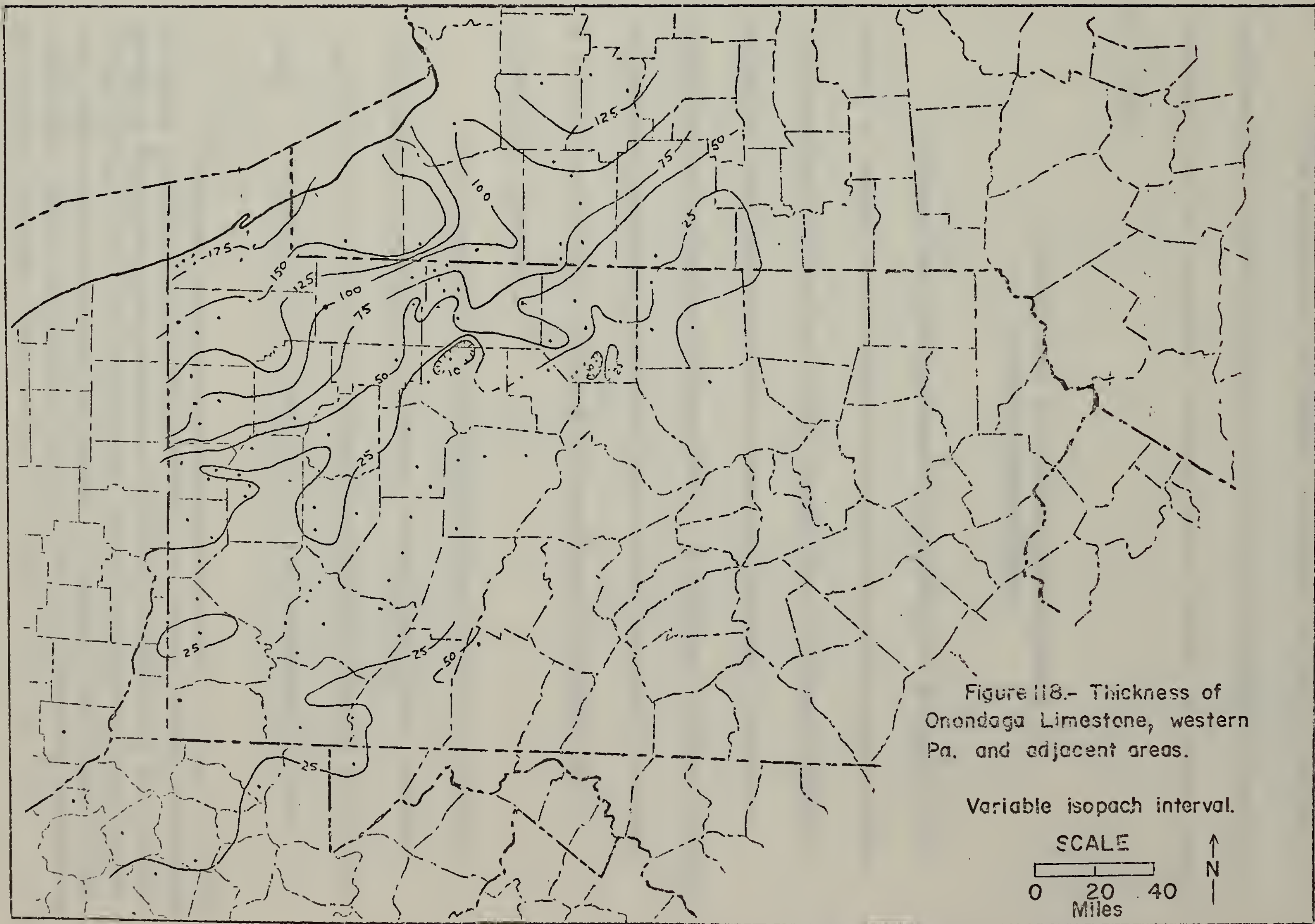

Figure 118.- Thickness of Onondaga Limestone, western Pa. and adjacent areas.

Variable isopach interval.

The subsurface Onondaga Limestone, as herein defined, is believed to be contemporaneous with the type Onondaga of New York outcrops, and is, therefore, Eifelian (lower Middle Devonian) in age (p. 133).

Natural Gas in Onesquethawan Rocks of the Plateau Region

At least two Onesquethawan rock units are presently productive of natural gas in western Pennsylvania and adjacent states. The Huntersville Chert commonly yields large volumes of gas from structural traps associated with Oriskany (Ridgeley) Sandstone reservoirs in the eastern plateau area. In addition, several recently discovered subsurface, coralline reefs in the Onondaga Limestone of south-central New York have all been found to contain gas in commercial quantities.[18]

The Huntersville Chert gas pools lie mainly in a belt that trends southwestward across western Pennsylvania from northern Clearfield Co. to southern Somerset and Fayette counties (Fig. 119; Table 11). Northeast of Clearfield Co., the Huntersville is not

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[18] Another probable Onesquethawan reservoir is the so-called Oriskany Sandstone of extreme northwestern Pennsylvania, which may in fact be the Springvale Sandstone (p. 272). (See Kelley and others, 1970a; Lytle, 1973.) The Springvale (?) is productive in Erie, Crawford, and McKean counties from small, irregularly distributed structural traps, which may be controlled by Silurian evaporite distribution (Kelley and McGlade, 1969; Kelley and others, 1970b, p. 34).

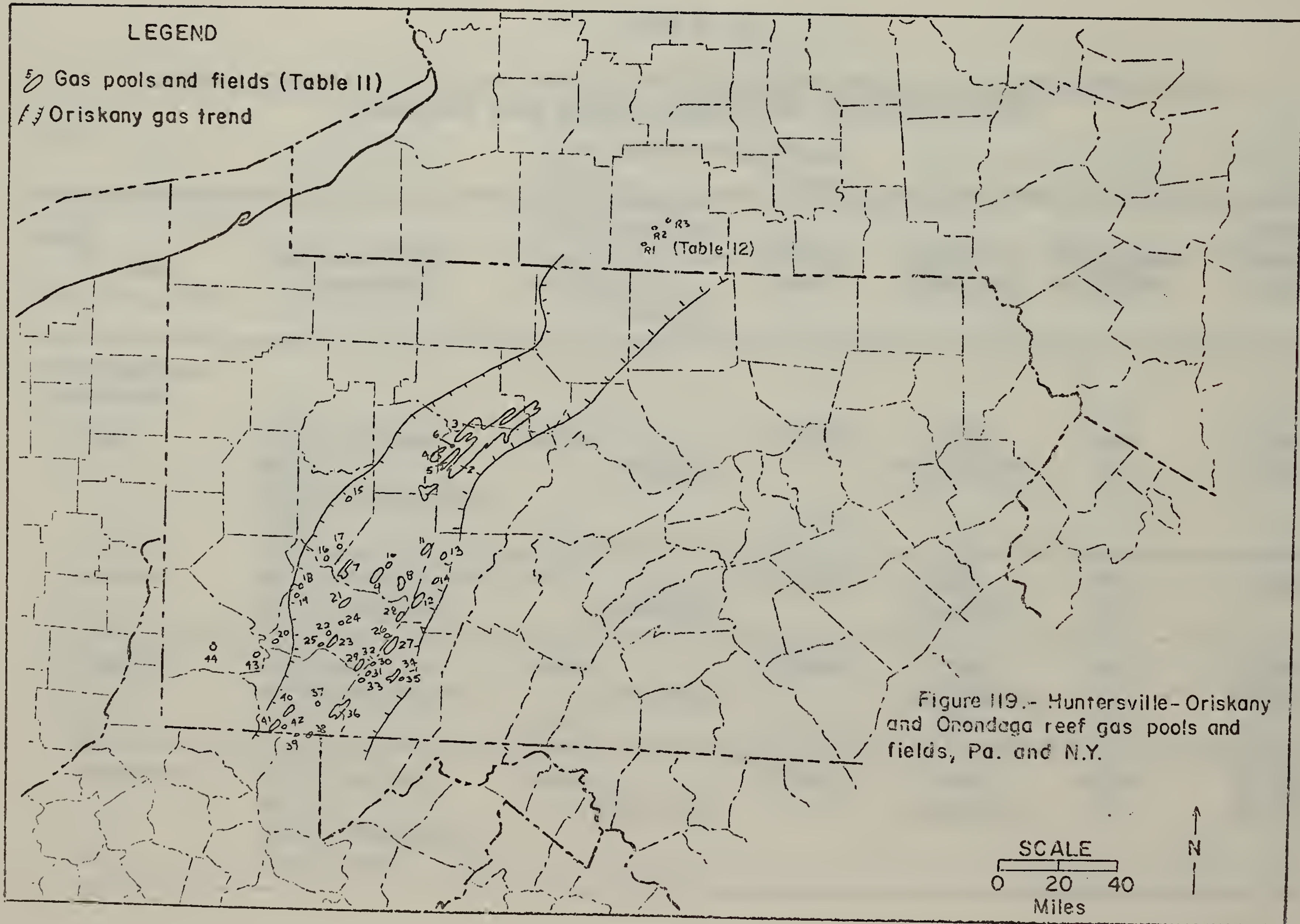

Figure 119.- Huntersville-Oriskany and Onondaga reef gas pools and fields, Pa. and N.Y.

TABLE 11

INITIAL PRODUCTION STATISTICS OF DISCOVERY WELLS IN HUNTERSVILLE-ORISKANY GAS POOLS, WESTERN PENNSYLVANIA

(AF = after fracturing)

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location: Township	Well Location: County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
Punxsutawney-Driftwood							
Reed	Clair K. Reed No. 1 (Fairman Drilling Co.)	Gaskill	Jefferson	5/10/55	7462 (Top chert)	990 AF	3,850 4 days
Deemer (1)	Alice Irwin No. 13 (F. C. Deemer)	Bell	Clearfield	12/01/53	2295 (Top Do)	700 AF	1,240
Rockton (2)	Eva Moore No. 1 (Rockton Drilling Co.)	Union	Clearfield	2/25/55	7135 (Top chert)	515 AF	3,275 44 hrs.
Boone Mtn. (3)	Pa. Tract 65, No. 1 (N.Y. State Nat. Gas Corp.)	Huston	Clearfield	8/19/58	7256 (Top chert)	6,501 AF	3,703 112 hrs.

TABLE 11—Continued

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location Township	 County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
Dubois (4)	Green Glen Wt. 3594, No. 1-1 (S. W. Jack Co.)	Sandy	Clearfield	1/06/60	7274 (Top chert)	30,370 AF	3,875 48 hrs.
Helvetia (5)	R. H. Kriner No. 1 (N.Y. State Nat. Gas Corp.)	Brady	Clearfield	5/11/60	7215	10,645 AF	3,610 41 hrs.
Sabula (6)	Green Glen Corp. No. 4 (N.Y. State Nat. Gas Corp., Devonian Oil & Gas Co.)	Sandy	Clearfield	8/26/63	7411	9,191 AF	3,813 463 hrs.
Jacksonville (7)	G. L. Stewart-R. & P. Coal Co. No. 1 (Manufacturers Light & Heat Co.)	Young	Indiana	9/21/56	7339 (Top chert)	9,000 AF	4,230 45 hrs.

TABLE 11---Continued

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location: Township	Well Location: County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
Nolo (8)	I. R. Smith No. 1 (Columbia Carbon Co.)	Brush Valley	Indiana	9/30/56	7601 (Top chert)	1,540 AF	4,250 72 hrs.
Cherry Hill							
Crichton (9)	A. B. Crichton No. 1 (Manufacturers Light & Heat Co.)	Brush Valley	Indiana	1/07/63	7566	7,710 AF	4,033 72 hrs.
Hadden (10)	Annie Hadden No. 1 (Fairman Drilling Co.)	Cherryhill	Indiana	7/11/63	7812	1,175 AF	4,195 95 hrs.
Strongstown							
Pineton (11)	R. Hanwell, Jr. No. 1 (Felmont Oil Corp.)	Green	Indiana	12/20/69	8139	6,150 AF	4,261 13 days

TABLE 11—Continued

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location: Township / County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
Rager Mtn. (12)	George L. Reade No. 1 (Peoples Nat. Gas Co., Bethlehem Steel Co., Snee and Eberly)	Jackson / Cambria	10/16/65	7699 (Top chert)	8,245 natural	3,193 168 hrs.
Patton						
Burley (13)	F. G. Burley No. 1 (Kewanee Oil Co., et al.)	West Carroll / Cambria	1/13/69	8395	2,100 AF	3,836 48 hrs.
Pindleton (14)	Albert Kubat No. 1 (Peoples Nat. Gas Co.)	Blacklick / Cambria	7/02/69	8577	4,750 AF	3845 5 days
Goheenville						
Snyderville (15)	Nellie C. Martin No. 1 - 4634 (Peoples Nat. Gas Co.)	Wayne / Armstrong	10/23/70	6420	1,100 AF	3,325 7 days

TABLE 11—Continued

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location Township County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
Roaring Run						
Roaring Run (16)	Canterbury Coal No. RR-1 (Pennzoil United, Inc.)	Kiskiminetas Armstrong	12/14/70	7047	2,170	3,950 5 days
Shellhammer						
Rupert (17)	M. Rupert No. 1 (Columbian Carbon Co.)	South Bend Armstrong	11/14/58	6962 (Top chert)	3,450 AF	3,850 13 days
Murrysville						
Sloan (18)	F. M. Sloan No. 1 (Fox and Sloan)	Franklin Westmoreland	8/02/65	7373 (Top Do)	2,000 AF	3,846 21 days
Duquesne (19)	Duquesne Gas Co. No. 1 (Fox, Coen, and Sloan)	Franklin Westmoreland	10/22/63	7701 (Top Do)	1,200 AF	3,832 24 hrs.

TABLE 11—Continued

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location Township County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
Jacobs Creek						
Bailey (20)	A. E. Bailey No. 1 (Peoples Nat. Gas Co., Snee and Eberly)	S. Huntington Westmoreland	12/26/61	7385	2,700 AF	3,950 4 days
Blairsville						
Kahl (21)	Joseph Kahl No. 1 (Peoples Nat. Gas Co.)	Derry Westmoreland	10/23/62	7710	9,500 AF	4,372 48 hrs.
Lycippus						
Piper (22)	W. Piper No. 1 (Peoples Nat. Gas Co.)	Unity Westmoreland	8/17/49	8223	243 after acidizing	3,875
St. Boniface Chapel (23)	J. G. Mailey (Peoples Nat. Gas Co.)	Mt. Pleasant Westmoreland	9/13/56	7306	11,000 AF	4,100 2 days

TABLE 11—Continued

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location: Township / County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
Derry (24)	Latrobe Construction Co. No. 1 (Peoples Nat. Gas Co.)	Ligonier / Westmoreland	12/05/58	7733 (Top chert)	1,087 AF	3,250 10 days
Hribal (25)	C. E. Hribal No. 1 (Felmont Oil Corp.)	Mt. Pleasant / Westmoreland	8/17/62	7790 (Top chert)	3,000 AF	3,340 41 hrs.
Johnstown						
Beck (26)	John Beck No. 2 (Snee and Eberly)	Ligonier / Westmoreland	5/16/57	7454 (Top chert)	6,700 natural	—
Williams (27)	C. E. Williams No. 1 (Peoples Nat. Gas Co., Snee and Eberly)	Jenner / Somerset	2/14/58	8048 (Top chert)	16,025 AF	3,560 72 hrs.

TABLE 11—Continued

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location: Township, County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas MCFGPD	Rock Pressure, psi
Baldwin (28)	Pa. Game Lands Tr. 42, No. 3 (Felmont Oil Corp.)	St. Clair, Westmoreland	5/22/60	7435	1,000 natural	2,836 7 days
Seven Springs						
Blair (29)	J. S. Blair No. 1 (Peoples Nat. Gas Co.)	Donegal, Westmoreland	12/05/58	7594 (Top chert)	9,115 AF	3,210 24 hrs.
Kooser (30)	Pa. Tract 75, No. 3 (Peoples Nat. Gas Co.)	Jefferson, Somerset	5/19/59	8472	10,933 natural	3,400 10 days
Clarke (31)	B. G. Clarke, No. 1 (Peoples Nat. Gas Co.)	Cook, Westmoreland	3/15/61	8365	6,500	3,309 96 hrs.
Tunnel (32)	J. S. Blair No. 4 (Peoples Nat. Gas Co.)	Cook, Westmoreland	3/10/65	8202	11,000 AF	2,722 24 hrs.

TABLE 11—Continued

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location: Township / County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
Seven Springs (33)	A. A. Dupree No. 1 (Peoples Nat. Gas Co.)	Middle Creek / Somerset	8/03/66	7960 (Top chert)	5,000 AF	3,320 144 hrs.
Boswell						
Boswell (34)	Royal Rhodes No. 1 (Felmont Oil Corp., Peoples Nat. Gas Co.)	Jenner / Somerset	11/02/58	8257 (Top chert)	3,500 AF	3,602 116 hrs.
Snyder (35)	R. I. Snyder No. 1 (Felmont Oil Corp., Peoples Nat. Gas Co.)	Lincoln / Somerset	6/16/60	8414	1,572 AF	3,293 44 hrs.
Ohiopyle (36)	Mueller-Herr No. 1 (Manufacturers Light & Heat Co.)	Stewart / Fayette	12/28/59	6841 (Top chert)	4,800 AF	3,450 162 hrs.

TABLE 11—Continued

Field / Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location: Township / County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
Spruell (37)	M. Spruell No. 1 (Peoples Nat. Gas Co., Snee and Eberly)	Stewart / Fayette	10/13/61	7640	3,110	3,423
Sandy Creek						
Fike (38)	Grimes No. 1 (Sun Oil Co.)	Wharton / Fayette	8/08/63	8018 (Top chert)	700 AF	3,375 24 hrs.
Quebec Run (39)	C. L. Ryan No. 2 (Zenith Exploration Co.)	Wharton / Fayette	6/03/69	7657	2,500 AF	3,400 72 hrs.
Summit						
N. Summit (40)	Leo F. Heyn No. 1 (W. E. Snee, N. Penn Gas Co.)	S. Union / Fayette	4/23/36	6611	1,800	3,050
S. Summit (41)	W. R. Barton Estate No. 1 (Greensboro Gas Co.)	Georges / Fayette	5/09/42	7147	1,500	3,275

TABLE 11—Continued

Field Pool (No., Fig. 119)	Discovery Well (Operator)	Well Location Township County	Compl. Date	Top Prod. Zone, Ft.	Initial Gas, MCFGPD	Rock Pressure, psi
E. Summit (42)	Earl Rahl No. 1 (Snee and Eberly, Peoples Nat. Gas Co.)	Wharton Fayette	12/31/60	7602	381 AF	1,800 24 hrs.
Belle Vernon						
Lover (43)	D. Duvall No. 1 (Snee and Eberly, et al.)	West Pike Run Washington	8/14/68	7831	1,500 AF	3,388 28 days
Daniels Run						
Glyde (44)	S. Cooper No. 1 (John T. Galey)	Amwell Washington	9/06/61	7451	1,000 AF	1,929 3 days

productive, all commercial natural gas being derived solely from the Oriskany Sandstone.

The greatest volume of Huntersville gas production is from pools in Clearfield, Indiana, Westmoreland, Somerset and Fayette counties. The North Summit Gas Pool, Fayette Co. (No. 40, Fig. 119), discovered in 1936, had produced a total of about 21,054,642 Mcf of natural gas to the end of 1972. Largest cumulative production from a Huntersville-Oriskany reservoir, however, is from the combined pools in the southern part of the giant Punxsutawney-Driftwood Field in Clearfield and Jefferson counties (No. 1-6, Fig. 119), where cumulative production to the end of 1972 has amounted to about 227,201,000 Mcf[19] (Lytle, 1973, pp. 23-24).

Accumulation of natural gas in the Huntersville is probably always structurally controlled, the chert-sandstone traps being mostly faulted anticlines. Gas from the Huntersville is generally associated with gas from the subjacent Oriskany (Ridgeley) Sandstone (Kelley and others, 1970b, p. 32). Where trapping in the Oriskany is predominantly structural, considerable production can be expected from the Huntersville throughout the area in question. Where the Oriskany reservoir is controlled by porosity or permeability pinch-outs, however, as in the Elk Run Pool, Jefferson Co. (Heyman, 1968),

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[19]Includes predominantly Oriskany production from Sykesville Pool.

the Huntersville will not be productive.

Porosity in the Huntersville is predominantly of the fracture type, although some interstitial porosity may also be present (Fettke, 1940, p. 440). Generally the chert yields commercial quantities of natural gas only after fracturing (Table 11; Lytle, 1965).

Natural gas from the Huntersville-Oriskany pools of Pennsylvania is composed mostly of methane (Roth, 1968, p. 1713). An analysis of gas from the Rockton Pool, Clearfield Co., is as follows (Edmunds and Berg, 1971, p. 127):

Methane	97.0 per cent
Ethane	2.0
Propane	0.1
Nitrogen	0.6
Carbon Dioxide	0.1
Helium	trace
Heating Value[20]	1025 BTU

The newly discovered Onondaga reef fields are shown on Fig. 119 and are listed in Table 12.

All known subsurface reefs are in Steuben Co., N.Y., and are localized in an area of regional thinning of the Onondaga Limestone (Kelley and others, 1970b). Normal thickness of the Onondaga in the area of reefing is 20 to 50 feet, but the reefs themselves attain thicknesses of 150 to 200 feet (Fig. 120; Van Tyne, 1972). Apparently the reefs represent a facies of the Edgecliff

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[20] Calculated gross BTU per $ft.^3$, dry, at 60° F and 30 in. Hg.

TABLE 12

ONONDAGA REEF FIELDS, NEW YORK

(Kreidler and others, 1968; Kreidler and Van Tyne, 1972)

Field (No., Fig. 119)	Discovery Well (Operator)	Well Location		Compl. Date	Tops (Ft.)	Production MCFGPD
		Township	County			
Wyckoff (R1)	D. Cornell No. 1 (Wyckoff Dev. Co.)	Jasper	Steuben	6/13/67	Don (reef) 4661 Do 4814	Reef 1000 Do 7400
Adrian (R2)	W. Raish No. 1 (Cabot Corp., _et al._)	Bradford	Steuben	7/03/71	Not released	Not released
Thomas Corners (R3)	Sylvania Corp. No. 1 (Cabot Corp., _et al._)	Bath	Steuben	7/25/71	Not released	Not released

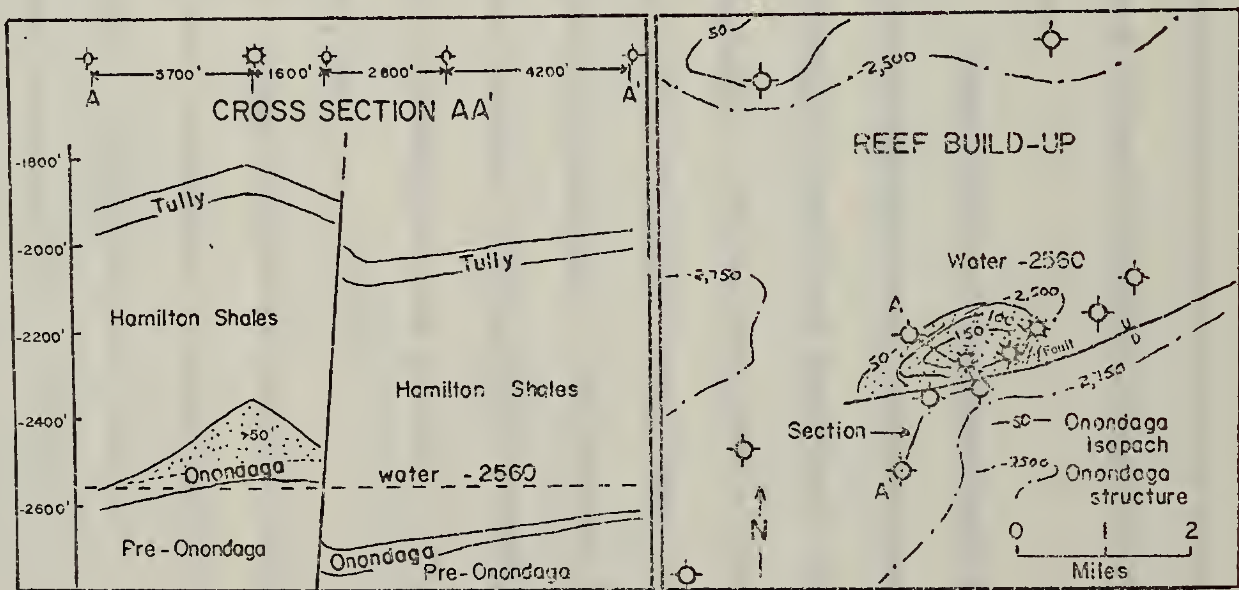

Figure 120.—Wyckoff Reef Field, Steuben Co., N.Y. (From Kelley and others, 1970, p. 33.)

Member (Van Tyne, 1972), although their extreme vertical relief as contrasted to Edgecliff reefs of the outcrop belt suggests that they may have continued growing throughout upper Onesquethaw time. The reefs were probably topographic highs on the sea floor during the time of lower Hamilton deposition (Kreidler and others, 1968, p. 941).

Since 1967, when the Wyckoff Field, the first productive subsurface Onondaga reef, was discovered, fourteen reef tests have been drilled in New York (Van Tyne, 1973, p. 1468) and one in Pennsylvania. Of the wells drilled in New York, only seven actually found reef build-up (Van Tyne, 1973, p. 1468). The Pennsylvania test, the T. Davis No. 1 well (Anderson Oil Co.), drilled on a seismic anomaly in Brookfield Township, Tioga Co., found only 26 feet of Onondaga and was abandoned after reaching the Helderberg (Lytle, 1973, pp. 13, 35).

Gas in the reefs occurs in conjunction with large volumes of gas in the underlying Oriskany Sandstone (Kreidler and others, 1968, p. 943). The largest initial open flow from the reef reservoir in the Wyckoff Field was 10.5 MMCFGPD from the H. Banks No. 1 well (Sylvania Corp.), whereas the Oriskany in the same well had an open flow of 20 MMCFGPD (Kreidler, Van Tyne, and Jorgenson, 1972, p. 266). Trapping in the reefs themselves is mainly stratigraphic, the enveloping Hamilton shales forming a tight seal preventing upward migration of the gas. The Oriskany traps may be predominantly structural, at least one edge of the Wyckoff Field, for example, being formed by a steep reverse fault (Fig. 120). Occurrence of the Wyckoff reef on the upthrown side of the fault suggests the possibility that contemporaneous faulting may have contributed to localization of the reef. (See Kelley and others, 1970b, pp. 33-34.)

Until January, 1972, gas produced from the Wyckoff Field came from the Oriskany Sandstone. At that time one of the wells was recompleted to produce from the reef zone. In October, 1972, a second well in this field was recompleted for reef production. The Adrian Reef Field also went on line in October, 1972 (Van Tyne, 1973, p. 1469).

Summary and Conclusions

Stratigraphic Framework of Onesquethaw Stage in the Study Area

Plates 2, 3, 4, and 5 show the detailed stratigraphic framework of Onesquethawan rocks in Pennsylvania and adjacent states, as derived from previously presented data. The presumed correlations of the rock stratigraphic units and ranges of diagnostic fossils are summarized in Fig. 121.

The lower contact of the Onesquethaw Stage is conformable

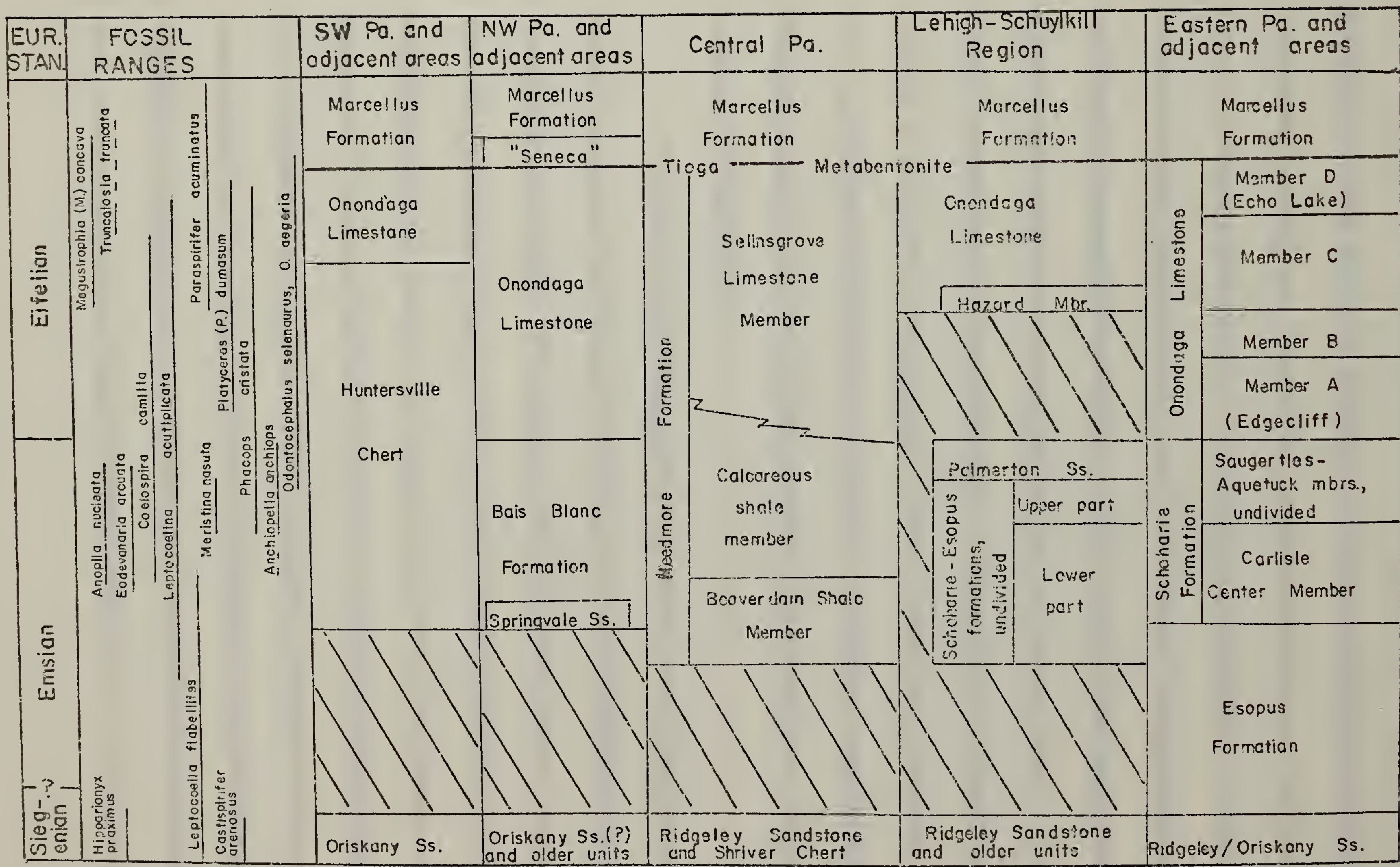

Figure 121.—Stratigraphic correlation of Onesquethawan rock units within study area and ranges of some diagnostic fossils.

only in eastern New York, northern New Jersey, and eastern Pennsylvania, where the thick Esopus Formation overlies Deerparkian limestone, chert, and sandstone (Glenerie Limestone, Shriver Chert, Oriskany Sandstone, and Ridgeley Sandstone). Farther west the base of the Onesquethaw is disconformable, the disconformity reaching its greatest magnitude in western New York and in the outcrop belt west of the Schuylkill River in Pennsylvania. In these areas, rocks of late Onesquethawan, or latest early Onesquethawan, age lie on late Silurian (Cayugan) strata. Generally, however, only the lowermost Onesquethawan is absent, and upper lower Onesquethawan rocks rest on Deerparkian units, as over much of central and western Pennsylvania.

The lowermost Onesquethawan strata in the study area belong mostly to the Esopus Formation of early early Emsian and latest Siegenian age. The Esopus attains a thickness of about 350 feet in southeastern New York and eastern Pennsylvania, but is absent over all of central and western New York and western Pennsylvania. Tracing of units in deep well records in the Anthracite and northeastern Allegheny Plateau regions of eastern Pennsylvania shows that the lowermost part of the Needmore Formation of central Pennsylvania (Beaverdam Shale Member) is probably equivalent, in part, to the uppermost Esopus (Plate 3, DD', FF'). Likewise, the lowermost portion of the Schoharie-Esopus formations, undivided, in the Lehigh-Schuylkill region may have been deposited at the same time as the upper Esopus of eastern Pennsylvania.

The presence of strata equivalent to the Esopus in the subsurface of western Pennsylvania cannot be rigorously documented. Indeed, the occurrence of a widespread disconformity between upper Emsian/lower Eifelian units and older strata in the Mid-continent area (Johnson, 1970b) suggests that rocks equivalent in age to the Esopus are probably absent over all of western Pennsylvania.

Upper lower Onesquethawan (Upper Emsian) strata are present throughout most of the study area, except in central and west-central New York, north-central Pennsylvania, and in the western part of the Lehigh-Schuylkill area, Pennsylvania. Rocks of this age include the Schoharie Formation of eastern Pennsylvania and adjacent New York, the Schoharie-Esopus formations, undivided (upper part) and Palmerton Sandstone of the Lehigh-Schuylkill region, the lower part of the Needmore Formation of central Pennsylvania (except for the Beaverdam Shale Member in the central Susquehanna Valley area, which is probably older), the Bois Blanc Formation of north-western Pennsylvania and adjacent New York and Ohio, and the lower part of the Huntersville Chert of western and southwestern Pennsyl-vania and adjacent Maryland and West Virginia.

Correlation of these strata as shown in Fig. 121 is suggested by the following:

1. *Taonurus*-markings are profuse in both the Carlisle Center Member of the Schoharie Formation and the lower part of the Schoharie-Esopus formations, undivided.

2. The Saugerties-Aquetuck members, undivided, of the Schoharie Formation contain *Acrospirifer duodenaria*, *Mucrospirifer macra*, and *Eodevonaria arcuata*, brachiopod species which are also common in the upper part of the Schoharie-Esopus formations, undivided.

3. The uppermost part of the Saugerties-Aquetuck members, undivided, is coarse, sandy siltstone, strongly suggesting its equivalence to the Palmerton Sandstone of the Lehigh-Schuylkill region (Johnsen, 1957).

4. The Schoharie Formation can be clearly recognized in deep wells as far west as Sullivan Co., Pa., and can be traced into the middle part of the Needmore Formation (calcareous shale member) in wells in Northumberland Co., Pa. (Plate 3, FF'.)

5. *Leptocoelina acutiplicata* is most abundant in the middle and lower parts of the calcareous shale member of the Needmore Formation and in the Carlisle Center Member of the Schoharie Formation. The presence of such Lower Devonian brachiopods as *Anoplia nucleata* in the calcareous shale member of the Needmore and *Acrospirifer duodenaria* and *Eodevonaria arcuata* in the Schoharie also tends to support the age equivalence of these two units within the Onesquethaw Stage.

6. The calcareous shale member of the Needmore Formation can be physically traced into the Huntersville Chert in deep wells west of the Allegheny Front in west-central Pennsylvania (Plate 3, EE', GG'; Plate 4, HH', II'; Plate 5, OO'). Chert is also present in basal Needmore strata at outcrops near the Allegheny Front in Blair and Huntingdon counties, Pa. (e.g., P59). The occurrence of Emsian faunal elements in the Huntersville supports a correlation of its lower part with the Emsian-age portion of the Needmore.

7. Although the Bois Blanc Formation does not crop

out in Pennsylvania, its distribution in the subsurface of the extreme northwestern part of the state is now well established (Dow, 1962; Sanford, 1967; Rickard, 1969). The formation can be traced in the subsurface southward into the lower part of the Huntersville Chert (Plate 3, EE'; Plate 5, OO', PP', QQ', RR'). At outcrops it also contains a typical Emsian fauna (Boucot and Johnson, 1968).

Upper Onesquethawan (lower Eifelian) strata, represented by the Onondaga Limestone, the Selinsgrove Limestone Member of the Needmore Formation (and equivalent strata in south-central Pennsylvania), and the upper part of the Huntersville Chert, are more widespread in the study area than are those of lower Onesquethawan age. Rocks of this age are absent only immediately north of Harrisburg, Pa., and perhaps in the Green Pond-Schunemunk Mountain outlier.

The correlations shown on Fig. 121 are substantiated by the following:

1. The Onondaga Limestone of eastern Pennsylvania can be physically traced into the Onondaga of eastern New York. In both areas, the lower part

of the formation (Member A, Edgecliff Member) is characterized by large crinoid columns.

2. Along the outcrop belt in southwestern Monroe Co., Pa., the Onondaga thins over the Palmerton Sandstone bar. As a result of thinning over the bar and onto a major disconformity surface southwest of the Schuylkill, the Onondaga Limestone of the Lehigh-Schuylkill region (including the Hazard Member) is equivalent to only the upper part of the Onondaga Limestone of eastern Pennsylvania. This correlation is strengthened by the occurrence of a tuffaceous marker bed 22 feet below the top of the Onondaga at West Bowmans (P22) and 30 feet below the top at East Stroudsburg (P8) and Stroudsburg (P13) (Plate 3, GG').

3. Paraspirifer acuminatus occurs in the Moorehouse Member of the Onondaga Limestone in New York (Y1), the Echo Lake Member (Member D) of the Onondaga Limestone in eastern Pennsylvania (P13), and the Onondaga Limestone of the Lehigh-Schuylkill region (P27).

4. The Onondaga Limestone can be traced in subsurface records from eastern Pennsylvania, through the Anthracite region, and into the Selinsgrove Limestone Member of the Needmore Formation in central Pennsylvania (Plate 3, DD', FF'). Likewise, the Onondaga Limestone of central New York can be traced through deep well records into the Selinsgrove. The Selinsgrove Limestone Member, in turn, grades southwestward into at least the upper part of the calcitic shale and limestone subfacies of the Needmore in south-central Pennsylvania and adjacent Maryland and West Virginia (Plate 3, FF').

5. The Selinsgrove Limestone Member and calcitic shale and limestone subfacies contain such Middle Devonian fossils as large *Amphigenia elongata*, *Truncalosia truncata*, and *Styliolina fissurella*, species also found in the Onondaga Limestone of New York (Oliver, 1954; 1956a). *Odontocephalus selenourus* and *O. aegeria* are also common in both the Onondaga and Selinsgrove.

6. Presence of the Tioga Metabentonite at the top of the Selinsgrove Limestone Member of the Needmore Formation in central Pennsylvania, the Onondaga Limestone in the Lehigh-Schuylkill region, and the Moorehouse Member of the Onondaga Limestone in New York strongly suggests the age equivalence of the upper portions of these units.

7. Shales and argillaceous limestones which contain large crinoid columns at the top of the calcitic shale subfacies of the Needmore Formation at Gainesboro, Va. (V1) (Fig. 122), and in the upper part of the calcitic shale and limestone subfacies at Warfordsburg, Pa. (P63) may be correlative with the Edgecliff Member of the Onondaga Limestone.

8. Lateral gradation of the Onondaga Limestone of northwestern Pennsylvania southward into the Huntersville Chert of southwestern Pennsylvania is shown by numerous deep well records (Plate 5, OO', PP', QQ', RR').

The Tioga Metabentonite in the study area probably

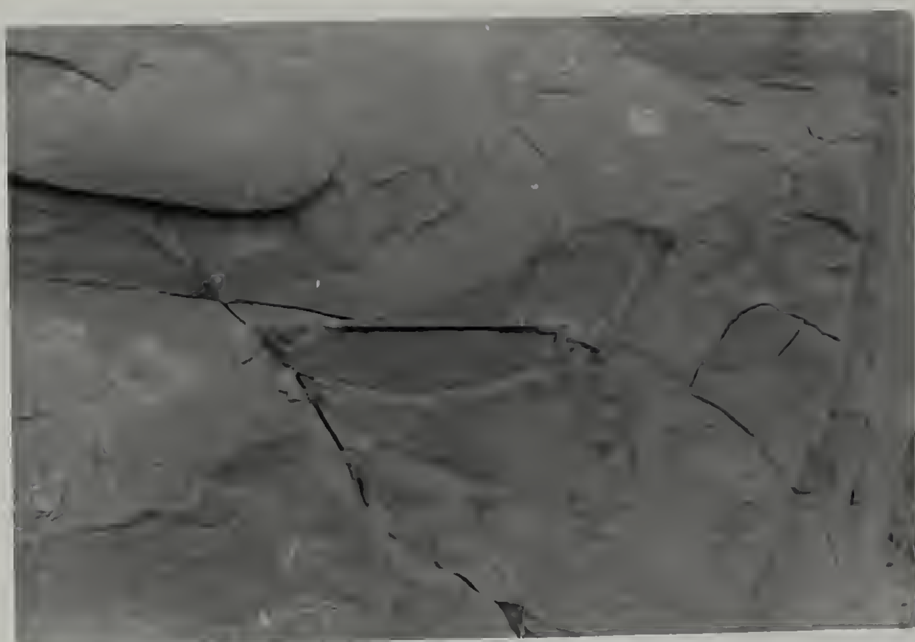

Figure 122.—Large crinoid column in Needmore Formation (top of calcitic shale subfacies), borrow pit along U.S. Rte. 522, 0.5 mile northwest of Gainesboro, Frederick Co., Va. (V1-7).

represents only the middle coarse mica zone of Dennison (1969). The metabentonite horizon generally contains two discrete beds that lie in the transition zone between the Onondaga Limestone (and its equivalents) and the Marcellus Formation. In western New York and parts of northwestern Pennsylvania, limestone included in the Onondaga Limestone (i.e., the Seneca Member) occurs above the Tioga. A thick sequence of argillaceous limestone also lies above a metabentonite bed (presumed to be the Tioga) in the subsurface of northeastern Pennsylvania (Plate 3, DD'; Plate 4, KK'; Kehn, Glick, and Culbertson, 1966). At outcrops in eastern Pennsylvania and the Lehigh--Schuylkill region, a thick tuffaceous bed that occurs from 7 to 30 feet below the top of the Onondaga Limestone (Plate 3, GG') may be either equivalent to the lower metabentonite bed in central Pennsylvania (bed A) or distinctly older than the Tioga middle coarse zone.

History of Deposition

The depositional history of Onesquethawan rocks in Pennsylvania and adjacent states can be interpreted from lithology and sedimentary structures, fossil content, and regional stratigraphic relationships. Figures 123, 124, 125, 126, and 127 show the postulated depositional environments for late Deerparkian (late Siegenian), early early Onesquethawan (early Emsian), late early Onesquethawan (late Emsian), late Onesquethawan (early Eifelian), and early Cazenovian (middle Eifelian) times, respectively.

Late Deerparkian time was a period of relatively stable conditions of sedimentation in the Appalachian basin. During numerous minor marine transgressions and regressions, well-sorted and well-rounded quartz sand (Oriskany-Ridgeley) was deposited on beaches, intertidal bars, and shallow subtidal bars and sheets. Fine material was winnowed from the sands and deposited in deeper water, below wave base (Glenerie-Shriver) (Fig. 123).

The Oriskany-Ridgeley sands are certainly recycled from older sedimentary rocks and were derived mainly from sources to the north, east, and southeast. Similar sands to the northwest of the "No-Sand" area in northwestern Pennsylvania may be younger (late early Onesquethawan) deposits with a provenance to the west and northwest (Summerson and Swann, 1970).

Faunal distribution in the late Deerparkian seas was controlled largely by depth of water and substrate mobility. The high energy, shallow subtidal bars were populated by a fauna of robust, thick shelled brachiopods, large platyceratid gastropods, and, presumably, large crinoids which served as hosts for the gastropods. In the deeper, more offshore environments, where

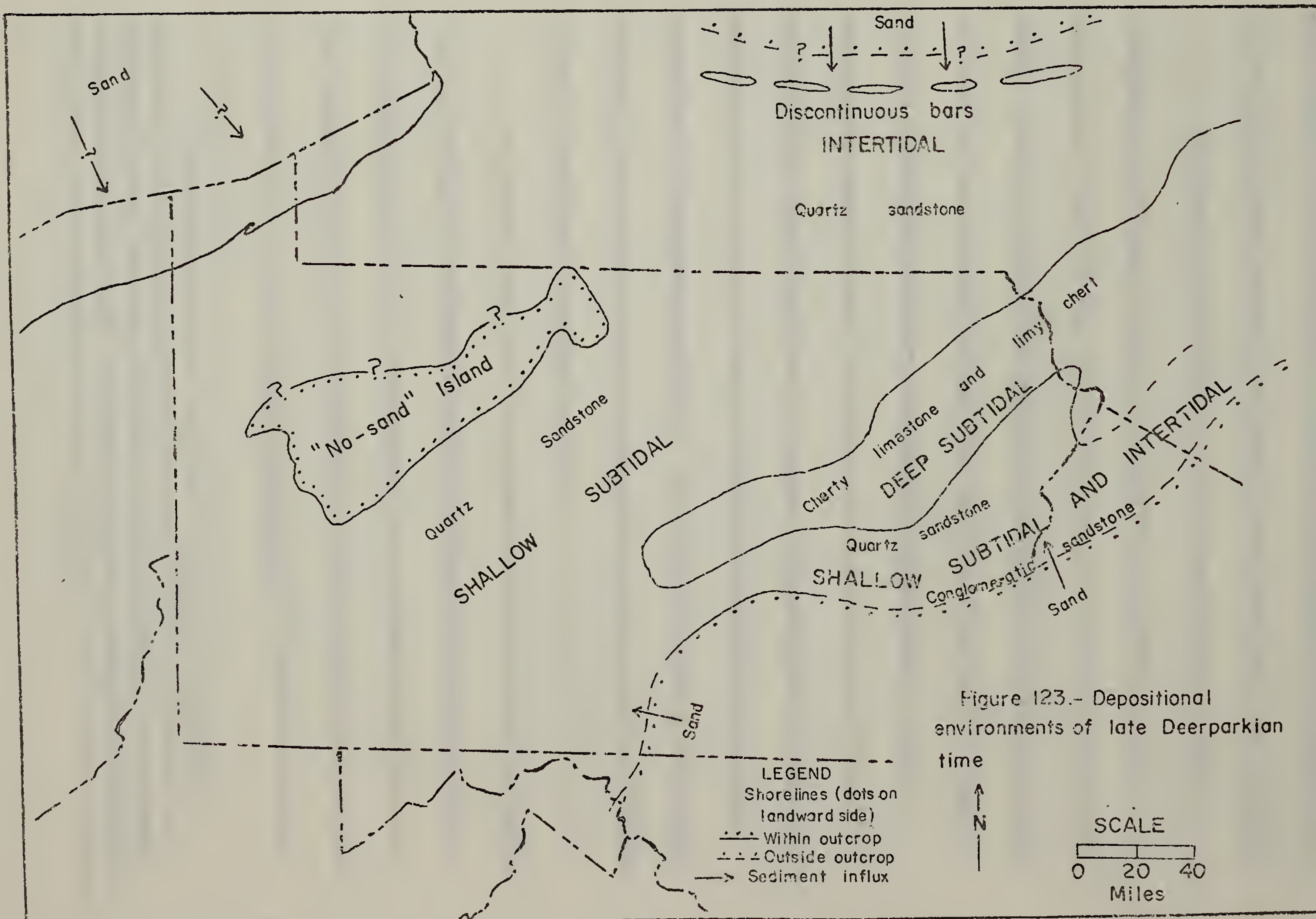

Figure 123.- Depositional environments of late Deerparkian time

wave energy was not a factor, a more diverse fauna, consisting of brachiopods, platyceratids, trilobites, and ostracodes, flourished.

Earliest Onesquethawan time was marked by a major regression of the epicontinental Appalachian sea that resulted in the emergence of central and western New York and western Pennsylvania. Much of central Pennsylvania also apparently lay above sea level for at least a brief period, and some weathering of the upper surface of the late Deerparkian sediments took place. Only in central and western New York and parts of northwestern Pennsylvania, where uppermost lower or upper Onesquethawan rocks overlie Helderbergian rocks, are there indications of substantial erosion during early Onesquethawan time. The region farther to the south, including most of central and western Pennsylvania, had insufficient relief for detectable erosion to occur.

In eastern New York, northwestern New Jersey, and eastern Pennsylvania, the subsidence which had characterized this area in upper Deerparkian time continued and the mudstone and siltstone of the Esopus Formation were deposited in a deep subtidal environment. The horizontal burrows (Taonurus caudagalli),[21] relatively sparse

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[21]Although the writer considers Taonurus caudagalli to represent the horizontal burrows of a filter-feeding organism (see Simpson, 1970), the origin of these curious markings has not been established beyond doubt. Recently Laskowski (1956) and Loring and Wang (1971) have postulated that the Taonurus organism was a marine

marine fauna, abundance of pyrite, and poorly sorted texture of the sediments, all of which characterize the Esopus, suggest deposition in relatively deep, poorly oxygenated waters. At the northeast edge of the Esopus basin in earliest Onesquethawan time, siliceous sponges proliferated in moderately shallow, well oxygenated waters. As the basin deepened, the sponge banks were smothered by terrigenous sediment influx (Fig. 124).

In central Pennsylvania to the southwest of the main Esopus basin, abrupt subsidence and rapid marine transgression followed a short period of emergence. Where Onesquethawan rocks overlie Deerparkian sandstone, the basal Onesquethaw contains quartz sand grains reworked during the early phase of this transgression. Due to the combined effects of a shorter period of deposition and a slower rate, lower lower Onesquethawan strata are very thin in central Pennsylvania. Sediments in that area actually equivalent in age to the Esopus may be present only in a narrow belt that extends from the Susquehanna Valley southwestward to northern Virginia. Farther to the west lowermost outcropping Onesquethawan rocks are younger than the Esopus, a result of progressive inundation of formerly emergent areas.

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plant. Plicka (1968; 1970), on the other hand, provides compelling evidence that such markings are the imprints of the prostomial parts of filter-feeding sabellid worms.

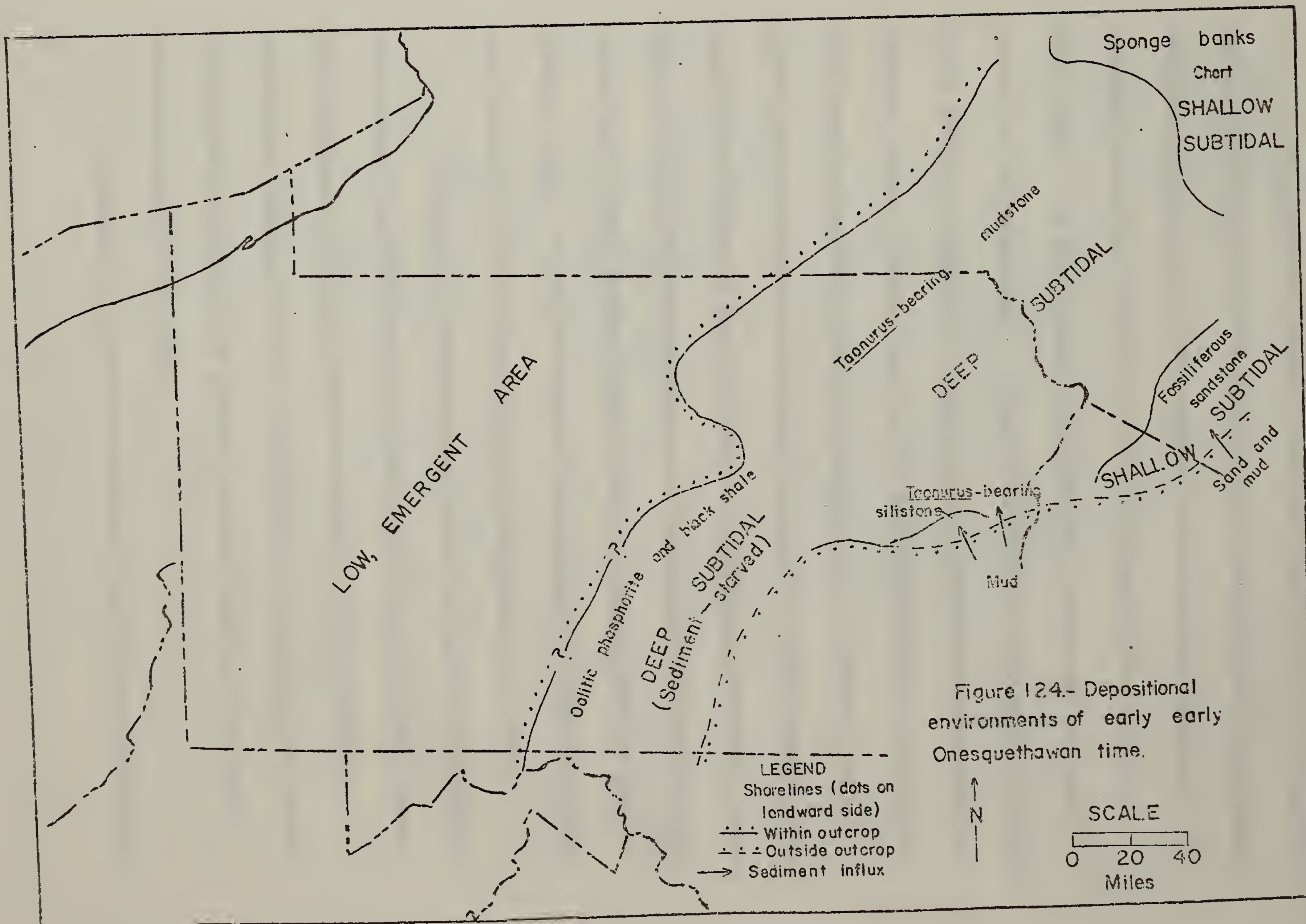

Figure 124.- Depositional environments of early early Onesquethawan time.

The sediment-starved conditions that prevailed over central Pennsylvania following this initial early Onesquethawan transgression favored the deposition of phosphorite in the forms of ooids and nodules (Beaverdam Shale Member of the Needmore Formation) (Fig. 124). The occurrence of phosphorite, along with abundant pyrite, in the Beaverdam, indicates deposition under slightly alkaline (pH 7.0-7.8), reducing (Eh less than 0.0) conditions (Krumbein and Garrels, 1952). The oolitic form of the phosphorite in the Beaverdam need not necessarily be the result of wave agitation. Recent oolitic chamosite (an iron silicate) that occurs in very poorly sorted sediment at depths of about 100 feet in Loch Etive, Scotland, apparently formed by the crystallization of chamosite tangentially around ovoid nuclei (sand grains, pellets, etc.) in place (Rohrlich and others, 1969). A similar mode of crystallization could account for the formation of oolitic phosphorite in the Beaverdam Shale.

In late early Onesquethawan time, the seas transgressed over much of western New York and western Pennsylvania, areas that previously had been largely emergent. Only a northeast-southwest trending platform in central New York and north-central Pennsylvania and parts of extreme western New York remained above sea level (Fig. 125).

In eastern New York and eastern Pennsylvania, calcareous

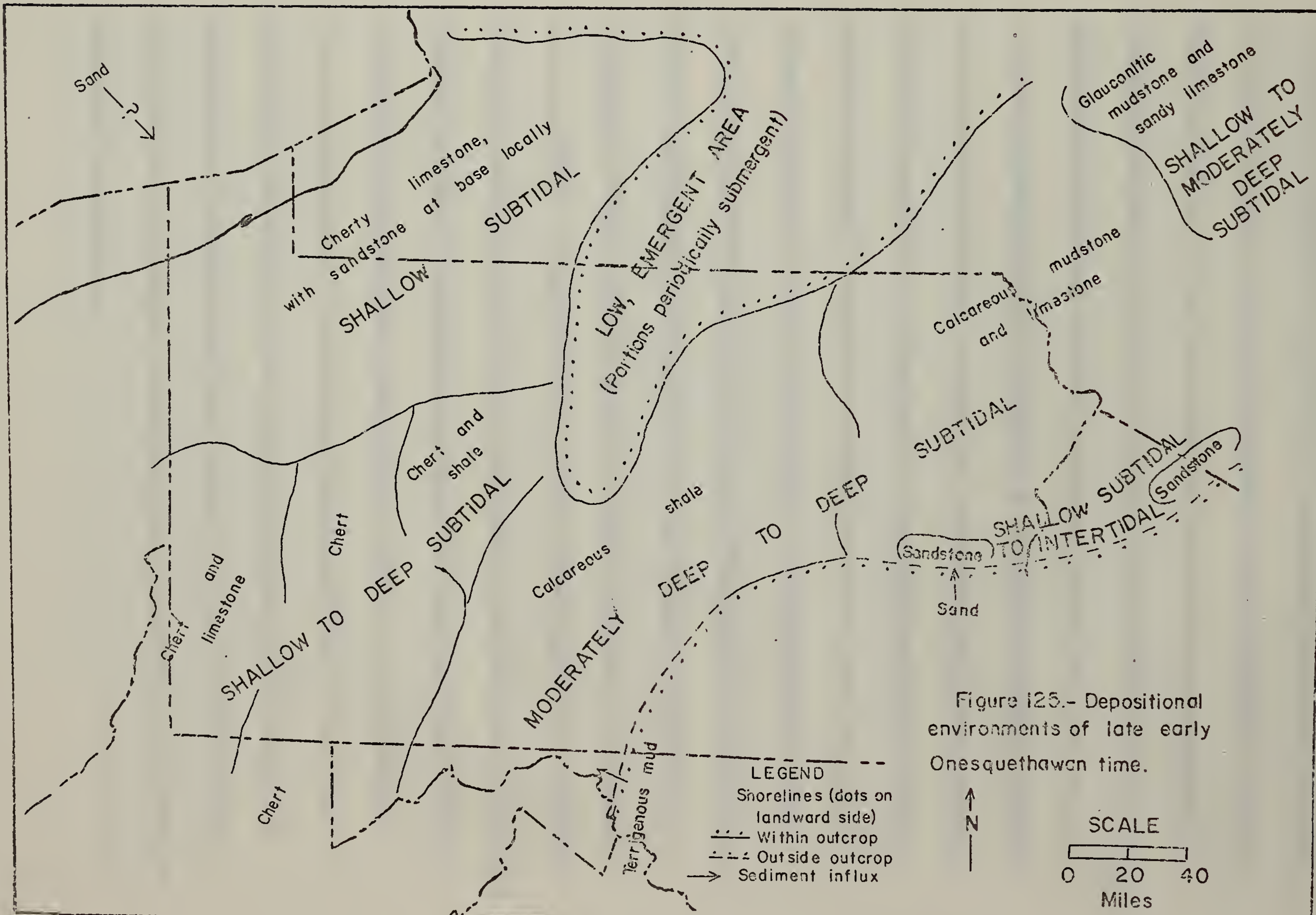

Figure 125.- Depositional environments of late early Onesquethawan time.

mudstone, limestone, and, locally, sandstone (Schoharie Formation, etc.) accumulated under deep subtidal to shallow subtidal or intertidal conditions. In the more offshore portions of the late early Onesquethaw sea in this area, the depositional sequence of Taonurus-bearing mudstone and siltstone (Carlisle Center Member), cherty calcareous mudstone and argillaceous limestone (Aquetuck Member), and highly fossiliferous, crystalline limestone (Saugerties Member) records deposition in a progressively shoaling sea (deep subtidal to shallow subtidal). Near shore areas exhibit the same depositional trend, although it is locally interrupted. In northeast New York extremely fossiliferous sandy limestone (Rickard Hill Member, very shallow subtidal) rests abruptly and in part disconformably on Taonurus-bearing siltstone (Carlisle Center Member, moderately deep subtidal). In eastern Pennsylvania the change from predominately horizontal burrows in the lower part of the Schoharie (Carlisle Center Member) to progressively larger vertical burrows in the upper Schoharie (Aquetuck-Saugerties members, undivided) also indicates deposition in increasingly shallower water. The most pronounced expression of this shoaling tendency is seen along the southeastern margin of the basin, where a series of offshore sand bars (Palmerton-Kanouse sandstones) were deposited at the close of the early Onesquethaw.

The terrigenous clastics of the Schoharie Formation were probably derived mostly from the southeast. Abundant plagioclase feldspar in the silt and fine sand fraction suggest a metamorphic or igneous provenance. The coarser sands (Palmerton-Kanouse) are fairly well rounded and probably reflect a sedimentary source.

Peculiar chemical conditions periodically characterized much of eastern New York at the time of deposition of the Schoharie Formation. Dolomite, glauconite, and pyrite occur together or singly in the Carlisle Center, Aquetuck, and Saugerties members. The widespread "black bed" of the Carlisle Center Member, which contains all three of these minerals, as well as silica and calcite, was deposited under moderately alkaline and slightly to moderately reducing conditions, at a time of reduced clastic sedimentation.

Farther to the southwest, in central Pennsylvania, calcareous shale, with minor argillaceous limestone (calcareous shale member of the Needmore Formation), was deposited in a moderately deep subtidal environment. Moderately reducing conditions apparently prevailed just below the sediment-water interface (as indicated by the occurrence of pyrite in the shales), but generally the sea floor itself was well oxygenated and able to support a fairly large fauna of filter feeders (brachiopods) and shallow deposit feeders, scavengers, and carnivores (trilobites, gastropods, and ostracodes).

In western Pennsylvania late early Onesquethawan sediments are largely siliceous chemical in the south and carbonate detrital in the north. Deposition of primary chert (Huntersville Chert) (Dennison, 1961, p. 27) was probably brought about by a combination of factors, including:

1. Distance from sources of terrigenous and carbonate clastics;
2. Chemical conditions (low pH) which favored deposition of silica over calcium carbonate;
3. Extreme chemical weathering of exposed land areas in the mid-continent region which provided a source for the silica.[22]

Depth of water was probably not a critical factor in the origin of the Huntersville, although the chert was certainly deposited below wave base. The mutual occurrence of pyrite and glauconite in the Huntersville indicates deposition in a mildly reducing environment (Dennison, 1961, p. 27).

In western New York, and possibly in northwestern

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[22] Onesquethawan time is marked by widespread silica deposition throughout eastern and central United States. Known or probable equivalents of the Huntersville include the Armuchee Chert of Georgia, the Camden Chert of Tennessee, the Clear Creek Chert of Illinois and western Kentucky, and portions of the Arkansas and Caballos novaculites of Arkansas and western Texas, respectively (Cooper and others, 1942; Oliver and others, 1969).

Pennsylvania, transgression of the late early Onesquethawan sea onto the irregular topographic surface of a previously eroded high (Oliver, 1967; Kelley and McGlade, 1969) resulted in deposition of a thin, discontinuous blanket of quartz sand (Springvale ? Sandstone) at the base of the Bois Blanc Formation. The Bois Blanc itself records mixed chert and carbonate deposition in a shallow subtidal environment where brachiopods and corals thrived. Chemical conditions in the sea water in the northwest were somewhat more alkaline and better oxygenated than in southwestern Pennsylvania.

At the end of early Onesquethawan time, much of the study area lay below sea level and was undergoing deposition. Only the platform area in north-central Pennsylvania and central New York and the shoreline promontory north and east of Harrisburg stood above the epicontinental sea. The Palmerton bar was probably also periodically emergent. Continuous and gradational deposition from late early Onesquethawan into late Onesquethawan time occurred in eastern New York and in most of Pennsylvania.

The Onesquethawan sea attained its maximum extent in the study area during the later portion of the stage (Fig. 126). By the close of late Onesquethawan time only the area immediately north of Harrisburg still lay above sea level.

Shallow carbonate banks existed throughout most of late

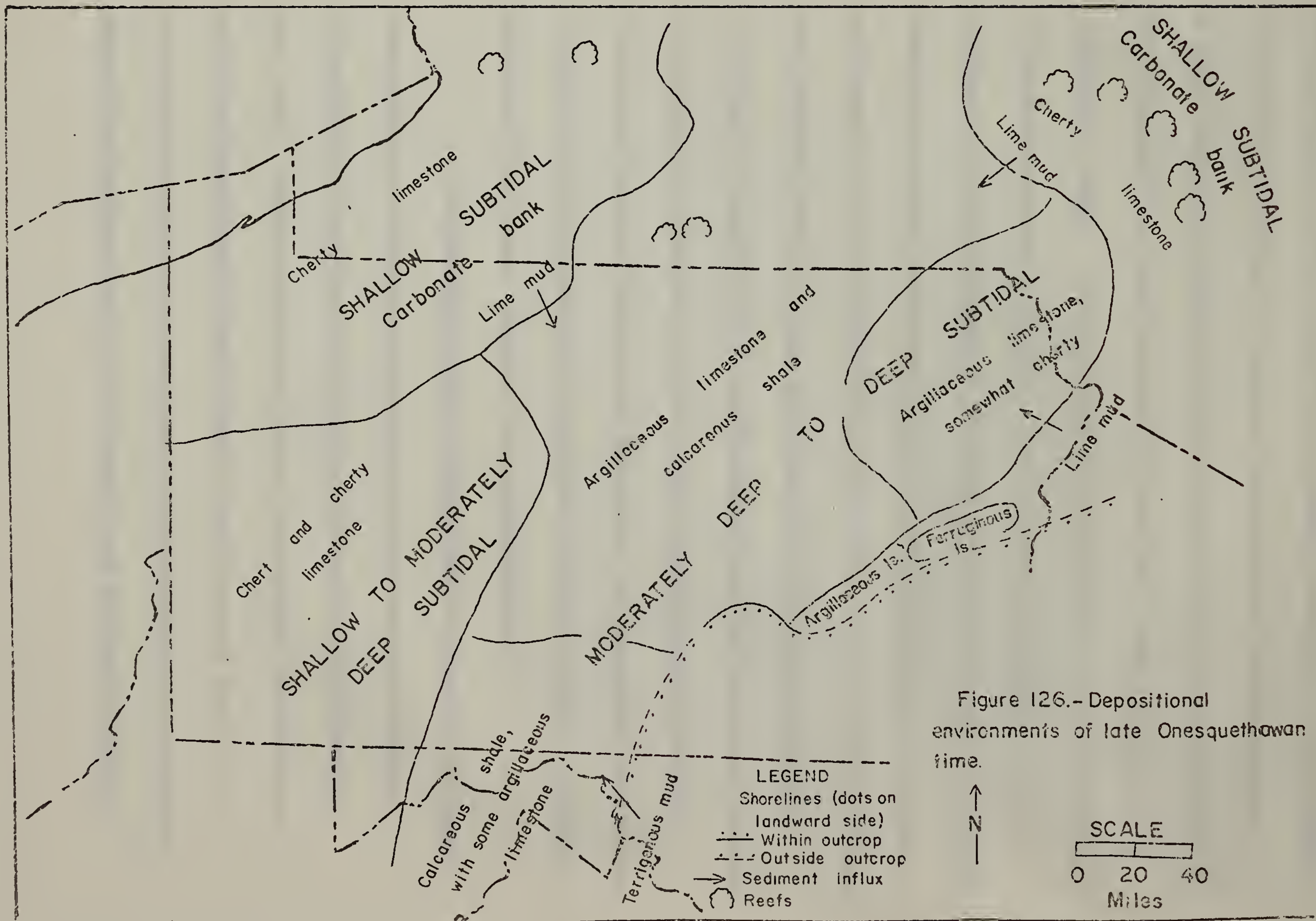

Figure 126.- Depositional environments of late Onesquethawan time.

Onesquethawan time in eastern and western New York, northwestern Pennsylvania, and part of eastern Pennsylvania. Between these shallow banks lay a somewhat deeper basin that broadened gradually from central New York into Pennsylvania (Fig. 126; Oliver, 1954; Lindholm, 1969). The bank areas were characterized by deposition of cherty bioclastic limestone, derived from widespread crinoid gardens and coral plantations, as well as localized coral patch reefs, whereas the basin underwent deposition of predominantly non-cherty, argillaceous limestone and calcareous shale. Deeper water inundated the carbonate banks at least once after they became established, resulting in deposition of the argillaceous Nedrow-Clarence members and Member B over the coralline, bioclastic Edgecliff Member. Shoaling of the sea followed this deep water incursion and culminated in eastern Pennsylvania with deposition of the Echo Lake coquinites (Member D) on a very shallow, wave-agitated bank.

The coralline patch reefs which characterize the upper Onesquethaw in New York established themselves on the banks following the initial early late Onesquethawan marine expansion (Fig. 126). Patch reefs which grew on the surface of the former early Onesquethawan platform area in south-central New York experienced a much more rapid rate of subsidence than did reefs in eastern and western New York. Hence, they attained heights of

150 to 200 feet in areas where the normal thickness of late Onesquethawan strata is less than 50 feet (Kelley and others, 1970a; Van Tyne, 1972). Presumably the growth of the corals was fast enough to maintain the top of the reef in well-aerated and well-lighted waters above wave base. The conversion of this early Onesquethawan platform into a basin having a moderate rate of subsidence was one of the most significant events of late Onesquethawan time, accounting for the localization of large, gas-productive reefs in this area.

Along the southeastern margin of the late Onesquethawan depositional basin, in the eastern part of the Lehigh-Schuylkill region, the upper Onesquethawan sea transgressed over the Palmerton sand bar. Apparently the bar restricted circulation in the area to the southeast, and iron-rich carbonate mud (Hazard Member of the Onondaga Limestone) was deposited on its landward side. Waters behind the bar were less alkaline and less oxygenated than normal marine waters, and perhaps also less saline. The abnormal conditions which existed behind the bar were found hospitable to many organisms—particularly trilobites—that are not particularly common in the more open marine environments of the Onesquethaw Stage (Willard and Whitcomb, 1938).

The deeper water limestones that were deposited in central Pennsylvania (Selinsgrove Limestone Member on the Needmore

Formation) are composed largely of lime mud that represents finely comminuted fossil debris which originated on the carbonate banks. Mixed with the lime mud are the profuse remains of nektonic styliolines. Benthonic organisms were somewhat less abundant in the deeper basinal areas, but large, brimmed odontocephalid trilobites rooted through the mud, and brachiopods and gastropods flourished locally. The Selinsgrove Limestone Member probably represents somewhat shallower conditions than the calcareous shale member. Continued shoaling of the sea as a result of deposition is suggested by the local occurrence of vertical burrows and probably current-sorted coquinites of catastrophically-killed juvenile brachiopods in the upper Selinsgrove.

In general, the lime for the Selinsgrove was derived mostly from the east and northwest, whereas the terrigenous muds for the shaly interbeds were derived from the south and north (Fig. 126). This is clearly shown by the southwestward gradation of the Selinsgrove Limestone Member into the calcitic shale and limestone subfacies on the one hand, and the argillaceous nature of the Onondaga throughout much of central New York and north-central Pennsylvania on the other.

In southwestern Pennsylvania the conditions which had favored the deposition of primary chert (Huntersville Chert) in the late early Onesquethaw persisted through much of late Onesquethaw time.

Onesquethawan deposition closed with the laying down of the Tioga ash bed(s) over the entire area. The source of the Tioga Metabentonite was a volcanic complex in eastern Virginia. At least two closely related episodes are recorded in central Pennsylvania (beds A and B of the middle coarse mica zone of Dennison). The volcanism killed off myriads of organisms, particularly juvenile brachiopods, which may have been less able to cope with the sudden influx of fine ash that settled to the bottom. It is possible that another volcanic source, probably well to the north and east of the one in Virginia, may have been responsible for the thick tuff bed in the upper Onesquethaw of eastern Pennsylvania and the Lehigh-Schuylkill region.

Following the nearly synchronous deposition of the Tioga Metabentonite, the black, pyritic, non-calcareous muds of the Marcellus Formation were introduced into the eastern part of the basin and gradually spread westward over the entire study area during early Cazenovian time (Fig. 127). These muds are believed to have been laid down in relatively deep water to the northwest of highlands which were rising in the first phase of the Acadian Orogeny. Sources for the mud were to the east and southeast.

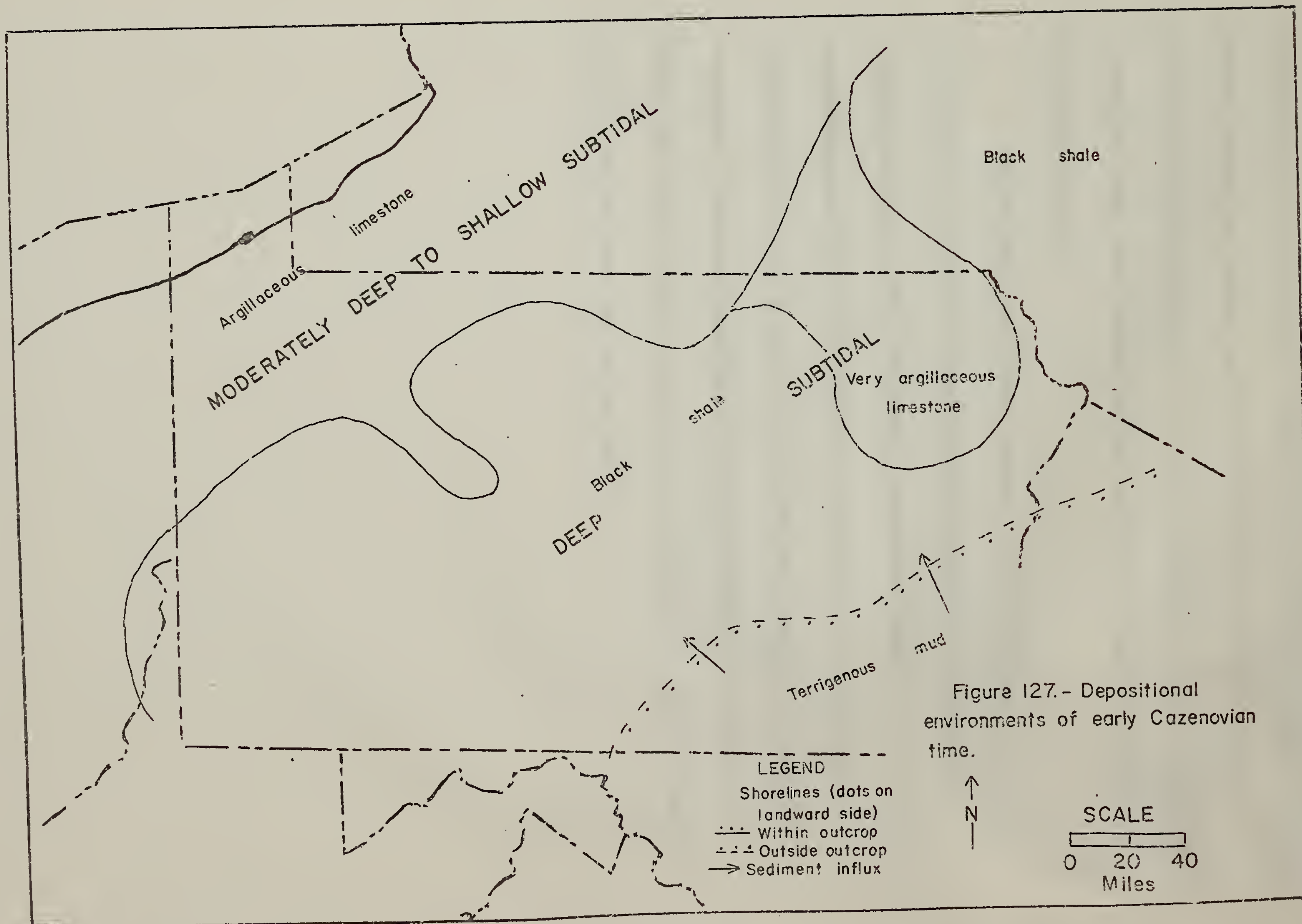

Figure 127.- Depositional environments of early Cazenovian time.

The black color, high pyrite content, and general barrenness of the typical Marcellus shales indicates that bottom conditions were acidic and strongly reducing. The few organisms which lived in the Marcellus seas were mostly either nektonic or else lived attached to floating objects.

To the west, the lower shales of the Marcellus grade off into limestone with a full complement of benthonic organisms (Seneca Member of the Onondaga Limestone, Delaware Limestone). Conditions favorable to carbonate deposition were reestablished temporarily in more eastern areas (Cherry Valley Limestone and "Purcell" Limestone members of the Marcellus Formation), but before the end of early Cazenovian time black, terrigenous clastics had spread out over the entire basin.

THE STRATIGRAPHY AND PALEONTOLOGY OF THE ONESQUETHAW STAGE IN PENNSYLVANIA AND ADJACENT STATES

Volume II

A Disseriation Presented

by

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Submitted to the Graduate School of the

University of Massachusetts in

partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 1975

Geology

SYSTEMATIC PALEONTOLOGY

Introduction

Many of the fossil species that occur in the Onesquethawan rocks of Pennsylvania and nearby states are described below. Several diagnostic Deerparkian and Cazenovian fossils are also included. Since the descriptions include only specimens actually collected by the writer for the present investigation, the treatment is not exhaustive. Brachiopods and trilobites are described most thoroughly; whereas corals, bryozoans, gastropods, bivalves, cephalopods, ostracodes, and cricoconarids are examined in less detail. The reader is referred to works cited in the synonomies for more information concerning Onesquethawan faunas, and to the Appendix of this report for detailed information on the collecting localities, each of which is designated in the descriptions by a letter-number code (e.g., Y6).

Table 13 is a general tabulation of the species described in this report. The classification scheme is that of the Treatise on Invertebrate Paleontology (R. C. Moore, editor) with only minor changes.

Descriptions

Phylum COELENTERATA

TABLE 13

ONESQUETHAWAN AND OTHER LOWER/MIDDLE DEVONIAN FOSSILS DESCRIBED IN THIS REPORT

(1 = Lower Onesquethawan (Lower Devonian); 2 = Upper Onesquethawan (Middle Devonian); 3 = Deerparkian; 4 = Cazenovian)

Fossils	1	2	3	4
Coelenterata				
Favosites basalticus (Goldfuss)		x		
Trachypora (?) sp.		x		
Syringaxan sp.		x		
Heterophrentis inflata (Hall)		x		
Heterophrentis simplex (Hall)	x	x		
"*Heterophrentis*" sp. A		x		
"*Heterophrentis*" sp. B		x		
Siphonophrentis yandelli (Edwards and Haime)		x		
Breviphrentis sp.		x		
Cylindrophyllum compactum (Hall)		x		
Acinophyllum stramineum (Billings)		x		
Blothrophyllum sinuosum Hall		x		
Cystiphylloides americanum (Edwards and Haime)		x		
Bryozoa				
Fenestrellina sp.		x		
Lichenalia sp.		x		
Brachiopoda				
Lingula sp.	x			
Orbiculoidea media (Hall)	x	x		
Levenea lenticularis (Vanuxem)	x	x		
Levenea sp.	x	x		
Leptaena rhomboidalis (Wilckens)	x	x		
Strophodonta (Strophodonta) demissa (Conrad)		x		
Megastrophia (Megastrophia) concava (Hall)		x		
Protoleptostrophia perplana (Conrad)	x			

TABLE 13—Continued

Fossils	1	2	3	4
Douvillina (Douvillina) inaequistriata (Conrad)		x		
Schellwienella pandora (Billings)	x	x		
Hipparionyx proximus Vanuxem			x	
Devonochonetes (?) lineatus (Vanuxem)				x
Longispina mucronatus (Hall)		x		
Anoplia nucleata (Hall)	x			
Eodevonaria arcuata (Hall)	x			
Eodevonaria elymencheri (Boucot and Harper)		x		
Eodevonaria sp.	x	x		
Truncalosia truncata (Hall)		x		
Cupulorostrum tethys (Billings)		x		
Leiorhynchus limitare (Vanuxem)				x
Leiorhynchus multicostum Hall				x
Atrypa reticularis (Linnaeus)	x	x		
Spinatrypa spinosa (Hall)		x		
Coelospira camilla Hall	x	x		
Leptocoelia flabellites (Conrad)	x			
Leptocoelina acutiplicata (Conrad)	x	x		
Meristella cf. *M. lata* (Hall)			x	
Meristina nasuta (Conrad)	x			
Pentagonia unisulcata (Conrad)		x		
Athyris spiriferoides (Eaton)		x		
Ambocoelia umbonata (Conrad)	x	x		
Cyrtinaella biplicata (Hall)		x		
Acrospirifer murchisoni (Castelnau)			x	
Acrospirifer duodenaria (Hall)	x			
Acrospirifer varicosus (Hall)		x		
Kozlowskiellina (Megakozlowskiella) raricosta (Conrad)	x	x		
Paraspirifer acuminatus (Conrad)		x		
Mucrospirifer macra (Hall)	x			
Brevispirifer gregarius (Clapp)		x		
Fimbrispirifer divaricatus (Hall)		x		
Costispirifer arenosus (Conrad)			x	
Elita fimbriata (Conrad)		x		
Rensselaeria elongata (Conrad)			x	
Amphigenia elongata (Vanuxem)		x		

TABLE 13—Continued

Fossils	1	2	3	4
Gastropoda				
Bembexia sp.	x			
Platyceras (*Platyceras*) *dumosum* (Conrad)		x		
P. (*Platystoma*) *ventricosum* Conrad			x	
P. (*Platystoma*) *turbinatum* Hall		x		
P. (*Platystoma*) *cochleatum* Hall	x			
Palaeozygopleura hamiltoniae (Hall)	x	x		
Bivalvia				
Nuculoidea sp.	x			
Praecardium cf. *P. multiradiatum* (Hall)	x			
Paracyclas lirata (Conrad)		x		
Cypricardinia indenta (Conrad)		x		
Cephalopoda				
Michelinoceras subulatum (Hall)	x			
Agoniatites (?) sp.	x			
Trilobita				
Proetus (*Crassiproetus*) *crassimarginatus* (Hall)		x		
Dechenella (*Dechenella*) *haldemani* (Hall)				x
Phacops cristata Hall	x	x		
Phacops pipa Hall and Clarke	x	x		
Phacops sp.	x	x		
Anchiopella anchiops (Green)	x			
Odontocephalus selenourus (Eaton)		x		
Odontocephalus aegeria Hall		x		
Odontocephauls bifidus (Hall)		x		
Ostracoda				
Bollia ungula Jones	x	x		
Favulella favulosa (Jones)	x	x		

TABLE 13--Continued

Fossils	1	2	3	4
Cricoconarida				
Tentaculites gracilistriatus Hall		x		
Tentaculites bellulus Hall		x		
Styliolina fissurella (Hall)		x		x

Class ANTHOZOA

Subclass ZOANTHARIA

Order TABULATA

Family FAVOSITIDAE

Subfamily FAVOSITINAE

Genus FAVOSITES Lamarck

FAVOSITES BASALTICUS (Goldfuss)

Pl. 6, fig. 1, 2

Favosites basalticus Grabau, 1906, pp. 194-195, fig. 121, 122. — Grabau and Shimer, 1909, p. 86, fig. 139.

Corallum large, flattened or tabular in shape, composed of many monomorphic corallites. Corallites, typically hexagonal, with thin walls that have faint longitudinal striations (impressions of very weak septa (?)). Mural pores large, uniserial, surrounded by thickened rim. Tabulae flat, complete, spaced at intervals of 0.5 to 1 mm.

Dimensions: Corallum 30 to 90 mm. high, up to at least 200 mm. in diameter. Corallites 1 to 2 mm. in diameter.

OCCURRENCE: Onondaga Limestone (Edgecliff Member) — Y2, Leroy, Genesee Co., N.Y.; Y7, Thompsons Lake, Albany Co., N.Y.; Y9, Hannacroix, Greene Co., N.Y.

Subfamily PACHYPORINAE

Genus TRACHYPORA Edwards and Haime

TRACHYPORA (?) sp.

Pl. 7, fig. 2

Dendropora neglecta Rominger, 1876, pp. 63-64, pl. 23, fig. 4. — Butts, 1941, p. 191, pl. 114, fig. 7, 8.

Corallum small, branched, composed of many subequal corallites that are irregularly arranged along branches. Corallites small, with ovoid calycal openings about 1 mm. in diameter that are separated by massive, pustuloe, colonial material.

Dimensions: Coralla average about 5 mm. in diameter. Material too fragmentary for determination of length of colonies.

OCCURRENCE: Needmore Formation (calcitic shale subfacies, calcitic shale and limestone subfacies) — V1, Gainesboro, Frederick Co., Va.

Order RUGOSA

Suborder STREPTELASMATINA

Superfamily CYATHOXONIICAE

Family LACCOPHYLLIDAE

Genus SYRINGAXON Lindstrom

SYRINGAXON sp.

Pl. 7, fig. 3, 4

Corallum small, ceratoid. Epitheca, thin, with conspicuous, rounded interseptal ridges. Major septa number about 22; extend about three-fourth distance to axis, becoming dilated and rhopaloid at axial end, forming inner wall, or aulos. In proximal portion of corallum, certain major septa (alars?) are aborted and dilation of neighboring septa cuts off two additional marginal fossulae that are also rimmed by inner wall. Minor septa very short. No dissepiments. Tabularium not observed.

Dimensions: Length 25 mm., diameter 12 mm., axial angle 30°.

OCCURRENCE: Onondaga Limestone (Nedrow Member) — Y4, Cherry Valley, Otsego Co., N.Y.

Superfamily ZAPHRENTICAE

Family STREPTELASMATIDAE

Genus HETEROPHRENTIS Billings

HETEROPHRENTIS INFLATA (Hall)

Pl. 7, fig. 5-9

Streptolasma inflatum Hall, 1882, p. 18. — Hall, 1883, p. 276, pl. 15, fig. 17-18. — Hall, 1884, p. 422, pl. 23, fig. 6, 7.

Heterophrentis inflata Stumm, 1964, p. 20, pl. 4, fig. 11, 12; pl. 7, fig. 1-5, 7-13; pl. 15, fig. 1.

Corallum large, trochoid. Epitheca, with irregularly spaced, concentric rugae and fine, longitudinal striae. Septa number about 90; major septa extend nearly to axis, deflected in a counter-clockwise direction distally; minor septa about one-third as long as major. Cardinal fossula on convex side of corallum. (Cardinal septum is about as long as adjacent minor septa.) Tabulae incomplete, distally arched. No dissepiments.

Dimensions:

Specimen	Length	Diameter
1 Djv	65 mm.	30 mm.
2 Don	47	29

OCCURRENCE: Onondaga Limestone (Edgecliff Member) — Y2 (float), Leroy, Genesee Co., N.Y. Jeffersonville Limestone (Brevispirifer gregarius zone) — K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

HETEROPHRENTIS SIMPLEX (Hall)

Pl. 8, fig. 1, 2

Strombodes simplex Hall, 1843, p. 209, fig. 6, pl. 48, fig. 6.

Zaphrentis simplex Hall, 1876, pl. 21, fig. 5, 8-10.

Zaphrentis cf. simplex Kindle, 1912, p. 66, pl. 11, fig. 1.

Heterophrentis simplex Stumm, 1964, p. 21, pl. 11, fig. 19; pl. 14, fig. 5, 6.

Corallum small to medium in size, simple, curved trochoid. Epitheca, with conspicuous rounded, interseptal ridges. Septa non-carinate, number about 70. Major septa extend nearly to axis; minor less than one-fourth as long. Cardinal fossula not observed. Tabulae not observed. No dissepiments.

Dimensions:

Specimen	Length	Diameter
1 Dn	14 mm.	11 mm.
2	20	14
3	30	20

OCCURRENCE: Onondaga Limestone — P29, Swatara Gap, Lebanon Co., Pa. Needmore Formation (calcareous shale member) — P35, Lewisburg, Union Co., Pa.; P50, Alinda, Perry Co., Pa.; P51, Falling Spring, Perry Co., Pa.

"HETEROPHRENTIS" sp. A

Pl. 8, fig. 3-5

Coralium medium in size, simple, trochoid. Epitheca reticulated by intersecting, fine, concentric and longitudinal ridges. Septa thick, non-carinate, number about 46. Major septa extend nearly to axis. Minor septa about one-fourth as long, regularly displaced from middle of space between adjacent major septa. Cardinal septa somewhat shorter than immediately adjacent major septa, but fossula not well developed. Tabulae appear to be distally arched, but recrystallization of specimen renders observation difficult. No dissepiments.

Dimensions:

Specimen	Length	Diameter
1 Dns	22 mm.	15 mm.
2 Dn	40	30

OCCURRENCE: Needmore Formation (Selinsgrove Limestone Member) — P55, Alfarata, Mifflin Co., Pa. (Calcitic shale and limestone subfacies) — P63, Warfordsburg, Fulton Co., Pa.

"HETEROPHRENTIS" sp. B

Pl. 8, fig. 6, 7

Corallum small, curved trochoid. Epitheca relatively smooth with only faint concentric rugation. Septa non-carinate, number about 70. Major septa extend to axis. Minor septa about one-fourth as long, obscured by silicification around periphery. Cardinal fossula not prominent, located on convex side of corallum. Tabulae not observed. No dissepiments.

Dimensions:

Specimen	Length	Diameter	Apical Angle
1 Djv	25 mm.	20 mm.	45°
2 Don	30	20	

OCCURRENCE: Onondaga Limestone (Echo Lake Member) — P1, Echo Lake, Monroe Co., Pa. Jeffersonville Limestone (*Brevispirifer gregarius* zone) — K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

Genus SIPHONOPHRENTIS O'Connell

SIPHONOPHRENTIS YANDELLI (Edwards and Haime)

Pl. 8, fig. 8-10

Amplexus yandelli Edwards and Haime, 1851, p. 344, pl. 3, fig. 2-2a. — Rominger, 1876, p. 155, pl. 54, lower tier.

Siphonophrentis yandelli Stumm, 1964, pp. 24-25, pl. 12, fig. 1-5; pl. 13, fig. 5-6.

Corallum simple, subcylindrical. Epitheca wrinkled by concentric annulations. Cardinal fossula present, formed by aborted cardinal septum and narrow, abrupt downwarping of tabulae in cardinal area. Septa non-carinate, number about 90. Major septa extend about two-thirds distance to axis. Minor septa very short. Stereozone present around periphery. Tabulae complete, horizontal. No dissepiments.

Dimensions:

Specimen	Length	Diameter
1 Djv	55 mm.	23 mm.
2	40	17

OCCURRENCE: Jeffersonville Limestone (Brevispirifer gregarius zone) — K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

Genus BREVIPHRENTIS Stumm

BREVIPHRENTIS sp.

Pl. 9, fig. 1-5

Corallum simple, trochoid. Epitheca with reticulate surface formed by closely-spaced intersecting concentric annulations and interseptal ridges. Calyx with steeply sloping walls and flat floor. Septa non-carinate, number about 100. Major septa extend about two-thirds distance to axis; minor septa, not apparent. Tabularium wide, fills most of corallum. Tabulae flat, slightly deflected proximally near periphery. Dissepiments not observed.

Dimensions:

Specimen	Length	Diameter
1 Don	75 mm.	37 mm.
2 Dj	76	26

OCCURRENCE: Onondaga Limestone (Edgecliff Member) — Y4, Cherry Valley, Otsego Co., N.Y. Jeffersonville Limestone (Brevispirifer gregarius zone) — K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

Family PHILLIPSASTRAEIDAE

Subfamily PHILLIPSASTRAEINAE

Genus CYLINDROPHYLLUM Simpson

CYLINDROPHYLLUM COMPACTUM (Hall)

Pl. 10, fig. 1, 2

Heliophyllum compactum Hall, 1882, p. 48. — Hall, 1883, p. 308, pl. 25, fig. 5. — Hall, 1884, p. 452.

Cylindrophyllum compactum Stumm, 1964, p. 42, pl. 29, fig. 3; pl. 35, fig. 11, 12; pl. 37, fig. 1-4, 12, 13.

Corallum phaceloid, composed of large, cylindrical to subcylindrical corallites. Epitheca thin, with distinct, irregularly spaced growth rugae and fine, longitudinal striae (spaced about 1 mm. apart) that represent septa. Septa carinate, with "yard-arm" carinae, number about 60 in mature corallites. Major septa appear to extend about three-fourths distance to axis, but all septa are obscured by silicification. Tabulae and dissepiments not observed.

Dimensions: Length 80 mm., diameter 10 to 20 mm. (Individual corallite.)

OCCURRENCE: Onondaga Limestone (Edgecliff Member) --- Y2 (float), Leroy, Genesee Co., N.Y.

Genus ACINOPHYLLUM McLaren

ACINOPHYLLUM STRAMINEUM (Billings)

Pl. 11, fig. 1, 2

Diphyphyllum stramineum Billings, 1859, pp. 135-136.

Acinophyllum stramineum McLaren, 1959, pp. 25-26, pl. 9, fig. 3-4; pl. 10, fig. 5; text-fig. 8.

Corallum phaceloid, composed of many slender, cylindrical corallites. Epitheca thin, with prominent growth constrictions at intervals of 1 to 2 mm. and longitudinal septal ridges about 0.5 mm. apart; very fine concentric and longitudinal striations also present. Calyces rather deep. Septa carinate, with "yard-arm" carinae; number between 40 and 46 in mature specimens. Major septa extend nearly to axis; minor septa about half as long. (Septa are of approximately equal length in upper part of corallite.) Dissepimentarium narrow, peripheral. Tabularium wide, with flat or axially-arched tabulae that are spaced about 1 mm. apart.

Dimensions: Length up to about 90 mm.; diameter averages 4 to 6 mm.

OCCURRENCE: Onondaga Limestone (Edgecliff Member) — Y7, Thompsons Lake, Albany Co., N.Y.

Suborder COLOMNARIINA

Family CHONOPHYLLIDAE

Subfamily BLOTHROPHYLLINAE

Genus BLOTHROPHYLLUM

BLOTHROPHYLLUM SINUOSUM Hall

Pl. 12, fig. 1, 2

Blothrophyllum sinuosum Hall, 1882, p. 45. — Stumm, 1964, p. 49, pl. 45, fig. 1-9.

Corallum simple, subcylindrical, with cone-in-cone structure produced by periodic rejuvenescence. Former calyx margins are spaced 3 to 10 mm. apart. Calyx with moderately sloping walls and slight axial boss produced by intertwined septa. Septa non-carinate, dilated peripherially. Major septa number about 50, extend to axis. Minor septa not observed. Tabulae not observed. Dissepiments, few, occur mainly around margin.

Dimensions: Length 125 mm., diameter 27 mm.

OCCURRENCE: Jeffersonville Limestone (Brevispirifer gregarius zone) — K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

Suborder CYSTIPHYLLINA

Family DIGONOPHYLLIDAE

Subfamily DIGONOPHYLLINAE

Genus CYSTIPHYLLOIDES Chapman

CYSTIPHYLLOIDES AMERICANUM (Edwards and Haime)

Pl. 12, fig. 3-6

Cystiphyllum americanum Edwards and Haime, 1851, p. 464, pl. 13, fig. 4-4a. — Rominger, 1876, pp. 138-139, pl. 50, upper tier and fig. 4.

Cystiphylloides americanum Stumm, 1949, pl. 19, fig. 3-5. — Stumm, 1964, p. 54, pl. 50, fig. 1-2, 6-9; pl. 54, fig. 5-8; pl. 55, fig. 7-9.

Corallum simple, subcylindrical. Epitheca thick, horizontally wrinkled, with fine horizontal striations between wrinkles. Septa, apparently very short, appear as tooth-like projections (that number over 100) on periphery and around thickened rejuvenescence zones in central portion. Tabulae not observed. Dissepimentarium wide, essentially fills interior; composed of many axially and distally convex dissepiments.

Dimensions:

Specimen	Length	Diameter
1 Don	115 mm.	40 mm.
2	100	28
3	53	20
4	55	19
5	47	24
6	48	24

Dimensions:—Continued

Specimen	Length	Diameter	
7 Don	55 mm.	25 mm.	
8	56	26	
9	50	25	
10	70	36	compressed

OCCURRENCE: Onondaga Limestone (Edgecliff Member) — Y7, Thompsons Lake, Albany Co., N.Y.

Phylum BRYOZOA

Class GYMNOLAEMATA

Order CRYPTOSTOMATA

Family FENESTELLIDAE

Genus FENESTRELLINA D'Orbigny

FENESTRELLINA sp.

Pl. 13, fig. 1, 2

Zoarium lacy, fan-shaped or funnel-shaped, composed of fine branches connected by dissepiments that are spaced about 1 mm. apart. Obverse side with two rows of rimmed apertures separated by low, continuous median carina. Reverse side smooth.

Dimensions:

	Length	Diameter	No./10 mm.
Fenestrules	—	—	5
Dissepiments	1.0 mm.	0.4 mm.	6
Branches	—	0.4	6-7

(Total size of zoaria is uncertain since only fragments were found.)

OCCURRENCE: Onondaga Limestone — P23, Germans, Carbon Co., Pa.; P26, Schuylkill Haven, Schuylkill Co., Pa.; P27, Auburn, Schuylkill Co., Pa.; P28, Moyers, Schuylkill Co., Pa.

Family RHINOPORIDAE

Genus LICHENALIA Hall

LICHENALIA sp.

Pl. 13, fig. 3

Only the undersurface (epitheca) of this species has been observed in the collections for the present study.

Epitheca thin, contorted, marked by irregular, concentric wrinkles (about 6 per 5 mm.) and fine transverse and longitudinal striae (about 20 per 5 mm.).

Dimensions (of most complete colony collected): Length 61 mm., width 21 mm.

OCCURRENCE: Onondaga Limestone (Moorehouse Member) — Y5, Schoharie, Schoharie Co., N.Y. Onondaga Limestone — P27, Auburn, Schuylkill Co., Pa.

Phylum BRACHIOPODA

Class INARTICULATA

Order LINGULIDA

Superfamily LINGULACEA

Family LINGULIDAE

Genus LINGULA Bruguiere

LINGULA sp.

Pl. 13, fig. 5

Description based on a single, imperfect valve.

Outline elongate-ovoid, with greatest width at mid-length. Length to width ratio about 2.0. External ornament of very fine, radiating striae and equally fine concentric growth lines.

Dimensions: Length 24 mm., width 13 mm.

OCCURRENCE: Schoharie Formation (Saugerties-Aquetuck members, undivided) — P14, Foxtown Gap, Monroe Co., Pa.

Order ACROTRETIDA

Superfamily DISCINACEA

Family TREMATIDAE

Subfamily ORBICULOIDEINAE

Genus ORBICULOIDEA D'Orbigny

ORBICULOIDEA MEDIA (Hall)

Pl. 13, fig. 6, 7

Discina media Hall, 1867, pp. 20-21, pl. 2, fig. 25-29.

Orbiculoidea media Hall and Clarke, 1892, pl. 1, pl. 4e, fig. 15-17.

Orbiculoidea lodiensis var. media Kindle, 1912, p. 69, pl. 2, fig. 9-11.

Shell small, subcircular in outline, biconvex. Both shells conical, showing holoperipheral growth, with apices placed slightly toward posterior margin. Surface bears fine, evenly spaced striae (about 10 per mm.).

Pedicle valve: External pedicle groove begins at apex and extends about 1 mm. toward posterior. In interior is a distinct ridge which encircles valve (parallel to plane of commissure) a little below apex. Pedicle groove does not extend posteriorly beyond ridge. Groove expressed as short septum in interior of valve.

Brachial valve: Similar to pedicle valve, but lacks pedicle groove.

OCCURRENCE: Needmore Formation (Beaverdam Shale Member) — P35, Lewisburg, Union Co., Pa. (Calcareous shale member) — P30, Dalmatia, Northumberland Co., Pa.; P31, Selinsgrove Junction, Northumberland Co., Pa.; P35, Lewisburg, Union Co., Pa.; P36, Montoursville, Lycoming Co., Pa.; P41, Mt. Pleasant Mills, Snyder Co., Pa.; P52, Newton Hamilton, Mifflin Co., Pa.; P60, Curtin Gap, Centre Co., Pa.; P61, Tyrone, Blair Co., Pa.; P63, Warfordsburg, Fulton Co., Pa. (Calcitic shale subfacies) — M2, Flintstone, Allegany Co., Md. (Selinsgrove Limestone Member) — P52, P53, Newton Hamilton, Mifflin Co., Pa.

REMARKS: These specimens show the distinct, elevated, concentric striae characteristic of O. media, and all lack the fine radiating folds of O. lodiensis.

Class ARTICULATA

Order ORTHIDA

Suborder ORTHIDINA

Superfamily ENTELETACEA

Family DALMANELLIDAE

Genus LEVENEA Schuchert and Cooper

LEVENEA LENTICULARIS (Vanuxem)

Pl. 14, fig. 1-8

Orthis lenticularis Vanuxem, 1842, p. 139, fig. 4. — Hall, 1867, pp. 35-36, pl. 5, fig. 1, 2.

Orthis (Dalmanella) lenticularis Hall and Clarke, 1892, pl. 5c, fig. 36-41.

Shell of medium size, unequally biconvex, with pedicle valve more convex. Anterior profile gently sulcate. Outline, subquadrate to subcircular. Length to width ratio about 1:1.1, with greatest width slightly posterior to mid-length. Hinge, strophic. Cardinal angles rounded to obtuse. Surface costellate, with about 20 costellae per 5 mm. at distance of 15 mm. from posterior margin. Costellae increase by bifurcation. Concentric ornament of indistinct, irregularly spaced growth lamellae. Shell material, endopunctate.

Pedicle valve: Very convex, subcarinate. Beak incurved over relatively low, apsacline to nearly orthocline, triangular interarea. Delthyrium open, wide, triangular, subtends an angle of about 60°.

Interior with strong teeth supported by stout dental plates that are fused to posterior part of shell. Muscle scars impressed in umbonal portion of valve; bilobed with prominent diductors, but inconspicuous adductors.

Brachial valve: Depressed convex, with a shallow, rounded sulcus that extends from beak to anterior margin and broadens rather strongly toward the front. Beak low. Interarea poorly defined, nearly linear.

Interior with stout, triangular brachiophores that are attached to floor of valve and project ventrally. (Sockets obscured by rock matrix.) Cardinal process obscure, probably bilobed, located posteriorly of brachiophores. Adductor scars elongate, divided medianly by a low, broad septum and bounded laterally and medianly by low ridges. The anterior and posterior adductors are separated by a vague line which divides them into pairs of approximately equal area.

Dimensions:

Specimen	Length	Width	Convexity
1 Dn	18 mm.	20 mm.	—
2	18	20	—
3	14	15	—

OCCURRENCE: Onondaga Limestone — P26, Schuylkill Haven, Schuylkill Co., Pa. Needmore Formation (calcitic shale subfacies) — V1, Gainesboro, Frederick Co., Va. (Calcitic shale and limestone subfacies) — P63, Warfordsburg, Fulton Co., Pa.; M2, Flintstone, Allegany Co., Md.

REMARKS: The genus Dalmanella is restricted to Ordovician and Lower Silurian rocks (Wright, in Williams and others, 1965, p. H333).

These specimens are assigned to the Devonian dalmanellid genus which they most nearly resemble.

LEVENEA sp.

Pl. 14, fig. 9-12

Dalmanella lenticularis Kindle, 1912, p. 79, pl. 5, fig. 12-6. — Kindle, in Prosser, Kindle, and Swartz, 1913, p. 164, pl. 13, fig. 22-25; pl. 14, fig. 11, 12.

Shell small, depressed, ventribiconvex. Anterior profile, rectimarginate. Outline transversely subovoid. Length to width ratio 1:1.3, with greatest width about mid-length. Hinge strophic. Cardinal angles, rounded to obtuse. Surface, unequally ramicostellate with about 18 costellae per 5 mm. at distance of 8 mm. from beak. Concentric ornament of irregularly spaced growth lamellae. Shell substance, endopunctate.

Pedicle valve: Convex. Beak, incurved over triangular, apsacline interarea. Interarea longitudinally striated on lateral margins.

Interior, with conspicuous bilobate diductor muscle scars that extend a little over one-third distance to anterior margin, and small relatively inconspicuous adductor scars which occur on postero-median side of diductor scars. Vascula media diverge at about mid-point of muscle scars.

Brachial valve: Depressed convex with some specimens showing very shallow sulcus that extends from beak to anterior margin. (Anterior portion of valve commonly concave as a result of post-depositional distortion.) Beak low. Interarea very low, anacline.

Interior not observed.

Dimensions:

Specimen	Length	Width	Convexity
1 Dn	10 mm.	13 mm.	2 mm.
2	11	13	4
3	12	15	4
4	10	14	—
5	11	15	3
6	10	13	3
7	8	11	—

OCCURRENCE: Needmore Formation (calcareous shale member) — P30, Dalmatia, Northumberland Co., Pa. (Selinsgrove Limestone Member) — P30, Dalmatia, Northumberland Co., Pa.; P42, Thompsontown, Juniata Co., Pa. (Calcitic shale and limestone subfacies) — P64, Warren Point, Franklin Co., Pa.; M2, Flintstone, Allegany Co., Md.

Order STROPHOMENIDA

Suborder STROPHOMENIDINA

Superfamily STROPHOMENACEA

Family LEPTAENIDAE

Genus LEPTAENA Dalman

LEPTAENA RHOMBOIDALIS (Wilckens)

Pl. 15, fig. 1-10

Conchita rhomboidalis Wilckens, 1769, p. 77, pl. 8, fig. 43, 44.

Strophomena rhomboidalis Hall, 1867, pp. 76-77, pl. 12, fig. 16-18.

Leptaena rhomboidalis Hall and Clarke, 1892, pl. 8, fig. 17-31; pl. 15A, fig. 40-42; pl. 20, fig. 21-24. — Prosser, in Prosser, Kindle, and Swartz, 1913, pp. 141-143, pl. 10, fig. 10, 11.

Shell medium to large, concavo-convex. Outline subcircular with maximum width at hinge line. Length to width ratio about 0.70. Hinge strophic. Cardinal angles, right angled to slightly acute. External ornament of fine, radial costellae and strong, concentric rugae. Costellae number 10 to 15 per 5 mm. at distance of 15 mm. from beak; rugae number 8 to 12, wider spaced toward anterior margin.

Pedicle valve: Strongly convex, geniculate with trail making a right angle with disc. Disc bears coarse rugae, the most anterior one of which is somewhat more elevated than others and slopes off to form trail. Trail bears only fine costellae. Beak slightly elevated over narrow, apsacline interarea.

Interior not observed.

Brachial valve: Concave, consisting of a flat disc bearing fine costellae and coarse, concentric rugae, and a dorsally directed trail, meeting disc at obtuse angle and bearing only fine costellae. Trail forms distinct lip around valve, being 5 mm. wide at anterior extremity on one specimen.

Interior not observed.

Dimensions:

Specimen	Length	Width
1 Don	25 mm.	31 mm.
2	20	27
3	13	16
4	15	17
5	17	25
6	22	27
7 Dse	17	25
8	?	20

OCCURRENCE: Schoharie-Esopus formations, undivided — P18, Kunkletown, Monroe Co., Pa.; P24, Stony Mountain School, Carbon Co., Pa. Onondaga Limestone (Edgecliff Member, Member A) — Y21, Trilobite Mountain, Orange Co., N.Y.; P1, Echo Lake, Monroe Co., Pa. (Moorehouse Member) — Y1, Stafford, Genesee Co., N.Y.; Y5, Schoharie, Schoharie Co., N.Y.; Y15, Saugerties, Ulster Co., N.Y. Onondaga Limestone — P26, Schuylkill Haven, Schuylkill Co., Pa.; P29, Swatara Gap, Lebanon Co., Pa.

Family STROPHEODONTIDAE

Subfamily STROPHEODONTINAE

Genus STROPHODONTA Hall

Subgenus STROPHODONTA Williams

STROPHODONTA (STROPHODONTA) DEMISSA (Conrad)

Pl. 16, fig. 1, 2

Strophomena demissa Conrad, 1842, p. 258, pl. 14, fig. 14.

Strophomena (Strophodonta) demissa Hall, 1857, p. 137, fig. 1.

<u>Strophodonta demissa</u> Hall, 1867, pp. 81, 101–104, pl. 11, fig. 14–17; pl. 12, fig. 1–5; pl. 17, fig. 2a–2g, 2k–2p, 2r–2s.

<u>Stropheodonta demissa</u> Hall and Clarke, 1892, pl. 14, fig. 7–12. — Prosser, in Prosser, Kindle and Swartz, 1913, pp. 136–137, pl. 10, fig. 1. — Cooper, in Shimer and Shrock, 1944, p. 339, pl. 131, fig. 12–14.

Shell medium in size, concavo-convex. Outline semicircular, with greatest width at hinge line. Length to width ratio about 0.67. Hinge strophic, entirely denticulate. Cardinal angles slightly auriculate. External ornament, finely costellate, except on umbo of pedicle valve, where there are from 6 to 10 strongly elevated costae. Shell substance pseudopunctate.

Pedicle valve: Convex, flattened on postero-lateral margins. Interarea low, triangular, apsacline. Delthyrium closed by pseudodeltidium.

Interior not observed.

Brachial valve: Concave, flattened on postero-lateral margins. Interarea sublinear.

Interior not observed.

Dimensions:

Specimen	Length	Width	Convexity
1 Don	20 mm.	30 mm.	5 mm.
2	22	27	—

OCCURRENCE: Onondaga Limestone (Moorehouse Member) — Y4, Cherry Valley, Otsego Co., N.Y. Onondaga Limestone — P29, Swatara Gap, Lebanon Co., Pa.

Genus MEGASTROPHIA Caster

Subgenus MEGASTROPHIA Williams

MEGASTROPHIA (MEGASTROPHIA) CONCAVA (Hall)

Pl. 16, fig. 3, 4

Strophomena (Strophodonta) concava Hall, 1857, pp. 115, 140, fig. 1.

Strophodonta concava Hall, 1867, p. 96, pl. 14, fig. 2a-2d; pl. 15, fig. 1-5, pl. 16, fig. 1a-1h.

Stropheodonta concava Hall and Clarke, 1892, pl. 14, fig. 16-23. — Schuchert, 1897, p. 420.

Megastrophia concava Cooper, in Shimer and Shrock, 1944, p. 339, pl. 130, fig. 25; pl. 131, fig. 1-4.

Megastrophia (Megastrophia) concava Williams, in Williams et al., 1965, p. 395, fig. 255, 5.

Shell large, subcircular, concavo-convex, with long, straight, denticulate hinge line. Length to width ratio about 0.70. Surface marked by many simple, elevated primary parvicostae and more numerous, finer, secondary parvicostae which occur in bundles of 4 to 6 between primaries, the number decreasing toward beak. Most primary parvicostae begin at beak and extend to margin; others arise by intercalation. Shell contains 60 to 75 primary, parvicostae, these being about 1 mm. apart at anterior margin. No conspicuous growth lines present, but fine concentric ribbing is present between primary parvicostae.

Pedicle valve: Strongly convex, with frontal one-third of valve steeply sloping.

Interior finely pustulose. Diductor scars long, flabellate, extending half the distance to anterior margin; occur laterally to much smaller, ovate adductor scars. A narrow septum separates right and left pairs of scars.

Brachial valve: Not observed.

Dimensions:

Specimen	Length	Width
1 Don	35 mm.	50 mm.
2	35	50

OCCURRENCE: Onondaga Limestone (Moorehouse Member) — Y1, Stafford, Genesee Co., N.Y. Onondaga Limestone — P26, Schuylkill Haven, Schuylkill Co., Pa.; P27, Auburn, Schuylkill Co., Pa.; P28, Moyers, Schuylkill Co., Pa.

Subfamily LEPTOSTROPHIINAE

Genus PROTOLEPTOSTROPHIA Caster

PROTOLEPTOSTROPHIA PERPLANA (Conrad)

Pl. 16, fig. 5

Strophomena perplana Conrad, 1842, p. 257, pl. 14, fig. 11.

Strophodonta perplana Hall, 1867, pp. 92, 98, pl. 11, fig. 22.

Stropheodonta (Leptostrophia) perplana Hall and Clarke, 1892, p. 288, pl. 15, fig. 2-13. — Prosser and Kindle, in Prosser, Kindle, and Swartz, 1913, p. 134, pl. 9, fig. 11-17.

<u>Protoleptostrophia perplana</u> Cooper, in Shimer and Shrock, 1944, p. 341, pl. 131, fig. 15-17.

Shell large, plano- to slightly concavo-complex, nearly flat. Outline semi-circular, with greatest width at hinge line. Length to width ratio about 0.90. Surface of valves with numerous very fine costellae, which increase by both bifurcation and intercalation. About 7 costellae per 5 mm. at distance of 27 mm. from beak. Costellae about as wide as intervening furrows. Hinge strophic, denticulate. Shell substance pseudopunctate.

Pedicle valve: Slightly convex. Interior with large, fan-shaped, diductor muscle scars.

Brachial valve: Plane, or slightly concave.

Interior not observed.

Dimensions: Length 31 mm., width 35 mm.

OCCURRENCE: Schoharie-Esopus formations, undivided -- P19, Little Gap, Carbon Co., Pa.

Subfamily DOUVILLININAE

Genus DOUVILLINA Oehlert

Subgenus DOUVILLINA Williams

DOUVILLINA (DOUVILLINA) INAEQUISTRIATA (Conrad)

Pl. 16, fig. 6

<u>Strophomena inaequistriata</u> Conrad, 1842, p. 25A, pl. 14, fig. 2.

Strophomena (Strophodonta) inaequistriata Hall, 1857, p. 142.

Strophodonta inaequistriata Hall, 1867, pp. 106-108, pl. 18, fig. 2a-2k.

Stropheodonta (Douvillina) inaequistriata Hall and Clarke, 1892, pl. 14, fig. 1-6; pl. 15B, fig. 9. — Prosser, in Prosser, Kindle, and Swartz, 1913, pp. 138-139, pl. 10, fig. 2-5.

Douvillina inaequistriata Cooper, in Shimer and Shrock, 1944, p. 341, pl. 132, fig. 8-11.

Shell medium-sized, concavo-convex. Outline semi-circular to semi-elliptical, with greatest width at hinge line. Length to width ratio about 0.75. Surface of valves unequally parvicostellate; costellae increase by intercalation. Hinge strophic, denticulate. Shell substance pseudopunctate.

Pedicle valve: Convex. Interior with teardrop shaped, diductor scars which extend about one-third distance to anterior margin. Muscle scars are surrounded by prominent muscle bounding ridges and are separated by a short median septum. Pallial markings lenniscate.

Brachial valve: Not observed.

Dimensions: Length 15 mm., width 20 mm.

OCCURRENCE: Onondaga Limestone — P22, West Bowmans, Carbon Co., Pa.

Superfamily DAVIDSONIACEA

Family MEEKELLIDAE

Genus SCHELLWIENELLA

SCHELLWIENELLA PANDORA (Billings)

Pl. 16, fig. 7-10

Streptorhynchus pandora Billings, 1860, p. 226, fig. 12, 13.

Schuchertella pandora Kindle, 1912, p. 76, pl. 3, fig. 7, 8.

Shell medium in size, unequally biconvex. Outline semicircular, with greatest width at hinge line. Length to width ratio about 0.83. Hinge strophic. Cardinal angles slightly acute. External ornament of fine costellae that number about 20 per 10 mm. at distance of 15 mm. from beak. Interspaces are somewhat wider than costellae.

Pedicle valve: Convex, with slightly elevated beak and depressed margins. Interarea apsacline, about half as wide as valve; cleft by triangular delthyrium. Pseudodeltidium not observed.

Interior with teeth supported by divergent, dental plates. Dental plates are thickened by secondary shell material where attached to valve, and with thickened posterior margin, bound a shallow, funnel-shaped opening that is directed postero-medianly. Area of teeth is laminated. Diductor scars impressed, slightly flabellate; appear to extend about one-fourth length of valve. Adductor scars restricted to umbo; separated by shallow depression, bounded by low ridges laterally and anteriorly and by thickened pad of secondary material posteriorly. Imprint of costellae only developed along periphery of shells.

Brachial valve: Not observed.

Dimensions:

Specimen	Length	Width
1 Dn	20 mm.	18 mm.
2 Dse	13	23
3 Don	22	30

OCCURRENCE: Schoharie-Esopus formations, undivided — P19, Little Gap, Carbon Co., Pa. Onondaga Limestone — P26, Schuylkill Haven, Schuylkill Co., Pa. Needmore Formation (calcareous shale member) — P35, Lewisburg, Union Co., Pa.

Family ORTHOTETIDAE

Subfamily ORTHOTETINAE

Genus HIPPARIONYX Vanuxem

HIPPARIONYX PROXIMUS Vanuxem

Pl. 16, fig. 11

Hipparionyx proximus Vanuxem, 1842, p. 124, fig. 29.

Orthis hipparionyx Hall, 1859, pp. 407-409, pl. 89, fig. 1-4; pl. 90, fig. 1-7; pl. 91, fig. 4, 5; pl. 94, fig. 4 (1861).

Hipparionyx proximus Hall and Clarke, 1892, pp. 257-259, pl. 9, fig. 33-36; pl. 15A, fig. 9-11. — Schuchert, in Schuchert, Swartz, Maynard and Rowe, 1913, pp. 333-334, pl. 61, fig. 10-13. — Williams, in Williams et al., 1965, p. H410, fig. 269, 3.

Description based on one internal mold of a pedicle valve.

Outline sub-circular, with greatest width at mid-length. Length to width ratio about 1.0. Hinge strophic. External ornament not observed.

Pedicle valve: Repressed convex. Interior with large muscle field that extends two-thirds distance to anterior margin. Diductor scars broad, flabellate, enclose narrow adductor scars that are located postero-medianly. Muscle field surround by well-defined ridge and split by low median septum. Teeth moderately large, supported by dental plates that extend to floor of valve and are connected to muscle bounding ridges.

Brachial valve: Not observed.

Dimensions: Length 45 mm., width 45 mm.

OCCURRENCE: Ridgeley Sandstone —P36A, Montoursville, Lycoming Co., Pa.

Suborder CHONETIDINA

Superfamily CHONETACEA

Family CHONETIDAE

Subfamily DEVONOCHONETINAE

Genus DEVONOCHONETES Muir-Wood

DEVONOCHONETES (?) LINEATUS (Vanuxem)

Pl. 17, fig. 1

Strophomena lineata Vanuxem, 1843, fig. 4.

Chonetes lineata Hall, 1867, pp. 121-123, pl. 20, fig. 3a-3f. — Hall and Clarke, 1892, pl. 16, fig. 34.

Shell small, concavo-convex. Interior profile rectimarginate. Outline semi-circular, with greatest width at hinge line. Length to width ratio averages about 0.75. Hinge strophic. Cardinal angles about 90°. Surface costellate, with 7 to 10 low, rounded costellae per 2 mm. at distance of 5 mm. from beak. Costellae increase by bifurcation and intercalation. Most specimens have a total of 50 to 65 costellae, the cardinal angles being smooth. Shell substance pseudopunctate.

Pedicle valve: Convex, with the cardinal angles somewhat flattened; shallow sulcus is rarely present.

Interior with broad, somewhat flabellate diductor scars which extend nearly one-half distance to anterior margin; pustulose and bearing strong impression of costellae.

Brachial valve: Concave.

Interior not observed.

Dimensions:

Specimen	Length	Width	L/W	Convexity
1 Don	5 mm.	6 mm.	0.83	2 mm.
2	5	7	0.71	2
3	4	5	0.80	1.5
4	6	10	0.60	2

OCCURRENCE: Onondaga Limestone (Seneca Member) — Y3, Nedrow, Onondaga Co., N.Y.

Genus LONGISPINA Cooper

LONGISPINA MUCRONATUS (Hall)

Pl. 17, fig. 2

Strophomena mucronata Hall, 1843, p. 180, fig. 3.

Chonetes mucronata Hall, 1867, pp. 124-126, pl. 20, fig. 1a-1d; pl. 21, fig. 1a-1g.

Chonetes mucronatus Schuchert, 1897, p. 176. — Kindle, 1912, p. 71, pl. 3, fig. 13, 14. — Prosser, in Prosser, Kindle, and Swartz, 1913, pp. 146-148, pl. 11, fig. 11-17.

Longispina mucronatus Cooper, 1942, p. 230. — Ellison, 1965, pp. 87-88, pl. 10, fig. 1-8.

Shell small, concavo-convex. Outline semi-circular, with greatest width along hinge in some specimens, but appears to be anterior of hinge in most. Length to width ratio about 0.65. Hinge strophic. Surface ornament of rather coarse costellae that number about 10 per 5 mm. along anterior commissure. Total number of costellae generally less than 30. Shell substance pseudopunctate.

Pedicle valve: Highly convex. Interarea narrow, orthocline to anacline. Delthyrium triangular, open. Spines not observed.

Interior with prominent median septum in some specimens.

Brachial valve: Concave. Interior with median septum dividing prominent diductor scars. Cardinal process stout, posteriorly directed beyond hinge line.

Dimensions:

Specimen	Length	Width	Convexity
1 Don	5 mm.	7 mm.	3 mm.
2	4	5	—
3	3	5	—
4	4	6	2
5	4	4	2
6 Dn	6	8	—

OCCURRENCE: Onondaga Limestone (Echo Lake Member, Member D) — P1, Echo Lake, Monroe Co., Pa.; P11, East Stroudsburg, Monroe Co., Pa.; P13, Stroudsburg, Monroe Co., Pa.

Family ANOPLIIDAE

Genus ANOPLIA Hall and Clarke

ANOPLIA NUCLEATA (Hall)

Pl. 17, fig. 3, 4

Leptaena (?) nucleata Hall, 1857, p. 47. — Hall, 1859, p. 419, pl. 94, fig. 1a-1d.

Anoplia nucleata Hall and Clarke, 1892, pl. 15A, fig. 17, 18; pl. 20, fig. 14-17. — Kindle, 1912, p. 73, pl. 5, fig. 8-11. — Kindle, in Prosser, Kindle, and Swartz, 1913, pp. 159-160; pl. 13, fig. 10-13. — Cooper, in Shimer and Shrock, 1944, p. 342, pl. 135, fig. 17-20.

Shell very small, very strongly concavo-convex. Outline semi-circular. Length to width ratio about 0.83, with greatest width at hinge line. Hinge strophic. Cardinal angles slightly auriculate in some specimens. Surface smooth, except for faint, concentric growth lines. Shell substance pseudopunctate.

Pedicle valve: Very strongly convex. Beak prominent, incurved over low interarea.

Interior not observed.

Brachial valve: Concave.

Interior not observed.

Dimensions:

Specimen	Length	Width	Convexity
1 Dn	5 mm.	6 mm.	2 mm.
2	4	5	2
3	4	3	1

OCCURRENCE: Needmore Formation (calcareous shale member) — P52, Newton Hamilton, Mifflin Co., Pa. (Calcitic shale subfacies) — P63, Warfordsburg, Fulton Co., Pa.

Family EODEVONARIIDAE

Genus EODEVONARIA Breger

EODEVONARIA ARCUATA (Hall)

Pl. 17, fig. 5

Chonetes arcuata Hall, 1857, p. 116. — Hall, 1867, p. 119, pl. 20, fig. 7. — Hall and Clarke, 1892, pl. 16, fig. 15, 35, 36.

Chonetes arcuatus Schuchert, 1897, p. 172.

Chonetes (Eodevonaria) arcuatus Kindle, 1912, p. 71, pl. 3, fig. 9-12.

Eodevonaria arcuata Cooper, in Shimer and Shrock, 1944, p. 347, pl. 135, fig. 3-5. — Boucot and Johnson, 1968, p. 10, pl. 3, fig. 1-5.

Shell moderately large, strongly concavo-convex. Outline semi-circular, with greatest width at hinge line. Hinge strophic, denticulate. Surface finely costellate, with about 25 costellae per 10 mm. near anterior commissure. Total number of costellae is generally about 100. Costellae generally simple, but some bifurcate anteriorly. Most specimens are deformed.

Pedicle valve: Strongly convex, with incurved umbo. Interior not observed.

Brachial valve: Not observed.

Dimensions: Length, uncertain; width 20 to 25 mm.

OCCURRENCE: Schoharie-Esopus formations, undivided — P18, Kunkletown, Monroe Co., Pa.

EODEVONARIA ELYMENCHERI Boucot and Harper

Pl. 17, fig. 6-8

Eodevonaria elymencheri Boucot and Harper, 1968, p. 157, pl. 27, fig. 17; pl. 28, fig. 1a-1c.

Shell small to medium in size, concavo-convex. Anterior commissure rectimarginate. Outline semi-circular, with greatest width at hinge line. Length to width ratio about 0.80. Hinge strophic, denticulate along entire length. Cardinal angles acute to auriculate. External surface finely costellate, with about 15 narrow, rounded costellae per 5 mm. at distance of 5 mm. from beak. Costellae increase by bifurcation and intercalation.

Pedicle valve: Strongly convex. Interior with median septum extending one-half to two-thirds distance to anterior margin. Cardinal process bilobed, directed posteriorly. Interior shows impress of costellae.

Dimensions:

Specimen	Length	Width	Convexity
1 Don	8 mm.	10 mm.	2 mm.
2	9	12	—
3	8	13	2
4	8	10	2
5	10	14	2

OCCURRENCE: Onondaga Limestone — P20, Palmerton, Carbon Co., Pa.; P22, West Bowmans, Carbon Co., Pa.

EODEVONARIA sp.

Pl. 17, fig. 9-18

Shell medium to small in size, strongly concavo-convex. Anterior commissure, rectimarginate. Outline subcircular to transversely suboval, with greatest width slightly anterior to hinge line. Length to width ratio about 0.70. Hinge strophic, denticulate along entire length. Cardinal angles generally subrounded. External surface finely costellate, with 15 to 20 narrow, rounded costellae per 5 mm. at distance of 5 mm. from beak. Costellae increase mainly by intercalation, but also by bifurcation.

Pedicle valve: Strongly convex. Interarea low, orthocline, with triangular delthyrium that is partly covered by a strongly convex pseudodeltidium.

Interior not observed.

Brachial valve: Concave. Interarea linear. Shell substance thinner than pedicle valve.

Interior with discontinuous median septum that extends beyond mid-length. Socket ridges strong, long, diverge from hinge at angle of about 45°.

Dimensions:

Specimen	Length	Width	L/W	Convexity
1 Dn	9 mm.	14 mm.	0.65	5 mm.
2	11	15	0.73	5
3	9	13	0.69	4
4	9	14	0.64	5
5	10	15	0.62	—
6	11	15	0.73	—

OCCURRENCE: Needmore Formation (calcareous shale member) — P31, Selinsgrove Junction, Northumberland Co., Pa.; P35, Lewisburg, Union Co., Pa.; P36, Montoursville, Lycoming Co., Pa.; P60, Curtin Gap, Centre Co., Pa.

Suborder PRODUCTIDINA

Superfamily STROPHALOSIACEA

Family STROPHALOSIIDAE

Subfamily HETERALOSIINAE

Genus TRUNCALOSIA Imbrie

TRUNCALOSIA TRUNCATA (Hall)

Pl. 17, fig. 19

Strophomena pustulosa Hall, 1843, p. 189, fig. 4.

Productus truncatus Hall, 1857, p. 171.

Productella truncata Hall, 1867, pp. 160-162, pl. 23, fig. 12-24.

Strophalosia truncata Hall and Clarke, 1892, pl. 15B, fig. 24-26; pl. 17, fig. 10-15. — Kindle, 1912, p. 77, pl. 5, fig. 5-7. — Prosser, in Prosser, Kindle, and Swartz, 1913, pp. 160-162, pl. 13, fig. 14-16.

Productella truncata Cooper, in Shimer and Shrock, 1944, p. 347, pl. 135, fig. 21-23.

Truncalosia truncata Imbrie, 1959, p. 401.

Shell small, concavo-convex. Outline semi-circular. Length to width ratio about 1.0, with greatest width at hinge line. Hinge strophic.

Pedicle valve: Convex. Beak abruptly truncated by large cicatrix of attachment. Surface bearing about 30 prominent pustules (spine bases). Concentric ornament of very fine, closely-spaced growth lines.

Brachial valve: Not observed.

Dimensions:

Specimen	Length	Width
1 Dns	4 mm.	4 mm.
2	4	3

OCCURRENCE: Needmore Formation (Selinsgrove Limestone Member) — P43, Old Port, Juniata Co., Pa.

Order RHYNCHONELLIDA

Superfamily RHYNCHONELLACEA

Family TRIGONIRHYNCHIIDAE

Genus CUPULAROSTRUM Sartenaer

CUPULAROSTRUM TETHYS (Billings)

Pl. 18, fig. 1-3

Rhynchonella tethys Billings, 1860, p. 270.

Camarotoechia tethys Hall and Clarke, 1894, pl. 57, fig. 1, 2.

Shell medium sized, biconvex, gibbous. Anterior profile flat, with a pugnaceous aspect. Outline ovate-subtrigonal. Length to width ratio about 1.0. Hinge non-strophic. Surface with strong, angular to rounded, non-bifurcating plications; interspaces rounded and somewhat wider than plications.

Pedicle valve: Convex, depressed in the posterior but gibbous toward the anterior. A broad, flat sulcus becomes apparent about one-quarter distance from beak to anterior margin and is abruptly turned up in front. Sulcus bears 5 simple plications.

Brachial valve: Not observed.

Dimensions:

Specimen	Length	Width	Convexity
1 Don	11 mm.	11 mm.	10 mm.
2	6	8	---
3	—	20	---

OCCURRENCE: Onondaga Limestone (Edgecliff Member) — Y9, Hannacroix, Greene Co., N.Y. (Moorehouse Member) — Y5, Schoharie, Schoharie Co., N.Y. (Echo Lake Member) — P1, Echo Lake, Monroe Co., N.Y.

REMARKS: This species is assigned to Cupulorostrum rather than Camarotoechia, because it lacks the bifurcating costae characteristic of the latter.

Family CAMAROTOECHIIDAE

Subfamily CAMAROTOECHIINAE

Genus LEIORHYNCHUS (Hall)

LEIORHYNCHUS LIMITARE (Vanuxem)

Pl. 18, fig. 4

Orthis limitaris Vanuxem, 1842, p. 146, fig. 3.

Leiorhynchus limitaris Hall, 1860, p. 85. — Hall, 1867, p. 356, pl. 56, fig. 6-21.

Liorhynchus limitaris Hall and Clarke, 1894, pl. 59, fig. 1-5.

Leiorhynchus limitare Schuchert, 1897, p. 237. — Cooper, in Shimer and Shrock, 1944, p. 313, pl. 119, fig. 42.

Shell small, biconvex (crushed flat in shales). Outline subcircular, with greatest width at mid-length. Length to width ratio about 1:1. Hinge non-strophic. Surface plicate. Plications low, subangular, separated by narrower interspaces; number about 20 on average specimens; increase by bifurcation; become obsolete on beak. Faint growth lines present on some specimens.

Pedicle valve: Convex, with shallow sulcus which appears to bear about 6 plications. Interior with median septum which extends about one-third distance to anterior margin. (Valves invariably crushed in shales.)

Brachial valve: Convex, with median fold which appears to bear 6 to 7 plications. (Valves crushed in shales.)

Dimensions:

Specimen	Length	Width
1 Dm	7 mm.	7 mm.
2	7	7
3	9	9

OCCURRENCE: Marcellus Formation — P29, Swatara Gap, Lebanon Co., Pa.; P31, Selinsgrove Junction, Northumberland Co., Pa.

REMARKS: L. limitare is the most common brachiopod occurring in the Marcellus black shales. Although its presence is noted at only two localities, the species is probably ubiquitous in the Marcellus.

LEIORHYNCHUS MULTICOSTUM Hall

Pl. 18, fig. 5

Leiorhynchus multicosta Hall, 1860, p. 85, fig. 14, 15. — Hall, 1867, pp. 358-360, pl. 56, fig. 26-40.

Liorhynchus multicosta Hall and Clarke, 1894, pl. 59, fig. 8-10.

Leiorhynchus multicostum Cooper, in Shimer and Shrock, 1944, p. 313, pl. 119, fig. 8-9.

Shell medium in size, biconvex. Outline subtrigonal to subcircular. Length to width ratio 1:1. Cardinal angles rounded. Hinge non-strophic. Plications low, rounded, separated by narrower interspaces; increase by bifurcation; number about 25 to 30 on mature specimen. Eight plications per 10 mm. at distance of 15 mm. from beak; become obsolete on beak.

Pedicle valve: Convex, with very shallow sulcus which bears 6 or 7 plications. Beak rather strongly incurved.

Brachial valve: Not observed.

Dimensions: Length 18 mm., width 20 mm.

OCCURRENCE: Marcellus Formation (Cherry Valley Limestone Member) — Y4, Cherry Valley, Otsego Co., N.Y.

Order SPIRIFERIDA

Suborder ATRYPIDINA

Superfamily ATRYPACEA

Family ATRYPIDAE

Subfamily ATRYPINAE

Genus ATRYPA Dalman

ATRYPA RETICULARIS (Linnaeus)

Pl. 18, fig. 6-10

Anomia reticularis Linnaeus, 1767, p. 1132.

Atrypa reticularis Hall, 1852, p. 72, pl. 23, fig. 8; p. 270, pl. 55, fig. 5. — Hall, 1867, pp. 316-321, pl. 52, fig. 1-3, 7-12; pl. 53, fig. 3-19; pl. 53A, fig. 22, 23. — Kindle, 1912, p. 80, pl. 5, fig. 24, 25. — Prosser, in Prosser, Kindle, and Swartz, 1913, pp. 183-185, pl. 16, fig. 4-6.

Shell medium in size, unequally biconvex or convexi-plane.

Outline subcircular, with greatest width at about mid-length. Length to width ratio generally about 1.0. Hinge non-strophic. Cardinal angles rounded. Surface ornament of numerous, low, rounded costae that increase toward anterior margin by bifurcation and intercalation. Costae number 10 to 12 per 10 mm. at distance of 15 mm. from beak. Frill-like growth lines are prominent, especially on anterior portion of valves. Intersecting costae and growth lines form distinctive reticulate pattern.

Pedicle valve: Repressed convex, except for umbonal region which is more strongly convex. Shallow sulcus at anterior commissure extends less than half the distance to beak. Beak elevated, incurved.

Brachial valve: Strongly convex (gibbous). Uniplicate commissure is generally present, but valve lacks actual fold.

Dimensions:

Specimen	Length	Width	Convexity
1 Don	16 mm.	14 mm.	8 mm.
2	15	15	7
3	24	27	13
4 Ds	30	26	18
5	30	32	23
6	30	30	21

OCCURRENCE: Schoharie Formation (Saugerties Member) — Y11, Leeds, Greene Co., N.Y.; Y17, Kingston, Ulster Co., N.Y. (Saugerties-Aquetuck members, undivided) — Y21, Trilobite Mountain, Orange Co., N.Y. Onondaga Limestone (Edgecliff Member) —

P1, Echo Lake, Monroe Co., Pa. (Member B) — P11, East Stroudsburg, Monroe Co., Pa. (Member C) — P1, Echo Lake, Monroe Co., Pa. (Moorehouse Member) — Y15, Saugerties, Ulster Co., N.Y. Onondaga Limestone — P26, Schuylkill Haven, Schuylkill Co., Pa.; P27, Auburn, Schuylkill Co., Pa.; P28, Moyers, Schuylkill Co., Pa.; P29, Swatara Gap, Lebanon Co., Pa. Needmore Formation (calcareous shale member) — P30, Dalmatia, Northumberland Co., Pa. (Selinsgrove Limestone Member) — P30, Dalmatia, Northumberland Co., Pa. (Calcitic shale and limestone subfacies) — P63, Warfordsburg, Fulton Co., Pa.; M2, Flintstone, Allegany Co., Md. Jeffersonville Limestone (Brevispirifer gregarius zone) — K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

Genus SPINATRYPA Stainbrook

SPINATRYPA SPINOSA (Hall)

Pl. 18, fig. 11-13

Atrypa spinosa Hall, 1843, p. 200, fig. 1, 2. — Hall, 1867, pp. 322-325, pl. 53A, fig. 1-14, 18, 24, 25. — Hall and Clarke, 1894, pl. 55, fig. 21, 22. — Cooper, in Shimer and Shrock, 1944, p. 319, pl. 121, fig. 4, 5.

Shell medium in size, unequally biconvex with brachial valve more convex. Anterior commissure gently uniplicate, but valves lack fold and sulcus. Outline subcircular. Length to width ratio about 1.0. Greatest width slightly less than one-half distance from posterior to anterior margin. Hinge non-strophic. Cardinal extremeties rounded.

Surface costate, with 8 costae per 10 mm. at anterior margin. Costae rounded, separated by shallow interspaces of about same width, rarely bifurcating, obsolete on extreme lateral flanks. Concentric ornament of growth lamellae that are spaced about 1 mm. apart near anterior margin. Intersection of costae and concentric lamellae marked by distinctly elevated nodes. (Nodes are produced as spines in perfectly preserved specimens.)

Pedicle valve: Repressed convex, with flattened lateral margins. Beak abruptly rounded.

Brachial valve: Convex. Beak incurved, concealed by apex of opposite valve.

Dimensions: Length 20 mm., width 20 mm., convexity 8 mm.

OCCURRENCE: Onondaga Limestone (Moorehouse Member) — Y1, Stafford, Genesee Co., N.Y.; Y5, Schoharie, Schoharie Co., N.Y.

Superfamily DAYIACEA

Family ANOPLOTHECIDAE

Subfamily COELOSPIRINAE

Genus COELOSPIRA Hall

COELOSPIRA CAMILLA Hall

Pl. 19, fig. 1-10

Coelospira camilla Hall, 1867, p. 329, pl. 52, fig. 13-19.

Anoplotheca camilla Kindle, in Prosser, Kindle, and Swartz, 1913, p. 209, pl. 20, fig. 24.

Coelospira camilla Boucot and Johnson, 1968, p. B13, pl. 4, fig. 1-25.

Shell small, weakly biconvex to concavo-convex with a shallow median depression on the brachial valve. Outline transversely suboval. Length to width ratio about 1.0, with maximum width somewhat posterior to mid-length. Hinge non-strophic. Ornament of low, rounded, non-bifurcating costae, 9 to 12 per valve, with U-shaped interspaces that are equal to or wider than costae. Concentric growth lines are prominent on anterior portion of valves.

Pedicle valve: More convex of two valves. Commonly the median two costae are slightly larger than the lateral costae.

Brachial valve: Convex, but with a shallow sulcus that broadens strongly anteriorly and renders larger specimens apparently concave. Bears median costa that is somewhat flattened anteriorly and is bounded by two short costae that originate slightly anterior to beak.

Interior with small, U-shaped sockets that are bounded posteriorly by edge of valve and medianly and anteriorly by massive socket plates. Socket plates are joined posteriorly to thick, low cardinal process, forming massive, triangular structure with apex pointed posteriorly. A low myophragm extends from cardinal process anteriorly along floor of valve to about mid-length.

Dimensions:

Specimen	Length	Width	Convexity
1 Dscc	6 mm.	10 mm.	2 mm.
2 Dn	8	8	1
3	2	2	--
4 Don	10	10	2
5	10	8	2

OCCURRENCE: Schoharie Formation (Carlisle Center Member) — Y11, Leeds, Greene Co., N.Y. Onondaga Limestone — P29, Schuylkill Haven, Schuylkill Co., Pa. Needmore Formation (calcareous shale member) — P35, Lewisburg, Union Co., Pa.

Family LEPTOCOELIIDAE

Genus LEPTOCOELIA Hall

LEPTOCOELIA FLABELLITES (Conrad)

Pl. 19, fig. 11, 12

Atrypa flabellites Conrad, 1841, p. 55.

Leptocoelia flabellites Hall, 1859, pp. 449-450, pl. 103B, fig. 1a-1f; pl. 106, fig. 1a-1f. — Hall and Clarke, 1894, pl. 53, fig. 40-46, 53. — Boucot, 1959, p. 741, pl. 91, fig. 1-6.

Shell medium in size, unequally biconvex. Anterior commissure, uniplicate and crenulate. Outline semi-circular to transversely subtrigonal with greatest width slightly posterior to mid-length. Length to width ratio averages 0.80. Hinge non-strophic. Cardinal angles rounded. External surface plicate, with about 10 to 12 simple, sub-angular plications on each valve. Concentric ornament of strong growth lamellae that are most prominent near anterior commissure.

Pedicle valve: Evenly convex, with narrow median sulcus that consists of a depressed plication and flanking interspaces. Lateral flanks each bear about 5 plications.

Interior with strong hinge teeth that diverge at angle of about 45° and prominent, flabellate diductor muscle scars that extend about one-half length of valve.

Brachial valve: Repressed convex, lateral and anterior portions nearly flat, with median fold that consists of two elevated plications near anterior commissure.

Interior with triangular cardinal process. Median septum extends half distance to anterior, dividing adductor field and merging posteriorly with cardinal process.

Dimensions:

Specimen	Length	Width	
1 De	13 mm.	15 mm.	Pedicle
2 Dse	11	14	"
3	12	15,	Brachial
4	12	17	"
5	10	12	"

OCCURRENCE: Esopus Formation (Highland Mills Member) — Y25, Highland Mills, Orange Co., N.Y. Schoharie-Esopus formations, undivided — P24, Stony Mountain School, Carbon Co., Pa.

Genus LEPTOCOELINA Johnson

LEPTOCOELINA ACUTIPLICATA (Conrad)

Pl. 20, fig. 1-12

Atrypa acutiplicata Conrad, 1841, p. 54. — Hall, 1862, pl. 11, fig. 17.

Leptocoelia acutiplicata Hall, 1867, p. 365, pl. 57, fig. 30-39.

Anoplotheca (Coelospira) acutiplicata Hall and Clarke, 1893, p. 136, pl. 53, fig. 32-39. — Prosser and Kindle, in Prosser, Kindle, and Swartz, 1913, pp. 207-209, pl. 20, fig. 16-23.

Anoplotheca acutiplicata Schuchert, 1897, p. 144. — Kindle, 1912, p. 84, pl. 6, fig. 1-15.

Shell generally medium in size, biconvex, usually episulcate in anterior profile. Outline subcircular to transversely suboval with greatest width at mid-length. Length to width ratio varies between 0.8 and 1.0. Hinge non-strophic. Cardinal angles rounded. External ornament consists of a few low, rounded plications that are separated by U-shaped interspaces of about the same width as plications. Radial ornament of prominent, imbricate growth lamellae that occur at regular intervals.

Pedicle valve: Convex, with broad, deep sulcus that first becomes distinct 3 to 5 mm. from beak and flares widely toward anterior. A low plication generally bisects the sulcus. Most prominent plications border sulcus. Three or four plications occur on lateral slopes; these are well-defined on posterior portion of valve but broaden and become subdued toward anterior. Pedicle opening, very small, lies near hinge line and is apparently subapical.

Interior with triangular hinge teeth that lack dental lamellae and are attached directly to posterior portion of valve. Muscle scars moderately to deeply impressed. Diductor scars of moderate size, flabellate, enclosing small, oval, deeply impressed adductors. Thin median septum separates adductor scars. Interior faintly crenulate by impress of plications.

Brachial valve: Convex, with median fold formed by two median plications with narrow interspace. Fold first becomes distinct 3 to 5 mm. from beak and then becomes distinctly raised anteriorly. Lateral slopes, with three to five low, rounded plications that are well-defined posteriorly but subdued anteriorly.

Interior with a sharp-crested, rather broad median septum that extends anteriorly to about mid-length and thickens posteriorly to fill notothyrial cavity. Cardinal process simple, knob-like. Interior is faintly crenulated by impress of plications.

Dimensions:

Specimen	Length	Width	Convexity
1 Dn	20 mm.	20 mm.	8 mm.
2	12	15	6
3	12	14	3
4	11	12	3
5	17	20	7
6	11	12	5
7	12	16	4
8	14	17	7
9	13	15	6
10	11	11	3

OCCURRENCE: Esopus Formation — P7, Buttermilk Falls, Monroe Co., Pa. Schoharie Formation (Carlisle Center Member) — Y17, Kingston, Ulster Co., N.Y.; P7, Buttermilk Falls, Monroe Co., Pa. Onondaga Limestone — P22, West Bowmans, Carbon Co., Pa. Needmore Formation (Beaverdam Run Member) — P35, Lewisburg, Union Co., Pa. (Beaverdam Run subfacies) — M3, LaVale, Allegany Co., Md. (Calcareous shale member) — P30, Dalmatia, Northumberland Co., Pa.; P31, Selinsgrove Junction, Northumberland Co., Pa.; P33, Danville, Montour Co., Pa.; P35, Lewisburg, Union Co., Pa.; P36, Montoursville, Lycoming Co., Pa.; P41, Mt. Pleasant Mills, Snyder Co., Pa.; P42, Thompsontown, Juniata Co., Pa.; P43, Old Port, Juniata Co., Pa.; P52, Newton Hamilton, Mifflin Co., Pa.; P60, Curtin Gap, Centre Co., Pa.; P61, Tyrone, Blair Co., Pa. (Calcitic shale subfacies) — M2, Flintstone, Allegany Co., Md. (Selinsgrove Limestone Member) — P58, Orbisonia, Huntingdon Co., Pa.; P42, Thompsontown, Juniata Co., Pa.; P52, Newton Hamilton, Mifflin Co., Pa. (Calcitic shale and limestone subfacies) — P63, Warfordsburg, Fulton Co., Pa.

REMARKS: The writer follows Johnson (1970) in assigning this species to Leptocoelina.

Suborder ATHYRIDIDINA

Superfamily ATHYRIDACEA

Family MERISTELLIDAE

Subfamily MERISTELLINAE

Genus MERISTELLA Hall

MERISTELLA cf. M. LATA (Hall)

Pl. 21, fig. 1-3

Merista lata Hall, 1859b, p. 431, pl. 101, fig. 3a-3m (1861).

Meristella lata Hall and Clarke, 1894, pl. 44, fig. 12. — Schuchert, in Schuchert, Swartz, Maynard and Rowe, 1913, pp. 445-446, pl. 74, fig. 9-11.

Shell small to medium size, unequally biconvex, uniplicate in anterior profile. Outline transversely-subrhomboidal. Length to width ratio 0.70 to 0.75, with greatest width somewhat anterior to mid-length. Hinge non-strophic. Surface smooth except for concentric growth lamellae which are more conspicuous near the anterior commissure. (Exfoliated shells show very fine radial striae.)

Pedicle valve: Convex, with shallow sulcus that arises about mid-length and extends to front. Beak incurved.

Interior with strong, deeply impressed, longitudinally striate muscle scar and pitted flanks.

Brachial valve: Convex, somewhat more so than pedicle valve, with low fold on anterior portion.

Interior shows median septum that extends at least one-quarter distance to anterior margin.

Dimensions:

Specimen	Length	Width	Convexity	
1 Ds	20 mm.	28 mm.	9 mm.	Articulated
2	15	20	—	Pedicle

OCCURRENCE: Shriver Chert — P35 (float), Lewisburg, Union Co., Pa.

REMARKS: These specimens resemble Meristella lata from the Oriskany Sandstone (and Ridgeley Sandstone), Albany and Schoharie counties, N.Y., and Cumberland, Md., as illustrated by Hall (1861). Specimens from Warren Point, Franklin Co., Pa., pictured in Schuchert and others (1913) have a more carinate brachial valve and a longer, narrower pedicle sulcus.

Genus MERISTINA Hall

MERISTINA NASUTA (Conrad)

Pl. 21, fig. 4

Atrypa nasuta Conrad, 1842, p. 265.

Meristella nasuta Hall, 1860, p. 93, fig. 8, 9. — Hall, 1867, p. 229-302, pl. 48, fig. 1-25. — Hall and Clarke, 1894, pl. 43, fig. 18-20; pl. 44, fig. 13, 14, 19-22, 24-26. — Kindle, 1912, p. 85, pl. 7, fig. 7. — Boucot, 1959, pp. 746-747, pl. 94, fig. 5-8, 12.

Meristina nasuta Boucot and Johnson, 1968, pp. B13-B14, pl. 4, fig. 26-43.

Shell large, unequally biconvex. Outline subtriangular to subrhomboidal, with greatest width about two-thirds distance from beak to anterior margin. Length to width ratio is about 1.0. Hinge non-strophic. External ornament, not observed.

Pedicle valve: Highly convex, with greatest convexity at mid-length, sloping abruptly to the sides. Beak prominent, incurved.

Interior with strong, triangular, longitudinally-striate muscle field which extends about two-thirds distance to anterior margin. Muscle field is about 13 mm. long, 8 mm. wide. Dental plates obscure, but appear to be short and restricted to apex of valve: Cast of pedicle cavity is prominent.

Brachial valve: Not observed.

Dimensions: Length about 35 mm., width about 35 mm.

OCCURRENCE: Schoharie-Esopus formations, undivided — P23, Germans, Carbon Co., Pa.

Genus PENTAGONIA Cozzens

PENTAGONIA UNISULCATA (Conrad)

Pl. 21, fig. 5-10

Atrypa unisulcata Conrad, 1841, p. 56.

Meristella (Pentagonia) unisulcata Hall, 1867, pp. 309-311, pl. 50, fig. 18-35.

Pentagonia unisulcata Hall and Clarke, 1895, pl. 42, fig. 22-32. — Cooper, in Shimer and Shrock, 1944, p. 333, pl. 127, fig. 37. — Boucot, 1959, pp. 748-749, pl. 94, fig. 9, 10.

Shell medium to large in size, biconvex, uniplicate in anterior profile. Outline pentagonal. Length to width ratio about 0.80, with greatest width anterior to mid-length. Hinge non-strophic. Surface generally smooth, but one specimen shows distinct growth lines. (This specimen is also distinctly mucronate.)

Pedicle valve: Moderately convex, with broad sulcus which occupies nearly entire width of valve. Lateral slopes abrupt, separated from sulcus by angular ridges.

Brachial valve: Convex, with broad, rounded fold that has a median groove in some specimens.

Dimensions:

Specimen	Length	Width	
1 Don	20 mm.	25 mm.	
2	20	25	
3	20	25	
4	22	25	
5	12	20	(mucronate)

OCCURRENCE: Onondaga Limestone — P28, Moyers, Schuylkill Co., Pa.

Family ATHYRIDIDAE

Subfamily ATHYRIDINAE

Genus ATHYRIS M'Coy

ATHYRIS SPIRIFEROIDES (Eaton)

No fig.

Terebratula spiriferoides Eaton, 1831, p. 137.

Spirifera spiriferoides Hall, 1857, p. 153, fig. 1, 2.

Athyris spiriferoides Hall, 1867, p. 285, pl. 46, fig. 5-31. — Prosser and Kindle, in Prosser, Kindle, and Swartz, 1913, pp. 211-212, pl. 21, fig. 1, 2.

Shell small, biconvex. Outline subovate with rounded cardinal extremities. Length to width ratio about 1.0, with greatest width anterior of hinge line. Hinge relatively short, non-strophic. Surface of valves with concentric growth lines that are more closely imbricated toward anterior. Costae absent.

Pedicle valve: Moderately convex, with gibbous umbo and incurved beak.

Brachial valve: Somewhat more convex than pedicle valve, with a more gibbous umbo.

Dimensions:

Specimen	Length	Width
1 Don	9 mm.	10 mm.
2	8	9

OCCURRENCE: Onondaga Limestone — P27, Auburn, Schuylkill Co., Pa.

REMARKS: The above description is based on a few, small, young individuals collected from the lower Onondaga. No mature specimens were found anywhere in the study area.

Suborder SPIRIFERIDINA

Superfamily CYRTIACEA

Family AMBOCOELIIDAE

Genus AMBOCOELIA Hall

AMBOCOELIA UMBONATA (Conrad)

Pl. 22, fig. 1, 2

Orthis umbonata Conrad, 1842, p. 264.

Ambocoelia umbonata Hall, 1860, p. 71. — Hall, 1867, pp. 259-260, pl. 44, fig. 7-18. — Hall and Clarke, 1893, pl. 29, fig. 17; pl. 39, fig. 4-9. — Kindle, 1912, p. 83. — Prosser and Kindle, in Prosser, Kindle, and Swartz, 1913, p. 200, pl. 20, fig. 1, 2. — Cooper, in Shimer and Shrock, 1944, p. 329, pl. 126, fig. 21-26.

Shell small, plano-convex to unequally biconvex. Sub-rhombic in lateral profile. Length to width ratio varies between 0.6 and 1.0, with greatest width at, or slightly anterior to, hinge line. Hinge strophic. Cardinal angles abruptly rounded.

Pedicle valve: Strongly convex, with prominent sulcus extending from beak to anterior margin. Sulcus one-fourth of valve width at anterior margin. Beak prominent, incurved, extending back about one-fourth of total valve length. Interarea high, arched. Lateral slopes and sulci of most specimens appear bald, but some have faint radial and concentric striations.

Brachial valve: Generally plane, with no fold. Some valves show slight concavity at anterior margin and slight convexity from mid-length to hinge line. Finely striate radial ornament. Concentric ornament consists of coarse rugae, numbering four or five.

Dimensions: Length 6-10 mm., width 7-12 mm., convexity 5-7 mm.

OCCURRENCE: Needmore Formation (calcareous shale member) — P30, Dalmatia, Northumberland Co., Pa.; P35, Lewisburg, Union

Co., Pa.; P42, Thompsontown, Juniata Co., Pa.; P43, Old Port, Juniata Co., Pa.; P45, East Waterford, Juniata Co., Pa.; P58, Orbisonia, Huntingdon Co., Pa.; P60, Curtin Gap, Centre Co., Pa.; P62, Eichelbergertown, Bedford Co., Pa. (Calcitic shale subfacies) — P63, Warfordsburg, Fulton Co., Pa.; P64, Warren Point, Franklin Co., Pa.; V1, Gainesboro, Frederick Co., Pa. (Selinsgrove Limestone Member) — P30, Dalmatia, Northumberland Co., Pa.; P31, Selinsgrove Junction, Northumberland Co., Pa.; P42, Thompsontown, Juniata Co., Pa.; P43, Old Port, Juniata Co., Pa.; P45, East Waterford, Juniata Co., Pa.; P49, Alinda, Perry Co., Pa.; P52, Newton Hamilton, Mifflin Co., Pa.; P56, Jackson Corner, Huntingdon Co., Pa.; P58, Orbisonia, Huntingdon Co., Pa.; P62, Eichelbergertown, Bedford Co., Pa. (Calcitic shale and limestone subfacies) — P63, Warfordsburg, Fulton Co., Pa.; P64, Warren Point, Franklin Co., Pa.; M2, Flintstone, Allegany Co., Md.; M4, Corriganville, Allegany Co., Md.

Superfamily SUESSIACEA

Family CYRTINIDAE

Genus CYRTINAELLA Frederiks

CYRTINAELLA BIPLICATA (Hall)

Pl. 22, fig. 3, 4

Cyrtia biplicata Hall, 1857, p. 165.

Cyrtina biplicata Hall, 1867, pp. 266-267, pl. 27, fig. 5-10.

Cyrtinaella biplicata Pitrat, 1965, p. H678, pl. 549, fig. 2a-c. — Boucot and Johnson, 1968, p. B18, pl. 7, fig. 11-17.

Shell medium sized, biconvex, parasulcate in anterior profile. Outline subquadrangular, with greatest width at hinge line. Length to width ratio about 1.0. Hinge strophic. Surface very gently plicate. No radial or concentric ornament observed. Shell structure endopunctate.

Pedicle valve: Convex, with a broad, deep sulcus that begins at the beak and broadens strongly toward anterior margin. Sulcus bounded by two strong plications. Lateral slopes generally smooth, but with a few obsolescent plications apparent at the anterior margin. Beak strongly elevated, slightly incurved. Interarea apsacline, high, nearly flat, with a narrow, triangular delthyrium that is partially closed by a convex pseudodeltidium.

Brachial valve: Convex, with a high, sharp fold, bounded by a pair of vague, narrow lateral furrows. Lateral slopes smooth, but with a few obsolescent plications. Interarea anacline, narrow.

Dimensions: Length 23 mm., width 25 mm., convexity 13 mm.

OCCURRENCE: Onondaga Limestone (Edgecliff Member) — Y9, Hannacroix, Greene Co., N.Y.

REMARKS: The single specimen of C. biplicata in the material collected for this study differs from the norm in possessing a few vague plications on the lateral slopes of both pedicle and brachial valve. In external form, the specimen approaches Cyrtina hamiltonensis, which is distinctly plicate.

Superfamily SPIRIFERACEA

Family DELTHYRIDIDAE

Subfamily ACROSPIRIFERINAE

Genus ACROSPIRIFER Helmbrecht and Wedekind

ACROSPIRIFER MURCHISONI (Castelnau)

Pl. 22, fig. 5-9

Spirifer murchisoni Castelnau, 1843, p. 41, pl. 12, fig. 1, 2.

Spirifer arrectus Hall, 1859, pp. 422-425, pl. 97, fig. 1a-1h, 2a-2i.

Spirifer murchisoni Schuchert, 1897, p. 398. — Clarke, 1900, pp. 46-48, pl. 6, fig. 26-30. — Schuchert, in Schuchert, Swartz, Maynard, and Rowe, 1913, pp. 411-413, pl. 70, fig. 1-5.

Acrospirifer murchisoni Cooper, in Shimer and Shrock, 1944, p. 325, pl. 123, fig. 15, 16.

Hysterolites (Acrospirifer) murchisoni Amsten and Ventress, 1963, pp. 105-111, pl. 6, fig. 1-18; text fig. 33, 34.

Shell medium to large in size, biconvex, with distinct ventral sulcus and dorsal fold. Anterior commissure uniplicate and crenulate. Outline transversely subelliptical with greatest width at hinge line. Length to width ratio about 0.55. Hinge strophic. Cardinal angles acute to subrounded. Surface plicate, with 6 to 9 strong, subangular plications on lateral slopes. Concentric ornament of delicate growth lamellae crossing the plications. Each lamella bears a row of very fine granules. Growth lamellae are more strongly expressed anteriorly.

Pedicle valve: Strongly convex, with narrow, deep sulcus that extends from beak to anterior margin. Beak elevated, incurved over interarea. Interarea moderately broad, triangular, apsacline, longitudinally striate, extends to extremities.

Interior, with short dental plates that bound posterior part of muscle area. Plates are nearly perpendicular to hinge line in specimens with narrow muscle field, but diverge in those with broader muscle field. Diductor scars large, bilobed, rather narrow in some specimens, but generally broad, longitudinally striate.

Brachial valve: Convex, with elevated, narrow fold that extends from beak to anterior margin and is higher anteriorly. Beak incurved over low, anacline interarea.

Dimensions:

Specimen	Length	Width	Convexity
1 Ds	22 mm.	33 mm.	13 mm.
2	17	32	13
3	18	34	—
4	22	40	—

OCCURRENCE: Shriver Chert — P35 (float), Lewisburg, Union Co., Pa.; P36A, Montoursville, Lycoming Co., Pa. Ridgeley Sandstone —

P36A, Montoursville, Lycoming Co., Pa.

ACROSPIRIFER DUODENARIA (Hall)

Pl. 23, fig. 1-7

Delthyris duodenaria Hall, 1843, p. 171, fig. 5.

Spirifer duodenaria Hall, 1867, pp. 189-190, pl. 27, fig. 13-16; pl. 28, fig. 24-33.

Acrospirifer duodenaria Boucot and Johnson, 1968, pp. B14-B15, pl. 5, fig. 2-39.

Shell moderately large, biconvex, with prominent fold and sulcus. Outline transversely subtrigonal, with greatest width at hinge line. Length to width ratio varies between 0.4 and 0.5. Hinge strophic. Cardinal angles acute to mucronate. Surface plicate; plications, abruptly rounded, separated by U-shaped interspaces of about same width as plications. Lateral slopes, with 7 to 9 plications. Fold and sulcus bald. Concentric ornament of very closely-spaced, frilly growth lines.

Pedicle valve: Convex, with a broad, smooth sulcus that extends from the beak to the anterior margin; plications bordering the sulcus are somewhat more elevated than those on flanks. Beak elevated, incurved over relatively high, apsacline interarea.

Interior with short, widely divergent dental plates.

Brachial valve: Convex, with a prominent, narrow fold that is strongly elevated anteriorly. Fold bears median groove on crest.

Interior, with slightly divergent socket ridges that are thickened by the attachment of crural bases.

Dimensions:

Specimen	Length	Width	
1 Dse	15 mm.	40 mm.	Pedicle
2	16	25	"
3	16	27	"
4	11	20	Brachial
5	16	30	"
6 Ds	9	22	"
7	12	24	"

OCCURRENCE: Schoharie Formation (Saugerties-Aquetuck members, undivided) — P7, Buttermilk Falls, Monroe Co., Pa. Schoharie-Esopus formations, undivided — P18, Kunkletown, Monroe Co., Pa.; P19, Little Gap, Carbon Co., Pa.; P21, Bowmanstown, Carbon Co., Pa.; P22, West Bowmans, Carbon Co., Pa.; P24, Stony Mountain School, Carbon Co., Pa.

ACROSPIRIFER VARICOSUS (Hall)

Pl. 25, fig. 3-6

Spirifer varicosus Hall, 1857, p. 130.

Spirifera varicosa Hall, 1867, pp. 205-206, pl. 31, fig. 1-4.

Shell medium in size, biconvex, with prominent fold and sulcus. Outline transversely subtrigonal, with greatest width at hinge line. Length to width ratio about 0.60. Hinge strophic. Cardinal angles acute. Surface strongly plicate. Plications narrow, abruptly rounded, separated by narrow interspaces of about same width as plications. Lateral slopes with 7 to 10 plications. Fold and sulcus bald. Concentric ornament of fine, imbricated growth lamellae that give surface a varicose appearance.

Pedicle valve: Convex, with a prominent sulcus that is very narrow on umbo but which broadens toward anterior. Beak elevated, slightly incurved over high, triangular, nearly catacline interarea.

Interior, with short dental plates.

Brachial valve: Convex, with a strongly elevated fold that is flattened on summit. Fold is narrow on umbo but flares markedly toward anterior.

Dimensions:

Specimen	Length	Width	L/W
1 Don	8 mm.	15 mm.	0.53
2	9	13	0.69
3	14	27	0.52

OCCURRENCE: Onondaga Limestone (Echo Lake Member) — P1, Echo Lake, Monroe Co., Pa.; P11, East Stroudsburg, Monroe, Co., Pa.

REMARKS: This species has the short dental plates characteristic of Acrospirifer.

Subfamily KOZLOWSKIELLININAE

Genus KOZLOWSKIELLINA Boucot

Subgenus MEGAKOZLOWSKIELLA Boucot

KOZLOWSKIELLINA (MEGAKOZLOWSKIELLA) RARICOSTA (Conrad)

Pl. 24, fig. 7-12

Delthyris raricosta Conrad, 1842, p. 262, pl. 14, fig. 18.

Spirifera raricosta Hall, 1867, pp. 192-193, pl. 27, fig. 30-34; pl. 30, fig. 1-9.

Kozlowskiellina (Megakozlowskiella) raricosta Boucot and Johnson, 1968, p. B16, pl. 6, fig. 7-15.

Shell medium in size, strongly, but unequally, biconvex. Outline subquadrate to subcircular, with hinge line equal to greatest width. Length to width ratio about 1.0. Hinge strophic. Cardinal angles rounded to slightly mucronate. Surface strongly plicate; lateral slopes with two or three strongly elevated, rounded or angular plications that are separated by rounded, U-shaped interspaces of about same width as plications. Concentric ornament of closely-spaced, imbricate growth lamellae. Numerous fine, radially arranged striae on the growth lamellae give the surface a fimbriate appearance.

Pedicle valve: Strongly convex, with a deep sulcus that extends from beak to anterior margin. Lateral slopes with about three strong plications, the most prominent of which lie next to the sulcus. Beak strongly incurved. Interarea relatively low, apsacline.

Brachial valve: Convex, but not so strongly as pedicle valve, with prominent fold that extends from beak to anterior margin.

Lateral slopes with two or three strong plications.

Dimensions:

Specimen	Length	Width	Convexity
1 Don	15 mm.	16 mm.	12 mm.
2	8	12	—

OCCURRENCE: Onondaga Limestone (Nedrow Member) — Y9, Hannacroix, Greene Co., N.Y. (Moorehouse Member) — Y4, Cherry Valley, Otsego Co., N.Y.; Y6, Berne, Albany Co., N.Y. Onondaga Limestone — P22, West Bowmans, Carbon Co., Pa. Needmore Formation (calcareous shale member) — P31, Selinsgrove Junction, Northumberland Co., Pa.

Subfamily PARASPIRIFERINAE

Genus PARASPIRIFER Wedekind

PARASPIRIFER ACUMINATUS (Conrad)

Pl. 25, fig. 1-7

Delthyris acuminata Conrad, 1839, p. 65.

Spirifer acuminata Hall, 1857, p. 135.

Spirifera acuminata Hall, 1867, pp. 198-202, 234, pl. 29, fig. 9-18; pl. 35, fig. 24.

Spirifer acuminatus Hall and Clarke, 1893, pl. 39, fig. 39-42. — Kindle, 1912, p. 81, pl. 6, fig. 17, 18. — Prosser and Kindle, in Prosser, Kindle, and Swartz, 1913, p. 193, pl. 18, fig. 10.

Paraspirifer acuminatus Cooper, in Shimer and Shrock, 1944, p. 323, pl. 123, fig. 3-5.

Shell large, strongly biconvex (obese). Sharply carinate in anterior profile; greatest convexity equal to valve length. Outline subquadrate, with greatest width about mid-length. Length to width ratio about 0.75. Hinge strophic. Costae broad, low, numbering about 15 on each lateral slope, with superimposed, very fine radial striae. Concentric ornament of fine striations.

Pedicle valve: Convex, with deep, bald sulcus, which is especially pronounced at anterior margin. Sulcus equals 0.4 of valve width at anterior margin. Beak prominent, incurved. Interarea narrow.

Interior, with well-developed dental plates.

Brachial valve: Strongly convex, with sharp, angular, bald fold. Fold 0.40 of valve width at anterior margin. Sides of fold meet lateral slopes at straight angle; flanks slope steeply.

Dimensions:

Specimen	Length	Width	L/W	Convexity
1 Don	30 mm.	41 mm.	0.73	29 mm.
2	35	45	0.78	35

OCCURRENCE: Onondaga Limestone (Moorehouse Member) — Y1, Stafford, Genesee Co., N.Y. (Echo Lake Member) — P13, Stroudsburg, Monroe Co., Pa. Onondaga Limestone — P27, Auburn, Schuylkill Co., Pa.

Family MUCROSPIRIFERIDAE

Genus MUCROSPIRIFER Grabau

MUCROSPIRIFER MACRA (Hall)

Pl. 26, fig. 1-3

Spirifer macra Hall, 1857, p. 134.

Spirifera macra Hall, 1867, p. 190, pl. 27, fig. 17-28.

Spirifer macrus Hall and Clarke, 1894, pl. 34, fig. 1-3. — Schuchert, 1897, p. 396.

"Spirifer" macra Boucot, 1959, p. 745, pl. 93, fig. 1-10.

"Mucrospirifer" cf. macra Boucot and Johnson, 1968, p. 15, pl. 6, fig. 1-6.

Shell biconvex, laterally elongated. Length to width ratio about 0.45, with greatest width along hinge line. Hinge strophic. Flanks of valves bear 10 to 15 moderately strong, rounded plications. Concentric ornament not preserved on most specimens, but some show numerous closely-spaced, imbricate growth lines, spaced 2 or 3 per mm. Intersecting plications and growth lines form finely fluted surface.

Pedicle valve: Strongly convex, with prominent, generally bald, sulcus. (One specimen shows several striations in sulcus.)

Interior, with prominent diductor scars on elevated beak. Pitted, with pits especially noticeable near median plane, and becoming weaker toward lateral extremities.

Brachial valve: Convex, with narrow, considerably elevated, unstriated fold. Width of fold about same as two plications.

Dimensions:

Specimen	Length	Width	L/W
1 Dse	15 mm.	35 mm.	0.45
2	15	30	0.5
3	21	54	0.4

OCCURRENCE: Schoharie-Esopus formations, undivided — P18, Kunkletown, Monroe Co., Pa.; P19, Little Gap, Carbon Co., Pa.; P23, Germans, Carbon Co., Pa.

Genus BREVISPIRIFER Cooper

BREVISPIRIFER GREGARIUS (Clapp)

Pl. 26, fig. 4-6

Spirifer gregaria (Clapp MS) Hall, 1857, p. 127.

Spirifera gregaria Hall, 1867, pp. 195-196, pl. 28, fig. 1-11.

Spirifer gregaria Hall and Clarke, 1894, pl. 29, fig. 7; pl. 37, fig. 11, 12.

Brevispirifer gregarius Cooper, in Shimer and Shrock, 1944, p. 323, pl. 122, fig. 22-26.

Shell medium in size, biconvex. Length to width ratio about 0.80 with maximum width at, or slightly anterior to, hinge line. One specimen is mucronate. Hinge strophic. Moderately carinate in anterior profile; maximum convexity 0.67 shell length. Plications coarse, wide and rounded, numbering 4 to 6 on each lateral slope.

Pedicle valve: Strongly convex, with prominent bald sulcus that extends from anterior margin to beak. Sulcus to valve width ratio at anterior margin varies from 0.30 to 0.45, being greatest in specimen from Needmore Formation, somewhat less in most specimens from Jeffersonville Limestone. Beak prominent, incurved with high arched interarea.

Brachial valve: Moderately convex, with sharp, bald fold, especially prominent at anterior margin. Fold is 0.45 valve width at anterior margin (specimen from Needmore Formation). Flanks of fold are distinctly set off from lateral slopes.

Dimensions: Length 13–17 mm., width 17–20 mm., convexity 10 mm. (one specimen).

OCCURRENCE: Jeffersonville Limestone (*Brevispirifer gregarius* zone) — K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

Family FIMBRISPIRIFERIDAE

Genus FIMBRISPIRIFER Cooper

FIMBRISPIRIFER DIVARICATUS (Hall)

Pl. 27, fig. 1

Spirifer divaricatus Hall, 1857, p. 133. — Hall, 1867, p. 213, pl. 32, fig. 1–9.

Fimbrispirifer divaricatus Cooper, in Shimer and Shrock, 1944, p. 323, pl. 123, fig. 1, 9. — Boucot and Johnson, 1968, pp. B17-B18, pl. 6, fig. 32-37. — Fagerstrom, 1971, pp. 47-48, pl. 5, fig. 1-3.

Shell large, transverse. Length to width ratio about 0.7, with maximum width at, or only slightly anterior to, hinge line. Hinge strophic. Biconvex. Surface entirely costate. Costae relatively numerous, rounded, bifurcating.

Pedicle valve: Convex, with strong, costate sulcus that is broader toward anterior margin of shell.

Brachial valve: Not observed.

Dimensions: Length 25 mm., width 24 mm.

OCCURRENCE: Onondaga Limestone (Edgecliff Member) — Y9, Hannacroix, Greene Co., N.Y.

Family COSTISPIRIFERIDAE

Genus COSTISPIRIFER Cooper

COSTISPIRIFER ARENOSUS (Conrad)

Pl. 27, fig. 2-5

Delthyris arenosa Conrad, 1839, p. 65.

Spirifer arenosus Hall, 1859, pp. 425-427, pl. 98, fig. 1-8; pl. 99, fig. 1-10; pl. 100, fig. 1-8 (1861). — Hall and Clarke, 1894, pl. 29, fig. 1-4; pl. 30, fig. 3-8. — Schuchert, in Schuchert, Swartz, Maynard, and Rowe, 1913, pp. 415-417, pl. 71, fig. 1-9; pl. 72, fig. 1.

Costispirifer arenosus Cooper, in Shimer and Shrock, 1944, p. 323, pl. 122, fig. 27-31. — Amsden and Ventress, 1963, pp. 111-114, pl. 5, fig. 3-11.

Shell large, biconvex, with ventral sulcus and dorsal fold. Outline transversely subtrigonal with greatest width generally at hinge line. Length to width ratio about 0.75. Hinge strophic. Cardinal angles acute to rounded. External surface bears numerous low, broad, rounded costae with somewhat narrower interspaces. Costae number about 30 to 45, occur on fold and sulcus as well as on lateral slopes. No concentric ornament observed.

Pedicle valve: Strongly convex, with shallow, costate sulcus. Costae are simple on lateral slopes, but tend to bifurcate on sulcus. Beak elevated, incurved over rather narrow interarea.

Interior, with large, deeply impressed diductor muscle scars. Impression of costae are visible on internal molds of valves.

Brachial valve: Strongly convex, with low costate fold.

Interior shows impress of costae.

Dimensions: Length 45 mm., width 60 mm.

OCCURRENCE: Ridgeley Sandstone — P36, P36A, Montoursville, Lycoming Co., Pa.; M2, Flintstone, Allegany Co., Md.; M3, LaVale, Allegany Co., Md.

Superfamily RETICULARIACEA

Family ELYTHIDAE

Genus ELITA Frederiks

ELITA FIMBRIATA (Conrad)

Pl. 27, fig. 6, 7

Delthyris fimbriata Conrad, 1842, p. 263.

Spirifera fimbriata Hall, 1867, pp. 214-216, pl. 33, fig. 1-21.

Spirifer fimbriatus Hall and Clarke, 1894, pl. 36, fig. 17-22; pl. 38, fig. 9, 10.

Reticularia fimbriata Schuchert, 1897, p. 342.

Spirifer (Reticularia) fimbriatus Prosser and Kindle, in Prosser, Kindle, and Swartz, 1913, pp. 197-198, pl. 19, fig. 10-12.

Elytha fimbriata Butts, 1941, p. 191, pl. 117, fig. 9-11. — Cooper, in Shimer and Shrock, 1944, p. 327, pl. 126, fig. 1-3.

Elita fimbriata Pitrat, in Williams and others, 1965, p. H722, fig. 588, 4.

Shell medium in size, biconvex, uniplicate in anterior profile. Outline transversely subelliptical with greatest width slightly anterior to hinge line. Length to width ratio about 0.8. Hinge strophic. Cardinal angles rounded. Surface plicate, with 5 or 6 plications on each flank. Growth lamellae are prominent on anterior portion of shell. External micro-ornament of fine, concentrically arranged nodes on growth lamellae. (Nodes mark bases of closely-spaced spines.)

Pedicle valve: Convex, with rather shallow, rounded sulcus that is about 5 mm. wide at anterior margin. Beak incurved over relatively low, apsacline interarea.

Internal mold shows slight impress of plications, as well as fine, radiating striae on both lateral slopes and sulcus. Diductor muscle scars striate, slightly flabellate, extending a little over one-third distance to anterior margin.

Brachial valve: Convex, with fold that is relatively strongly elevated anteriorly but depressed posteriorly. Beak small, incurved over a very low interarea.

Internal mold is strongly impressed by lateral plications, with fine radiating striae on lateral slopes and fold. Adductor muscle scars elongate-ovoid, extending about one-third distance from posterior to anterior margin.

Dimensions: Length 17 mm., width 20 mm., convexity 8 mm.

OCCURRENCE: Onondaga Limestone — P26, Schuylkill Haven, Schuylkill Co., Pa.

Order TEREBRATULIDA

Suborder CENTRONELLIDINA

Superfamily STRINGOCEPHALACEA

Family CENTRONELLIDAE

Subfamily RENSSELAERIINAE

Genus RENSSELAERIA Hall

RENSSELAERIA ELONGATA (Conrad)

Pl. 28, fig. 1-3

Terebratula ovoides Eaton, 1832, p. 45 [not Sowerby, 1812].

Atrypa elongata Conrad, 1839, p. 65.

Rensselaeria ovoides Hall, 1859, p. 456, pl. 104, fig. 1-4; pl. 105, fig. 1-6. — Hall and Clarke, 1894, pl. 75, fig. 6, 8; pl. 76, fig. 16, 18.

Rensselaeria elongata Cloud, 1942, pp. 54, 57-58, pl. 4, fig. 21-24. — Amsden and Ventress, 1963, pp. 129-134, pl. 9, fig. 1-12; text fig. 40A, 40B.

Shell large, unequally biconvex, with rectimarginate anterior commissure. Outline elongate-ovoid, broader in posterior, narrowing toward anterior. Length to width ratio about 2.5. Hinge non-strophic. Surface costellate, with about 12 rounded costellae per 10 mm. at distance of 50 mm. from posterior margin. Concentric ornament consists of a few prominent growth lines.

Pedicle valve: Strongly convex, the greatest elevation being about one-third the distance from the posterior to the anterior margin. Beak small, incurved.

Brachial valve: Convex, but not as strongly as pedicle valve. Postero-central part of valve flattened, descending abruptly posteriorly and laterally and more gently anteriorly.

Interior shows a thick cardinal plate that is supported by two stout crural plates.

Dimensions:

Specimen	Length	Width
1 Dr	70 mm.	29 mm.
2	37	25
3	50	33

OCCURRENCE: Ridgeley Sandstone — P36A, Montoursville, Lycoming Co., Pa.; M3, La Vale, Allegany Co., Md. Limestone of Deerpark age (above Ridgeley Sandstone) — P43, Old Port, Juniata Co., Pa.

REMARKS: Several of the specimens of R. elongata (Conrad) collected for the present study show the very elongate outline typical of R. marylandica Hall. Amsden and Ventress (1963, p. 131) believe that the two forms are conspecific, a usage which is followed here.

Genus AMPHIGENIA Hall

AMPHIGENIA ELONGATA (Vanuxem)

Pl. 28, fig. 4

Pentamerus elongata Vanuxem, 1842, p. 132, fig. 1.

Amphigenia elongata Hall, 1867, pp. 383-384, pl. 58a, fig. 21-24; pl. 59, fig. 1-11. — Hall and Clarke, 1894, pl. 73, fig. 16-20; pl. 74, fig. 1-8. — Boucot, 1959, pp. 762, 764, pl. 100, fig. 8-13; pl. 101, fig. 10. — Boucot and Johnson, 1968, pp. B20-B21, pl. 8, fig. 1-13.

Shell large, biconvex, with rectimarginate anterior commissure. Outline elongate-ovoid, with greatest width at mid-length. Length to width ratio about 1.4. Hinge non-strophic. Surface markings obscure, but a few widely-spaced growth lines present.

Pedicle valve: Strongly convex, with steep lateral slopes and gentler anterior slope. Beak prominent, incurved.

Brachial valve: Not observed.

Dimensions: Length 55 mm., width 40 mm.

OCCURRENCE: Needmore Formation (Selinsgrove Limestone Member) — P43, Old Port, Juniata Co., Pa.

Phylum MOLLUSCA

Class GASTROPODA

Subclass PROSOBRANCHIA

Order ARCHAEOGASTROPODA

Suborder PLEUROTOMARIINA

Superfamily PLEUROTOMARIACEA

Family EOTOMARIIDAE

Subfamily EOTOMARIINAE

Genus BEMBEXIA Oehlert

BEMBEXIA sp.

No fig.

Shell small, sharply turbinate, dextrally coiled, with rapidly expanding whorls. Sutures not sharply impressed. Anomphalous or minutely phaneromphalous. Selenizone narrow, shallow, occurs in lower part of whorl between moderately strong threads. Ornament consists of transverse costae (15-20 per 5 mm.) that are slightly concave toward posterior both above and below selenizone.

Dimensions: Number of whorls 5, spiral angle 50°, height 15 mm., width 10 mm.

OCCURRENCE: Needmore Formation (calcareous shale member) — P52, Newton Hamilton, Mifflin Co., Pa.

Suborder TROCHINA

Superfamily PLATYCERATACEA

Family PLATYCERATIDAE

Genus PLATYCERAS Conrad

Subgenus PLATYCERAS Knight

PLATYCERAS (PLATYCERAS) DUMOSUM Conrad

Pl. 29, fig. 1

Platyceras dumosum Conrad, 1840, p. 205. — Hall, 1879, pp. 14–18, pl. 5, fig. 11–16; pl. 6, fig. 1.

Platyceras (Platyceras) dumosum Knight, in Shimer and Shrock, 1944, p. 473, pl. 193, fig. 15, 16.

Description based on several incomplete specimens.

Shell large, loosely coiled, with rapidly expanding body whorl. Surface has numerous long, stout, hollow spines.

Dimensions: Height 50 mm., width 35 mm.

OCCURRENCE: Onondaga Limestone (Moorehouse Member) — Y6, Berne, Albany Co., N.Y.; Y13, Catskill, Greene Co., N.Y.

REMARKS: In eastern New York, P. (P.) dumosum is present in the Nedrow Member and common in the Moorehouse Member (Oliver, 1956, p. 1468). The species is not known in Pennsylvania, Maryland, and West Virginia, but is reported by Butts (1941, pp. 178-179) from

Washington Co., Va.

Subgenus PLATYSTOMA Knight

PLATYCERAS (PLATYSTOMA) VENTRICOSUM Conrad

Pl. 29, fig. 2-4

Platystoma ventricosum Conrad, 1842, p. 275, pl. 77, fig. 5. — Hall, 1859, p. 300, pl. 55, fig. 9a-9d.

Diaphorastoma ventricosum Clarke, 1900, p. 30, pl. 3, fig. 25-28. — Ohern, in Schuchert, Swartz, Maynard, and Rowe, 1913, p. 482, pl. 87, fig. 1, 2.

Platyceras (Platystoma) ventricosum Knight, in Shimer and Shrock, 1944, p. 473, pl. 193, fig. 3, 4.

Shell relatively large, globose, naticiform, anomphalous to minutely phaneromphalous, dextrally coiled. Spire moderately elevated, consisting of three volutions. Body whorl strongly ventricose, with some exfoliated specimens showing concentric, irregularly spaced rugae. Surface ornament of fine, concentric striae.

Dimensions:

Specimen	No. of Whorls	Length	Height
1 Ds	4	45 mm.	22 mm.
2	4	39	21
3	4	45	22
4 Dr	—	35	29

OCCURRENCE: Shriver Chert — P37, Globe Mills, Snyder Co., Pa.; P41, Mt. Pleasant Mills, Snyder Co., Pa. Ridgeley Sandstone — M3, La Vale, Allegany Co., Md.

PLATYCERAS (PLATYSTOMA) TURBINATUM Hall

Pl. 29, fig. 5-9

Platystoma turbinatum Hall, 1879, pp. 27-28, pl. 9, fig. 12-24.

Platyceras (Platystoma) turbinatum Knight, in Shimer and Shrock, 1944, p. 473, pl. 193, fig. 13, 14.

Shell medium in size, globose, naticiform, dextrally coiled. Spire depressed, only slightly elevated above the outer volution, consisting of about three whorls. Body whorl rapidly expanding. Reticulate surface ornament of fine spiral and concentric striae.

Dimensions:

Specimen	No. of Whorls	Length	Height
1 Don	4	30 mm.	19 mm.
2	4	16	10
3	4	25	18
4 Dn	—	24	16
5 Dns	4	11	—

OCCURRENCE: Onondaga Limestone (Nedrow Member) — Y9, Hannacroix, Greene Co., N.Y.; Y13, Catskill, Greene Co., N.Y. Needmore Formation (calcitic shale subfacies) — V1, Gainesboro, Frederick Co., Va. (Selinsgrove Limestone Member) — P52, P53, Newton Hamilton, Mifflin Co., Pa.

PLATYCERAS (PLATYSTOMA) COCHLEATUM Hall

No fig.

Platystoma turbinata var. cochleatum Hall, 1879, pp. 28-29, pl. 9, fig. 1-11.

Shell medium in size, globose, naticiform, turbinate, dextrally coiled. Spire elevated, consisting of about three whorls. Body whorl rapidly expanding. No surface ornament observed.

Dimensions:

Specimen	No. of Whorls	Length	Height
1 Dn	4 - 5	15 mm.	20 mm.
2	—	13	—
3	—	10	—

OCCURRENCE: Needmore Formation (calcareous shale member) — P52, Newton Hamilton, Mifflin Co., Pa. (Calcitic shale subfacies) — M2, Flintstone, Allegany Co., Md.; V1, Gainesboro, Frederick Co., Va.

REMARKS: Specimens of P. (P.) cochleatum from the Needmore Formation are generally poorly preserved and pyritized. This species differs from P. (P.) turbinatum in its much more elevated spire.

Order CAENOGASTROPODA

Superfamily LOXONEMATACEA

Family PALAEOZYGOPLEURIDAE

Subfamily PALAEOZYGOPLEURINAE

Genus PALAEOZYGOPLEURA Horny

PALAEOZYGOPLEURA HAMILTONIAE (Hall)

Pl. 30, fig. 1-3

Loxonema hamiltoniae Hall, 1862, p. 53. — Hall, 1879, p. 45, pl. 13, fig. 15, 17. — Kindle, 1912, p. 100, pl. 13, fig. 9, 10. — Prosser, Kindle, and Swartz, 1913, pp. 294-295, pl. 36, fig. 16-19. — Knight, in Shimer and Shrock, 1944, p. 461, pl. 186, fig. 16.

Shell small to moderately large, slender, high spired, dextrally coiled. Costate, about 10-12 costae per 5 mm. on outer whorls; costae concave toward anterior, extending posteriorly from upper suture at moderate angle in older whorls and at more acute angle in younger whorls, then bending toward anterior about one-third distance across whorls. Tendency for costae to be obscure on apical whorls.

Dimensions:

Specimen	Length	Width	
1 Don	70 mm.	15 mm.	
2 Dn	30	7	
3	25	9	(incomplete)

OCCURRENCE: Onondaga Limestone (Moorehouse Member) — Y1, Stafford, Genesee Co., N.Y. Needmore Formation (calcareous shale member) — P35, Lewisburg, Union Co., Pa.; P52, Newton Hamilton, Mifflin Co., Pa.; P61, Tyrone, Blair Co., Pa.

REMARKS: This species strongly resembles in external form species assigned to Palaeozygopleura by Linsley (1968).

Class BIVALVIA

Subclass PALEAOTAXODONTA

Order NUCULOIDA

Superfamily NUCULACEA

Family NUCULIDAE

Genus NUCULOIDEA Williams and Breger

NUCULOIDEA sp.

Pl. 30, fig. 4

Shell small, elongate, narrowing somewhat to posterior. Strongly inflated, especially in umbonal region. Length to height ratio varies from 1.3 to 1.6. Surface ornament of fine, closely-spaced, concentric growth lines, some of which are rather strongly elevated.

Dimensions:

Specimen	Length	Height
1 Dn	13 mm.	8 mm.
2	13	8
3	9	7

OCCURRENCE: Needmore Formation (calcareous shale member) — P52, Newton Hamilton, Mifflin Co., Pa.

Subclass CRYPTODONTA

Order PRAECARDIOIDA

Superfamily PRAECARDIACEA

Family PRAECARDIIDAE

Subfamily PRAECARDIINAE

Genus PRAECARDIUM Barrande

PRAECARDIUM cf. PRAECARDIUM MULTIRADIATUM (Hall)

Pl. 30, fig. 5

Panenka multiradiata Hall, 1885, p. 417, pl. 69, fig. 5; pl. 94, fig. 18.

Panenka cf. P. multiradiata Kindle, in Prosser, Kindle, and Swartz, 1913, p. 225, pl. 23, fig. 11.

Shell large. Surface ornament of numerous, flattened costae that occasionally bifurcate and which are separated from each other by somewhat narrower interspaces. Costae are wider on distal portions of shell; number about 6 per 5 mm. on umbo, about 4 per 5 mm. near commissure. A few prominent growth lines are present.

OCCURRENCE: Needmore Formation (calcitic shale subfacies) — M2, Flintstone, Allegany Co., Md.

REMARKS: Description of this species is based on only fragmentary material. The relatively narrow costae suggest P. multiradiatum rather than P. dichotomum, which has broad costae.

Subclass HETERODONTA

Order VENEROIDA

Superfamily LUCINACEA

Family MACTROMYIDAE

Genus PARACYCLAS Hall

PARACYCLAS LIRATA (Conrad)

Pl. 30, fig. 6

Posidonia lirata Conrad, 1838, p. 116, unnumbered plate, fig. 12.

Lucina (Paracyclas) lirata Hall and Whitfield, 1872, p. 200.

Paracyclas lirata Hall, 1885, p. 441, pl. 72, fig. 2-19; pl. 95, fig. 19. — Prosser and Kindle, in Prosser, Kindle, and Swartz, 1913, p. 277, pl. 34, fig. 11-14.

Shell small, subcircular to broadly elliptical in outline, length slightly greater than height. Cardinal line very short. Valves moderately convex. Beak anterior to center, small, rising only slightly above hinge line.

Surface marked by fine concentric striae and by coarse, sharply defined concentric rugae, unevenly spaced and numbering about 12.

Dimensions: Length 14 mm., height 11 mm.

OCCURRENCE: Onondaga Limestone — P27, Auburn, Schuylkill Co., Pa.

Superfamily CRASSITELLACEA

Family CARDINIIDAE

Genus CYPRICARDINIA

CYPRICARDINIA INDENTA (Conrad)

Pl. 30, fig. 7

Cypricardites indenta Conrad, 1842, p. 244, pl. 12, fig. 12.

Cypricardinia indenta Hall, 1870, p. 83. — Hall, 1885, p. 485, pl. 79, fig. 6-16, 23; pl. 96, fig. 2. — Prosser and Kindle, in Prosser, Kindle, and Swartz, 1913, pp. 276-277, pl. 34, fig. 6-10.

Shell small, elongate-subovate in outline. Ventral margin straight, roughly parallel to dorsal margin. Anterior end short, abruptly rounded. Posterior end rounded below and obliquely truncate above. Length to height ratio about 1.5. Beak situated near antero-dorsal extremity.

Surface bears strong, concentric lamellae that number 10 to 12. Lamellae more widely spaced toward posterior and crossed by very fine, radial striae.

Dimensions: Length 14 mm., height 8 mm.

OCCURRENCE: Onondaga Limestone — P26, Schuylkill Haven, Schuylkill Co., Pa.

Class CEPHALOPODA

Subclass NAUTILOIDEA

Order ORTHOCERIDA

Superfamily ORTHOCERATACEA

Family ORTHOCERATIDAE

Subfamily MICHELINOCERATINAE

Genus MICHELINOCERAS Foerste

MICHELINOCERAS SUBULATUM (Hall)

Pl. 30, fig. 8

Orthoceras subulatum Hall, 1843, p. 180, fig. 1. — Hall, 1879, p. 283, pl. 38, fig. 3; pl. 84, fig. 1, 2, 4, 6-10; pl. 86, fig. 1, 2.

Michelinoceras subulatum Shimer and Shrock, 1944, p. 537, pl. 219, fig. 3.

Shell small, orthoconic; chambers, narrow, simple, about 1.25 to 3 mm. in width toward anterior, less toward apex. Siphuncle centrally located.

Dimensions: Length up to about 50 mm., diameter up to about 10 mm.

OCCURRENCE: Needmore Formation (calcareous shale member) — P52, Newton Hamilton, Mifflin Co., Pa. (Calcitic shale subfacies) — M2, Flintstone, Allegany Co., Md.

Subclass AMMONOIDEA

Order AMMONITIDA

Suborder ANARCESTINA

Superfamily ANARCESTACEA

Family AGONIATITIDAE

Subfamily AGONIATITINAE

Genus AGONIATITES Meek

AGONIATITES (?) sp.

Pl. 30, fig. 10

Conch medium in size, advolutely coiled, with deep umbilicus which exposes inner coils. Growth lines fine, very closely spaced, form deep sinus on ventral side and shallow sinus on sides. Sutures not observed. (All specimens occur in shale and are crushed flat.)

Dimensions:

Specimen	Diameter of Conch
1 Dn	30 mm.
2	30
3	35

OCCURRENCE: Needmore Formation (calcareous shale member) — P52, Newton Hamilton, Mifflin Co., Pa.; P61, Tyrone, Blair Co., Pa. (Calcitic shale subfacies) — P63, Warfordsburg, Fulton Co., Pa.

REMARKS: The specimens of Agoniatites (?) sp. collected for the present study are similar to the crushed individual figured by Miller (1938, pl. 35, fig. 4).

Phylum ARTHROPODA

Class TRILOBITA

Order PTYCHOPARIIDA

Suborder PTYCHOPARIINA

Superfamily PROETACEA

Family PROETIDAE

Subfamily PROETINAE

Genus PROETUS Steininger

Subgenus CRASSIPROETUS Stumm

PROETUS (CRASSIPROETUS) CRASSIMARGINATUS (Hall)

Pl. 31, fig. 1

Calymene crassimarginata Hall, 1843, p. 172, fig. 5.

Proetus crassimarginatus Hall, 1859, p. 88. — Hall, 1876, pl. 20, fig. 21-23, 26-31. — Hall and Clarke, 1888, pp. 99-101, pl. 20, fig. 6-8, 20-22, 26-31; pl. 22, fig. 20-26; pl. 25, fig. 8.

Proetus (Crassiproetus) crassimarginatus Stumm, 1953, pp. 15-17, pl. 1, fig. 2-13; pl. 2, fig. 9, 10.

One pygidium assignable to this species was collected during the present study.

Pygidium: Semi-ovate in outline, highly convex, with a moderately wide border. Equally trilobate. Axis strongly arched both longitudinally and transversely; composed of 13 or 14 smooth segments; tapers regularly to rounded termination just inside posterior border. Pleurae sloping steeply laterally; composed of at least 12 smooth segments.

Dimensions: Pygidium - Length 33 mm., width 35 mm., convexity (depth) 13 mm.

OCCURRENCE: Onondaga Limestone (Edgecliff Member) -- Y9, Hannacroix, Greene Co., N.Y.

Subfamily DECHENELLINAE

Genus DECHENELLA Kayser

Subgenus DECHENELLA Kayser

DECHENELLA (DECHENELLA) HALDEMANI (Hall)

Pl. 31, fig. 2-7

Proetus haldemani Hall, 1861, p. 74. — Hall and Clarke, 1888, pp. 113-116, pl. 21, fig. 7-9; pl. 23, fig. 13-15.

Small, distinctly and equally trilobate.

Cephalon: Semi-circular in outline, somewhat broader than long; surface evenly convex, except for prominent border. Border very slightly convex, with shallow marginal sulcus bounding inner edge, generally about 1.5 mm. wide in front, narrowing toward genal angles.

Glabella convex, somewhat triangular in outline, with three pairs of lateral furrows that are directed posteriorly. Anterior pair of furrows short, extend slightly over halfway to midline; second pair longer; third pair, directed more steeply posteriorly and intersecting occipital furrow near midline, also bifurcating near midline to form short accessory furrows between second and third furrows. Lateral furrows are most prominent on exfoliated specimens.

Remainder of cephalon not observed.

Thorax: Not observed.

Pygidium: Triangular, width to length as about 1.3 to 1, lateral slopes gentle with prominent smooth border. Axial lobe one-fourth width of shield at anterior margin, tapers regularly to rounded termination at posterior end; bears about 12 segments, posterior-most portion only faintly segmented. Pleura broad, bear 10 to 12 segments that tend toward obsolescence at posterior.

Dimensions:

	Specimen	Length	Width
Cephalon			
	1 Dcv	7 mm.	9 mm.
	2 Dmp	7	10
Pygidium			
	3 Dmcv	6	8
	4 Dmp	8	10
	5	10	15

OCCURRENCE: Marcellus Formation (Cherry Valley Limestone Member) — Y4, Cherry Valley, Otsego Co., N.Y. (Purcell Limestone Member) — P31, Selinsgrove Junction, Northumberland Co., Pa.

Order PHACOPIDA

Suborder PHACOPINA

Superfamily PHACOPACEA

Family PHACOPIDAE

Subfamily PHACOPINAE

Genus PHACOPS Emmrich

PHACOPS CRISTATA Hall

Pl. 31, fig. 8-10

Phacops cristata Hall, 1861, p. 67.

Phacops bombifrons Hall, 1861, p. 67.

Phacops cristata Hall and Clarke, 1888, pp. 14-18, pl. 6, fig. 1-13, 6-29; pl. 8A, fig. 1-4. — Kindle, 1912, pp. 107-108, pl. 10, fig. 6-8. — Kindle, in Prosser, Kindle, and Swartz, 1913, pp. 331-332, pl. 43, fig. 13-15. — Stumm, 1954, pp. 212-213, pl. 4, fig. 8, 10.

Medium in size, distinctly and equally trilobate.

Cephalon: Nearly semi-circular in outline, length to width ratio about 0.8. Glabella prominent, oval-shaped; protuberant anterior lobe extends somewhat beyond frontal margin. Second and third lobes restricted and obscure. Occipital furrow deep, forming conspicuous occipital segment. Eyes prominent, lunate, with about 60 lenses per eye. Short, stout spines occur on genal angles.

Thorax: Distinctly trilobed, with axial lobe about one-fourth total width. Axis strongly convex, evenly tapering, with short spines at centerline of each annulation. Pleura flat above, sloping off abruptly about two-thirds distance to lateral extremity.

Pygidium: Simple; posterior margin nearly a semicircle. Axial lobe about one-fourth width of shield, tapers toward posterior where it appears to become obsolete. Axis bears 5 annulations. Pleurae have about five annulations and traces of a sixth.

Dimensions:

	Specimen	Length	Width
Cephalon			
	1 Dn	10 mm.	12 mm.
Thorax			
	2	24	14
	3	15+	11

Dimensions:—Continued

	Specimen	Length	Width
Pygidium			
	4 Dn	5 mm.	9 mm.

OCCURRENCE: Needmore Formation (calcareous shale member) — P58, Orbisonia, Huntingdon Co., Pa. (Calcitic shale subfacies) — V1, Gainesboro, Frederick Co., Va. (Selinsgrove Limestone Member) — P42, Thompsontown, Juniata Co., Pa.

PHACOPS PIPA Hall and Clarke

Pl. 31, fig. 11-14; Pl. 32, fig. 1-3

Phacops cristata var. pipa Hall and Clarke, 1888, pp. 18-19, pl. 8A, fig. 5-18. — Kindle, 1912, p. 108, pl. 10, fig. 9, 10. — Kindle, in Prosser, Kindle, and Swartz, 1913, p. 332, pl. 43, fig. 16, 17.

Phacops pipa Stumm, 1954, p. 213, pl. 4, fig. 1-6, 9, 11.

Small to medium in size, distinctly and equally trilobate.

Cephalon: Nearly semi-circular in outline, length to width ratio about 0.65. Glabella prominent, suboval to subquadrate in outline; protuberant anterior lobe extends somewhat beyond frontal margin. Second and third lobes restricted and obscure. Occipital furrow deep, forming conspicuous occipital segment. Eyes prominent, lunate, with about 40 lenses per eye. Small spines occur on genal angles.

Thorax: Distinctly trilobed. Axis strongly convex, about one-third total width, not spinous. Pleura flat near axis, sloping off abruptly about two-thirds distance to lateral extremities.

Pygidium: Simple, posterior margin nearly a semicircle. Axial lobe about one-fourth width of shield, tapers toward posterior where it appears to become obsolete. About 6 annulations on axis. Pleurae have about 5 annulations, these being inclined about 60° to axis and trending straight toward margin, becoming obsolete at two-thirds distance to margin. On a few specimens there appear to be faint grooves down the middle of the annulations.

Dimensions:

	Specimen	Length	Width
Cephalon			
	1 Don	5 mm.	7 mm.
	2	10	17
	3	6	10
Thorax			
	4 Dn	15	10
	5	13	10
	6	22	20
Pygidium			
	7	7	15
	8	8	9
	9 Don	5	11

OCCURRENCE: Onondaga Limestone (Moorehouse Member) — Y5, Schoharie, Schoharie Co., N.Y. Onondaga Limestone — P29, Swatara Gap, Lebanon Co., Pa. Needmore Formation (calcareous shale member) — P49, Alinda, Perry Co., Pa. (Calcitic shale subfacies) — P63, Warfordsburg, Fulton Co., Pa. (Calcitic shale and limestone subfacies) — P65, Hyndman, Bedford Co., Pa.

REMARKS: All non-spinous phacopid thoraces (with attached pygidia) in the study collection are assigned to P. pipa.

PHACOPS sp.

Pl. 32, fig. 4-8

Only cephalons occur in the collections for this study.

Cephalon: Medium in size, nearly semicircular in outline, length to width ratio varies from 0.44 to 0.70. Glabella prominent, suboval to subquadrate in outline; protuberant, anterior extends beyond frontal margin. Second and third lobes obsolete. Occipital furrow deep, forming conspicuous occipital segment. Eyes prominent, lunate. Genal angles smooth, rounded.

Dimensions:

	Specimen	Length	Width
Cephalon			
	1 Dn	17 mm.	25 mm.
	2	11	25
	3	11	16
	4	8	17

OCCURRENCE: Needmore Formation (calcareous shale member) — P61, Tyrone, Blair Co., Pa. (Calcitic shale subfacies) — P63, Warfordsburg, Fulton Co., Pa.; V1, Gainesboro, Frederick Co., Va. (Selinsgrove Limestone Member) — P58, Orbisonia, Huntingdon Co., Pa. (Calcitic shale and limestone subfacies) — P63, Warfordsburg, Fulton Co., Pa.

REMARKS: Some phacopid cephalons from the Needmore Formation appear to lack the genal spines of *P. cristata* and *P. pipa*. These specimens approach *P. rana* of the Hamilton Group, but do not have a complete third glabellar lobe.

Superfamily DALMANITACEA

Family DALMANITIDAE

Subfamily DALMANITINAE

Genus ANCHIOPELLA Reed

ANCHIOPELLA ANCHIOPS (Green)

Pl. 32, fig. 9, 10

Calymena anchiops Green, 1832, p. 35.

Dalmanites anchiops Hall, 1876, pl. 9, fig. 1, 3-6, 10, 12, 13; pl. 10, fig. 6-14.

Dalmanites (Chasmops) anchiops Hall and Clarke, 1888, pp. 59-61, pl. 9, 10.

Anchiopsis anchiops Shimer and Shrock, 1944, p. 637, pl. 274, fig. 20-22. — Stumm, 1954, pp. 210-211, pl. 3, fig. 4, 5.

Anchiopella anchiops Richter, Richter, and Struve, in Harrington and others, 1959, pp. 0469-0470, fig. 371, 5.

Description based on several pygidia.

Pygidium: Large, subtriangular, with stout, upturned caudal spine. Composed of 9 segments. Axis less than one-third width of shield at anterior extremity, tapering regularly, but termination concealed. Pleura broad, rounded at margins; bear 9 annulations which become obsolete just within border. Border is about 3 mm. wide.

Dimensions: Pygidium - length 50 mm. (with spine), width 65 mm. (at thoracic end). Spine - length 12 mm., width 10 mm. (at base).

OCCURRENCE: Schoharie Formation (Saugerties Member) — Y17, Kingston, Ulster Co., N.Y. (Saugerties-Aquetuck members, undivided) — Y21, Trilobite Mountain, Orange Co., N.Y.; P7, Buttermilk Falls, Monroe Co., Pa.

Genus ODONTOCEPHALUS Conrad

ODONTOCEPHALUS SELENOURUS (Eaton)

Pl. 33, fig. 1-10

Asaphus selenourus Eaton, 1832, p. 31, pl. 1, fig. 1.

Odontocephalus selenourus Conrad, 1840, p. 204.

Dalmanites (Odontocephalus) selenurus Hall and Clarke, 1888, pp. 49-52, pl. 116, fig. 15-21; pl. 12, fig. 1-13.

Odontocephalus selenurus Kindle, 1912, p. 109, pl. 12, fig. 6.

Cephalon: Somewhat broader than long; surface convex, sloping abruptly in front and at the sides. Border moderately broad, but distinctive frontal portion not preserved, sloping on sides, rounded at genal angles. No spines apparent.

Glabella large, with bulbous anterior lobe. First glabellar furrow oblique to rear, extending two-thirds distance to axis; second and third furrows transverse and somewhat shorter, forming two distinct rounded glabellar lobes. Occipital furrow conspicuous, extends completely across axis.

Eyes large, lunate, with numerous lenses (probably about 50 per eye). Palpebral lobe conspicuous on inside of eye.

Suture proparian, arising about one-third distance from genal angle to anterior extremity, and, after short oblique trend toward front on border, swinging back to posterior part of eye. It then circles around in front of eye and bends forward to parallel the dorsal furrow.

Thorax: Distinctly and equally trilobate, with convex axis that is about one-third thoracic width. Pleura relatively flat near axis, sloping off about two-thirds distance to lateral extremities. Consists of about 10 segments.

Pygidium: Triangular to subtriangular, lateral slopes abrupt. Axial lobe one-third to one-fourth width of shield at anterior margin, tapers regularly to rounded termination at posterior end; bears 8 or 9 strong annulations and several faint ones at end, where indistinct furrows extend only part way to axis. Pleural lobes bear 8 or 9 annulations. Border is narrow but present; has slope continuous with pleura. Two caudal spines are often broken off, but presence can usually be ascertained.

Dimensions:

	Specimen	Length	Width
Cephalon			
	1 Dns	—	55 mm.
Thorax			
	2 Don	19 mm.	19
Pygidium (with spines)			
	3 Don	15	21
	4	23	38
	5 Dns	18	25
	6	16	20
	7	11	21
	8	18	24

OCCURRENCE: Onondaga Limestone (Moorehouse Member) — Y15, Saugerties, Ulster Co., N.Y.; Y20, Wawarsing, Ulster Co., N.Y. Onondaga Limestone — P23, Germans, Carbon Co., Pa. Needmore Formation (Selinsgrove Limestone Member) — P43, Old Port, Juniata Co., Pa.; P52, P53, Newton Hamilton, Mifflin Co., Pa.

REMARKS: Diagnostic characteristics of O. selenourus are: (1) nine tooth-like extensions on anterior border of cephalon; (2) rounded genal angles; and (3) eight annulations on pleural lobes of pygidium.

ODONTOCEPHALUS AEGERIA Hall

Pl. 34, fig. 1-8

Dalmania aegeria Hall, 1861, p. 57.

Dalmanites (Odontocephalus) aegeria Hall and Clarke, 1888, p. 53, pl. 11B, fig. 1-11.

Odontocephalus aegeria Kindle, 1912, pp. 109-111, pl. 10, fig. 11; pl. 11, fig. 3-5; pl. 12, fig. 1-5, 7, 8.

Cephalon: Somewhat broader than long; surface convex, sloping rather abruptly in front and at sides. Border broad, with eleven tooth-like processes (separated by open slots) around anterior brim. "Teeth" have maximum length of 2-3 mm., are about 1.0 mm. broad at proximal end, and are 1.5 to 2.0 mm. broad at distal end. Prominent genal spines are at least 20 mm. long.

Glabella large with bulbous anterior lobe, similar to _O. selenourus_ (pp. 435-436).

Eyes large, lunate with numerous lenses. Palpebral lobe conspicuous on inside of eye.

Suture not observed, but presumably proparian.

Thorax: Distinctly and equally trilobate, with convex axis that is one-third (or greater) of thoracic width. Pleura relatively flat near axis, slope off about two-thirds distance to lateral extremities. Consists of 10 to 12 segments.

Pygidium: Broadly triangular, lateral slopes only moderately abrupt. Axial lobe one-third to one-fourth width of shield at anterior margin, tapers regularly to rounded termination at posterior end; bears 9 or 10 strong annulations, and several faint ones at posterior end. Pleural lobes bear 10 annulations. Border is narrow, has slope continuous with pleura. Two caudal spines often broken off, but presence can usually be ascertained.

Dimensions:

	Specimen	Length	Width
Cephalon (without spine)			
	1 Dns	35 mm.	45 mm.
	2	20	23
Thorax			
	3	—	47
	4	33+	37
Pygidium (with spines)			
	5	20	27
	6	23	33
	7	29	45
	8	26	45

OCCURRENCE: Needmore Formation (calcitic shale subfacies) — V1, Gainesboro, Frederick Co., Va. (Selinsgrove Limestone Member) — P30, Dalmatia, Northumberland Co., Pa.; P31, Selinsgrove Junction, Northumberland Co., Pa.; P36, Montoursville, Lycoming Co., Pa.; P43, Old Port, Juniata Co., Pa.; P50, Alinda, Perry Co., Pa.; P52, P53, Newton Hamilton, Mifflin Co., Pa. (Calcitic shale and limestone subfacies) — P63, Warfordsburg, Fulton Co., Pa.; M2, Flintstone, Allegany Co., Md.

REMARKS: Diagnostic characteristics of O. aegeria are: (1) eleven tooth-like extensions on anterior border of cephalon; (2) prominent genal spines; and (3) ten annulations on pleural lobes of pygidium.

ODONTOCEPHALUS BIFIDUS (Hall)

Pl. 34, fig. 9

<u>Dalmania bifidus</u> Hall, 1861, p. 63.

<u>Dalmanites</u> (<u>Odontocephalus</u>) <u>bifidus</u> Hall and Clarke, 1888, p. 53, pl. 11b, fig. 22-25.

<u>Odontocephalus bifidus</u> Stumm, 1954, pp. 207-208, pl. 2, fig. 7.

Description based on one pygidium.

Pygidium: Triangular, convex, lateral slopes abrupt. Axial lobe about one-fourth width of shield at anterior extremity; bears eight clear annulations, one less clear, with short fused section at posterior end. Pleural lobes bear six clear annulations and one indistinct. Caudal extremity narrow and elongate, with two conspicuous spines, which are moderately long and close together.

Dimensions: Length 12 mm. (with spines), width 16 mm. (Caudal spines 2 mm. long.)

OCCURRENCE: Jeffersonville Limestone (<u>Brevispirifer gregarius</u> zone) — K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

Class CRUSTACEA

Subclass OSTRACODA

Order PALAEOCOPIDA

Suborder BEYRICHICOPINA

Superfamily DREPANELLACEA

Family BOLLIIDAE

Genus BOLLIA Jones and Holl

BOLLIA UNGULA Jones

No fig.

Bollia ungula (Claypole MS) Jones, 1889, pp. 338-339, pl. opp. p. 342, fig. 10. — Kindle, 1912, p. 113, pl. 9, fig. 9. — Kindle, in Prosser, Kindle, and Swartz, 1913, pp. 336-337, pl. 44, fig. 7. — Swartz and Swain, 1941, pl. 2, fig. 4a-4i. — Shimer and Shrock, 1944, p. 667, pl. 281, fig. 33-35, 67-69.

Carapace very small, generally subovoid in outline. Dorsal border straight; ventral border evenly rounded. Length to height ratio about 1.5, greatest length being near mid-height.

Distinguishing feature of external ornamentation is a centrally located horseshoe-shaped ridge that opens toward dorsal border and extends from dorsal border nearly to ventral border.

Dimensions: Length 1.0-1.5 mm., height 0.7-1.0 mm.

OCCURRENCE: Needmore Formation (calcareous shale member) — P42, Thompsontown, Juniata Co., Pa.; P60, Curtin Gap, Centre Co., Pa. (Calcareous shale and limestone subfacies) — P64, Warren Point, Franklin Co., Pa.

Order PODOCOPIDA

Suborder METACOPINA

Superfamily THLIPSURACEA

Family THLIPSURIDAE

Genus FAVULELLA Swartz and Swain

FAVULELLA FAVULOSA (Jones)

No fig.

Bythocypris favulosa Jones, 1889, p. 338, pl. opp. p. 342, fig. 1, 2a-2c. — Kindle, 1912, p. 114, pl. 9, fig. 14, 15.

Favulella favulosa Swartz and Swain, 1941, pp. 439-440, pl. 7, fig. 1-23; pl. 8, fig. 8. — Shimer and Shrock, 1944, p. 682, pl. 286, fig. 37-41.

Carapace very small, subreniform to subovoid in outline. Dorsal border straight to slightly rounded; ventral border gently rounded. Anterior end generally somewhat inflated relative to posterior end. Length to height ratio varies from 1.4 to 1.6.

External ornament consists of a strongly punctate area which is surrounded by a submarginal ridge; in the center of the punctate area is a smooth spot. Two small, posteriorly-directed spines are present at the posterior end.

Dimensions: Length 1.0-1.5 mm., height 0.6-1.0 mm.

OCCURRENCE: Needmore Formation (calcitic shale subfacies) — P64, Warren Point, Franklin Co., Pa. (Calcitic shale and limestone subfacies) — P64, Warren Point, Franklin Co., Pa.

Phylum Uncertain

Class CRICOCONARIDA

Order TENTACULITIDA

Family TENTACULITIDAE

Genus TENTACULITES Schlotheim

TENTACULITES GRACILISTRIATUS Hall

Pl. 35, fig. 1

Tentaculites gracilistriatus Hall, 1879, pp. 173-175, pl. 31, fig. 12-14; pl. 31A, fig. 37-47.

Shell very small, elongate-conical to acicular, straight, with rounded annulations spaced evenly along anterior portion, becoming obsolete toward posterior. Annulations are about 0.4 mm. apart. Circular in cross section.

Dimensions: Length 4 mm., maximum diameter about 0.8 mm.

OCCURRENCE: Needmore Formation (Selinsgrove Limestone Member) — P31, Selinsgrove Junction, Northumberland Co., Pa.

TENTACULITES BELLULUS Hall

Pl. 35, fig. 2, 3

Tentaculites bellulus Hall, 1876, pl. 26, fig. 15-18. — Hall, 1879, pp. 169-170, pl. 31, fig. 15-18; pl. 31A, fig. 48-51. — Shimer and Shrock, 1944, p. 526, pl. 24, fig. 43, 44.

Shell small, elongate-conical, straight, with prominent, evenly spaced, acute annulations which are about 1.5 mm. apart on anterior part of shell, decreasing to 1.0 mm. and less toward posterior. Annulations much subdued on internal molds. Circular in cross section. No fine transverse striae are visible.

Dimensions: Length 25 mm., maximum diameter 3 mm.

OCCURRENCE: Onondaga Limestone (Echo Lake Member) — P1, Echo Lake, Monroe Co., Pa. Onondaga Limestone — P25, Andreas, Schuylkill Co., Pa.

Order DACRYCONARIDA

Family STYLIOLINIDAE

Genus STYLIOLINA Karpinsky

STYLIOLINA FISSURELLA (Hall)

Pl. 35, fig. 4, 5

Tentaculites fissurella Hall, 1843, p. 180, fig. 9, 10; p. 222, fig. 4.

Styliola fissurella Hall, 1879, p. 178, pl. 31A, fig. 1-28.

Styliolina fissurella Clarke, 1885, p. 57. — Kindle, 1912, p. 103. — Prosser and Kindle, in Prosser, Kindle, and Swartz, 1913, pp. 300-301, pl. 37, fig. 17-20. — Shimer and Shrock, 1944, p. 526, pl. 215, fig. 53.

Shell minute, elongate-conical in outline. Surface smooth. Posterior apical portion solid. In shales, anterior portion is usually crushed, causing longitudinal furrow from which species derives name.

Dimensions: Length 3-4 mm., maximum diameter 0.5 mm.

OCCURRENCE: Needmore Formation (calcareous shale member) — P36, Montoursville, Lycoming Co., Pa.; P42, Thompsontown, Juniata Co., Pa.; P60, Curtin Gap, Centre Co., Pa.; P61, Tyrone, Blair Co., Pa., etc. (Selinsgrove Limestone Member) — ubiquitous in both limestone and dark shale. (Calcitic shale and limestone subfacies) -- ubiquitous in both limestone and dark shale. Marcellus Formation — P29, Swatara Gap, Lebanon Co., Pa., etc. (Probably ubiquitous in black shale and limestone.)

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FOSSIL PLATES

EXPLANATION OF PLATE 6

Figure 1,2 Favosites basalticus (Goldfuss)

1. Side view of a large, broken, tabular colony in a coarse, crinoidal matrix; x0.7. Onondaga Limestone (Edgecliff Member), Y7, Thompsons Lake, Albany Co., N.Y.
2. Distal surface of a tabular silicified colony; x1. Onondaga Limestone (Edgecliff Member), Y2 (float), Leroy, Genesee Co., N.Y.

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EXPLANATION OF PLATE 7

Figure 1 — Favosites sp. View of a small silicified colony; x1.5. Onondaga Limestone (Echo Lake Member), P1-13, Echo Lake, Monroe Co., Pa.

Figure 2 — Trachypora (?) sp. View of two branches of the same colony, showing ovoid calycal openings; x1.2. Needmore Formation (calcitic shale and limestone subfacies), V1-10, Gainesboro, Frederick Co., Va.

Figure 3,4 — Syringaxon sp.

3. Alar (side) view, showing ceratoid corallum; x1.3. Onondaga Limestone (Nedrow Member), Y4, Cherry Valley, Otsego Co., N.Y.
4. Transverse section of same specimen as 3, showing inner wall (aulos) formed by dilated and rhopaloid septa; x1.2.

Figure 5-9 — Heterophrentis inflata (Hall)

5. Alar view of silicified specimen, showing trochoid corallum; x1.3. Jeffersonville Limestone (Brevispirifer zone), K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.
6. Transverse section of same specimen as 5, showing major and minor septa, deflection of major septa in axial region, and weak cardinal fossula at top; x1.65.
7. Counter view of silicified specimen, showing trochoid corallum and broad calyx; x1.4. Onondaga Limestone (Edgecliff Member), Y2 (float), Leroy, Genesee Co., N.Y.
8. Cardinal view, showing well developed interseptal ridges on epitheca; x1.4. Same specimen as 7.
9. Transverse section of same specimen as 7 and 8, showing major septa and very short minor septa; x1.6.

PLATE 7

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EXPLANATION OF PLATE 8

Figure 1,2 — Heterophrentis simplex (Hall)

1. Longitudinal view, showing ceratoid corallum and simple external ornament; x1.25. Onondaga Limestone, P26-12, Schuylkill Haven, Schuylkill Co., Pa.
2. Longitudinal view of another specimen; x1.25. Onondaga Limestone, same locality and unit as 1.

Figure 3-5 — "Heterophrentis" sp. A

3. Longitudinal view of a small specimen; x1.3. Needmore Formation (Selinsgrove Limestone Member), P55, Alfarata, Mifflin Co., Pa.
4. Transverse sections of same specimen as 3; x1.5.
5. Longitudinal view of a large, inflated individual, showing trocoid corallum; x1.3. Needmore Formation (calcitic shale and limestone subfacies), P63-10, Warfordsburg, Fulton Co., Pa.

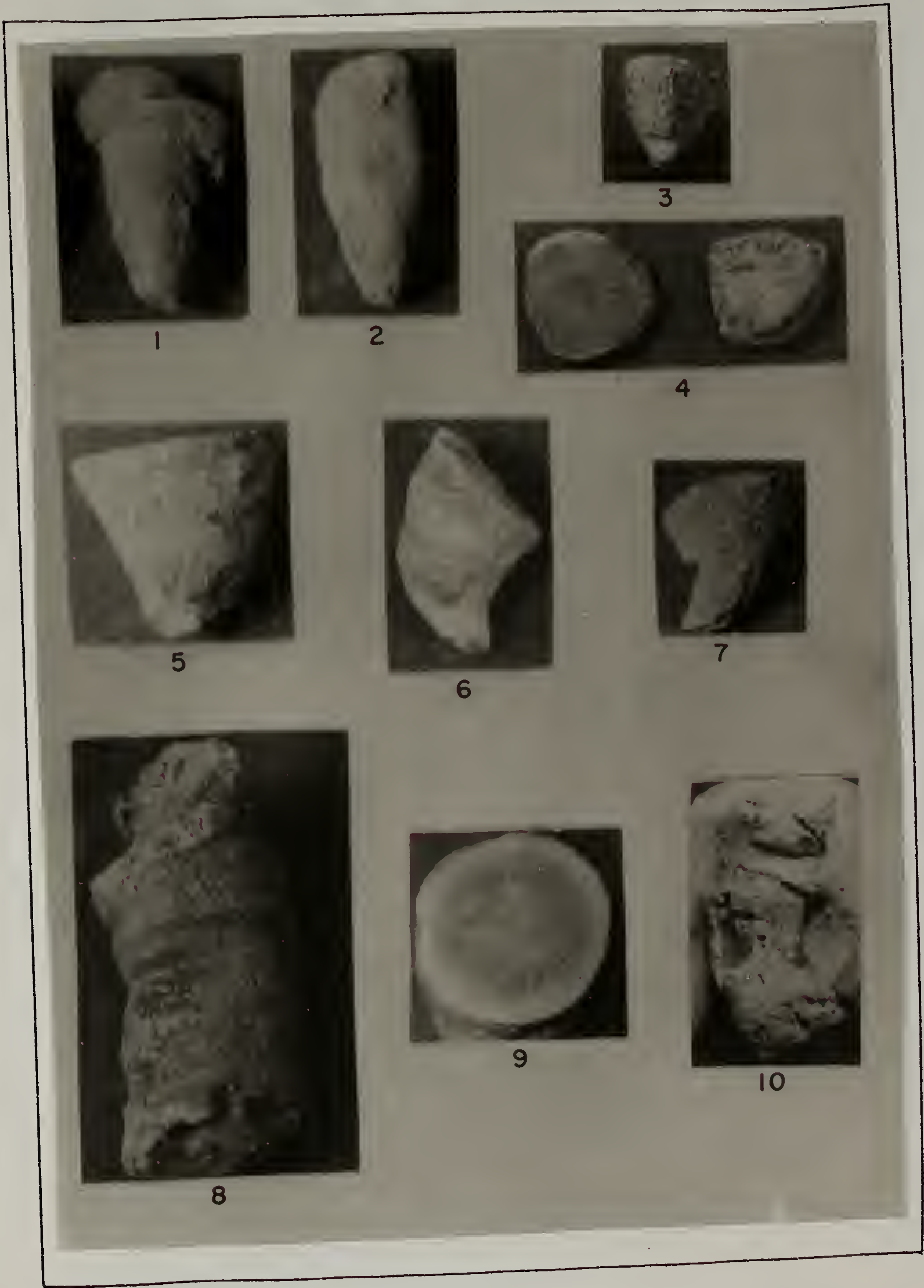
Figure 6,7 — "Heterophrentis" sp. B

6. Alar view of a small silicified specimen, showing trocoid corallum; x1.3. Jeffersonville Limestone (Brevispirifer zone), K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.
7. Alar view of a silicified specimen, showing curved, trocoid corallum; x1. Onondaga Limestone (Echo Lake Member), P1-13, Echo Lake, Monroe Co., Pa.

Figure 8-10 — Siphonophrentis yandelli (Edwards and Haime)

8. Alar view of silicified specimen, showing subcylindrical corallum; x1.3. Jeffersonville Limestone (Brevispirifer zone), K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.
9. Transverse section of the same specimen, showing cardinal fossula (top), amplexoid major septa, and very short minor septa; x1.4.
10. Alar view of a smaller silicified corallum; x1.1. Jeffersonville Limestone (Brevispirifer zone), same locality as 8 and 9.

PLATE 8.

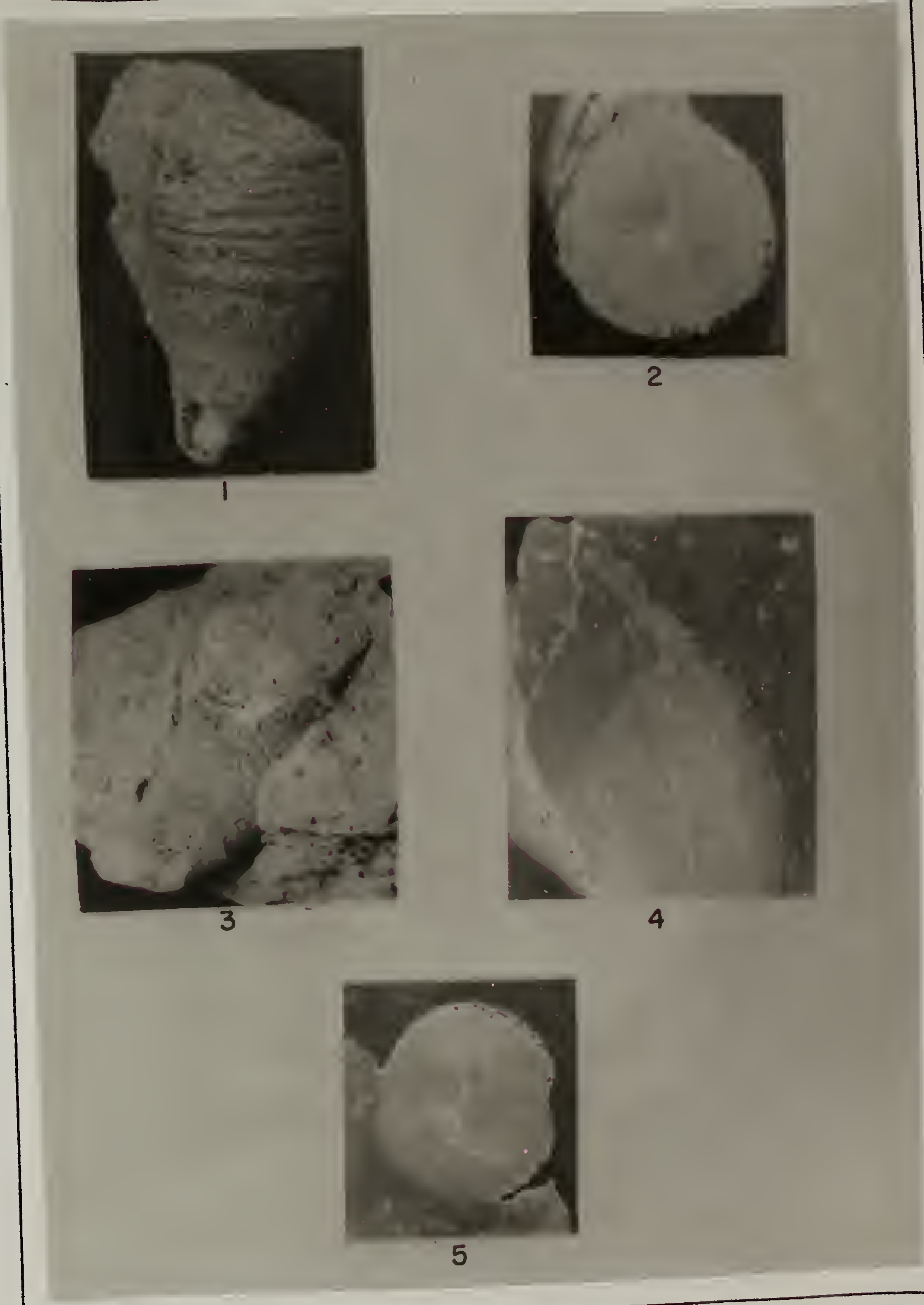


EXPLANATION OF PLATE 9

Figure 1-5 Breviphrentis sp.

1. Alar view of silicified specimen, showing curved-trochoid corallum; x1.3. Jeffersonville, Limestone (Brevispirifer zone), K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.
2. Transverse section of the same specimen as 1, showing major and minor septa; x1.5.
3. Longitudinal view of silicified specimen, showing curved-trochoid corallum; x1. Onondaga Limestone (Edgecliff Member), Y4-9, Cherry Valley, Otsego Co., N.Y.
4. Longitudinal section of the same specimen as 3, showing deep calyx and flat tabulae; x1.2.
5. Transverse section of same specimen as 3 and 4; x1.4.

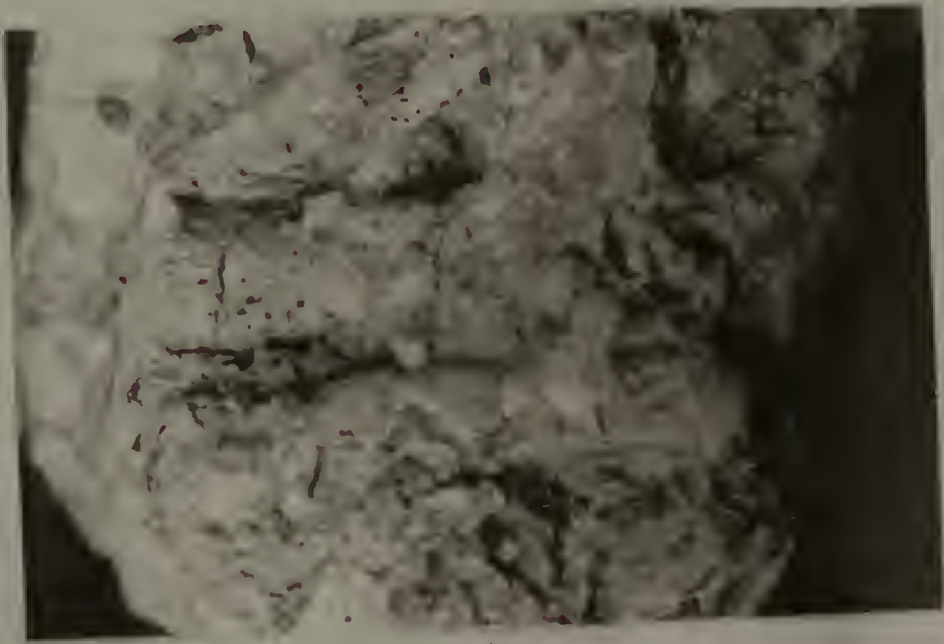
PLATE 9



EXPLANATION OF PLATE 10

Figure 1,2 Cylindrophyllum compactum (Hall)

1. Longitudinal view of silicified corallum, showing phaceloid arrangement of large cylindrical corallites; x0.95. Onondaga Limestone (Edgecliff Member), Y2 (float), Leroy, Genesee Co., N.Y.
2. Transverse view of same specimen as 1; x0.85.



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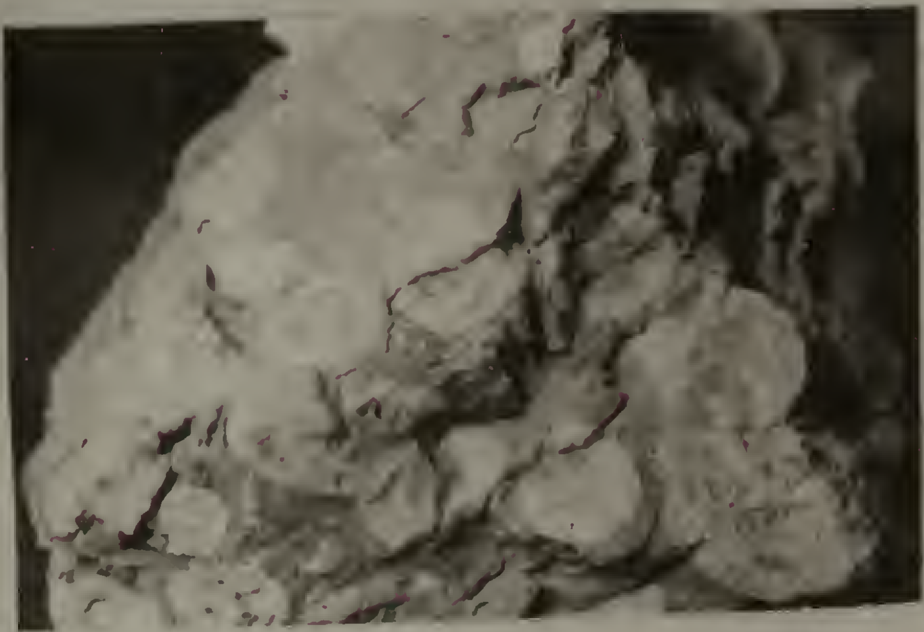

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EXPLANATION OF PLATE 11

Figure 1,2 Acinophyllum stramineum (Billings)

1. Longitudinal view of corallum, showing phaceloid arrangement of slender corallites; x0.8. Onondaga Limestone (Edgecliff Member), Y7, Thompsons Lake, Albany Co., N.Y.
2. Transverse section of a single corallite, showing major and minor septa with "yard-arm" carinae; x35. Onondaga Limestone (Edgecliff Member), same locality as 1.

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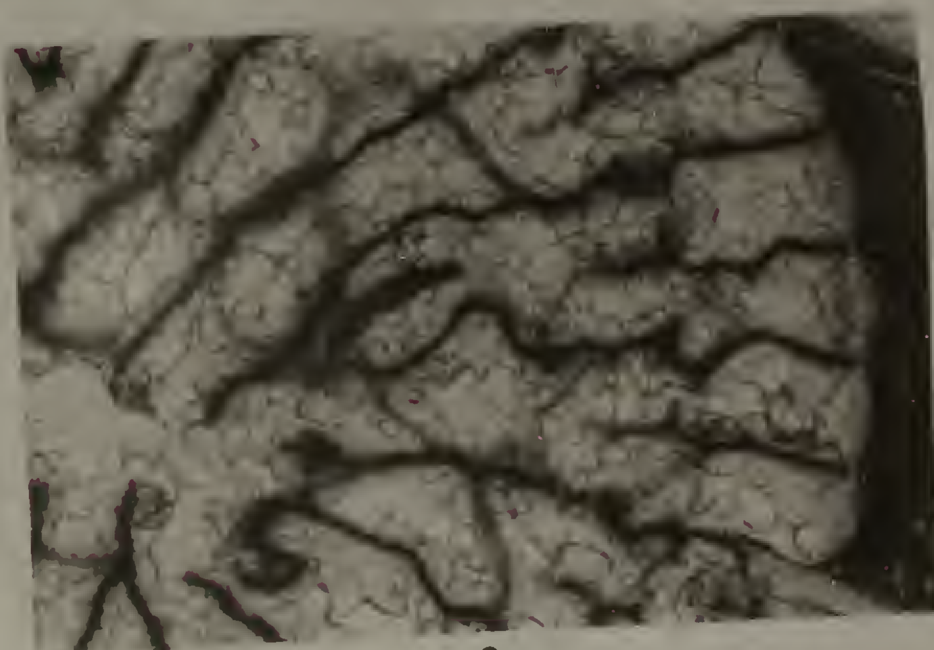

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EXPLANATION OF PLATE 12

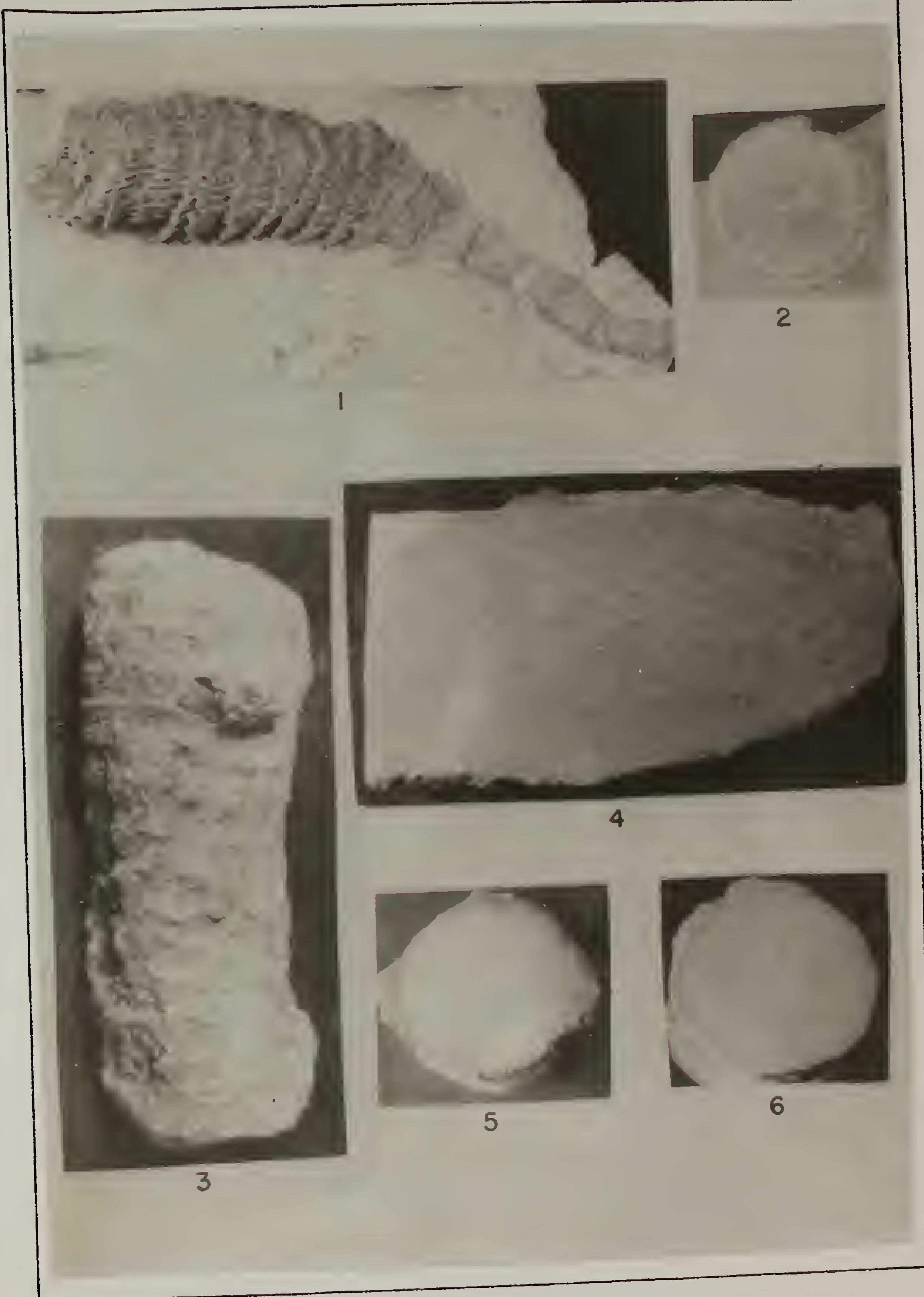
Figure 1,2 Blothrophyllum sinuosum (Hall)

1. Longitudinal view of a large, silicified and exfoliated specimen, showing ceratoid to subcylindrical corallum and cone-in-cone structure produced by repeated rejuvenescence; x0.9. Jeffersonville Limestone (Brevispirifer zone), K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.
2. Transverse section of the same specimen as 1, showing part of old calyx around periphery; x1.25.

Figure 3-6 Cystiphylloides americanum (Edwards and Haime)

3. A large specimen; x1. Onondaga Limestone (Edgecliff Member), Y7, Thompsons Lake, Albany Co., N.Y.
4. Longitudinal section of the same specimen as 1, showing dissepiments; x1.3.
5. Transverse section, showing dissepiments; x1.6. Onondaga Limestone (Edgecliff Member), same locality as 3 and 4.
6. Another transverse section, showing dissepiments; x1.5. Onondaga Limestone (Edgecliff Member), same locality as 3, 4 and 5.

PLATE 12



EXPLANATION OF PLATE 13

Figure 1,2 Fenestrellina sp.

1. Reverse side of colony, showing lacy network of branches and dissepiments; x1.2. Onondaga Limestone, P26-12, Schuylkill Haven, Schuylkill Co., Pa.
2. Reverse side of a silicified colony; x1. Onondaga Limestone (Edgecliff Member), Y10, Catskill Creek, Greene Co., N.Y.

Figure 3 Lichenalia sp. Under surface of colony, showing contorted wrinkled epitheca; x1.1. Onondaga Limestone, P27-2, Auburn, Schuylkill Co., Pa.

Figure 4 Encrusting bryozoan on gastropod shell; x1.2. Needmore Formation (calcitic shale subfacies), V1-7, Gainesboro, Frederick Co., Va.

Figure 5 Lingula sp. Single valve, showing typical elongate-ovoid outline and fine, concentric growth lines; x1.4. Schoharie Formation (Saugerties-Aquetuck members, undivided), P14, Foxtown Gap, Monroe Co., Pa.

Figure 6,7 Orbiculoidea media (Hall)

6. Brachial valve, showing conical shape; x1.25. Needmore Formation (calcareous shale member), P52-9, Newton Hamilton, Mifflin Co., Pa.
7. Pedicle valve, showing conical shape and pedicle groove (at top); x2. Needmore Formation (Selinsgrove Limestone Member), P52-47, Newton Hamilton, Mifflin Co., Pa.

Figure 8 Orbiculoidea sp. Broken valve, showing prominent holoperipheral growth lines; x1.3. Esopus Formation (mudstone below Highland Mills Member), Y24, Monroe, Orange Co., N.Y.

PLATE 13

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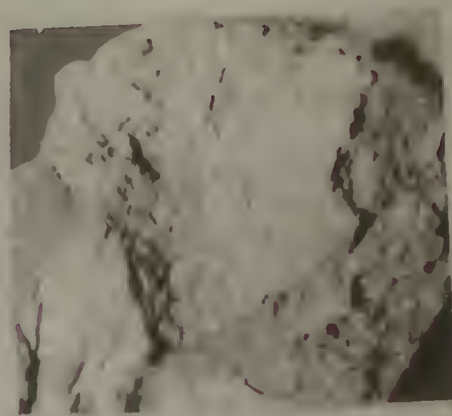

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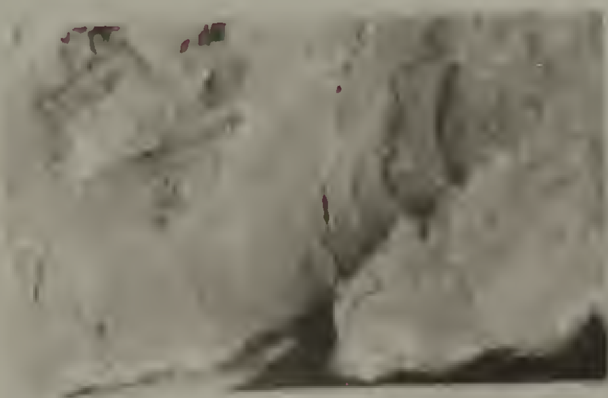

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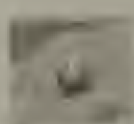

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EXPLANATION OF PLATE 14

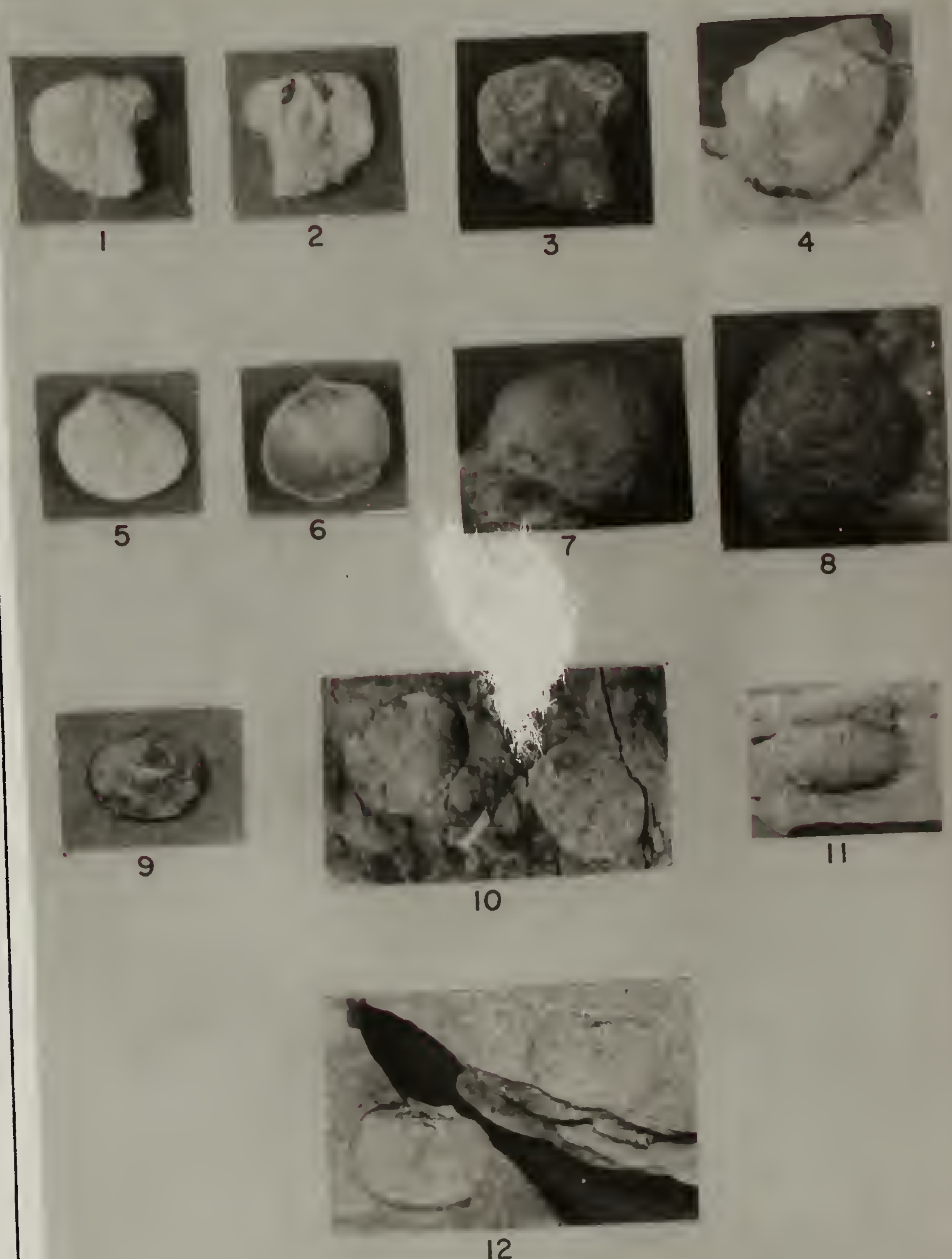
Figure 1-8 Levenea lenticularis (Vanuxem)

1. Exterior of brachial valve, showing shallow sulcus; x1.1. Needmore Formation (calcitic shale and limestone subfacies), M2-10, Flintstone, Allegany Co., Md.
2. Interior of same brachial valve as 1, showing adductor scars, median septum, and stout brachiophores; x1.1.
3. Exterior of brachial valve, showing shallow, flaring sulcus and fine costellae; x1.3. Needmore Formation (calcitic shale and limestone subfacies), same locality and unit as 1 and 2.
4. Exterior of brachial valve; x1. Needmore Formation (calcitic shale subfacies), V1-7, Gainesboro, Frederick Co., Va.
5. Exterior of pedicle valve, showing subcarinate profile and fine costellae; x1. Onondaga Limestone, P26-12, Schuylkill Haven, Schuylkill Co., Pa.
6. Interior of same pedicle valve as 5, showing triangular delthyrium, strong hinge teeth and diductor scars; x1.
7. Exterior of brachial valve, showing broad sulcus; x1.1. Needmore Formation (calcitic shale and limestone subfacies), M2-10, Flintstone, Allegany Co., Md.
8. Exterior of pedicle valve; x1.1. Needmore Formation (calcitic shale and limestone subfacies), same locality and unit as 7.

Figure 9-12 Levenea sp.

9. Exterior of pedicle valve, showing suboval outline and ramicostellate ornament; x1.4. Needmore Formation (calcitic shale and limestone subfacies), M2-8, Flintstone, Allegany Co., Md.
10. Internal molds of pedicle valves; x1.3. Needmore Formation (Selinsgrove Limestone Member), P42-11, Thompsontown, Juniata Co., Pa.
11. Interior mold of pedicle valve, showing bilobate diductor muscle scar; x1.3. Needmore Formation (calcitic shale and limestone subfacies), P64-5, Warren Point, Fulton Co., Pa.
12. Internal mold of brachial valve (mold at left), showing cardinal process and socket ridges; x1.3. Needmore Formation (calcareous shale member), P30-21, Dalmatia, Northumberland Co., Pa.

PLATE 14

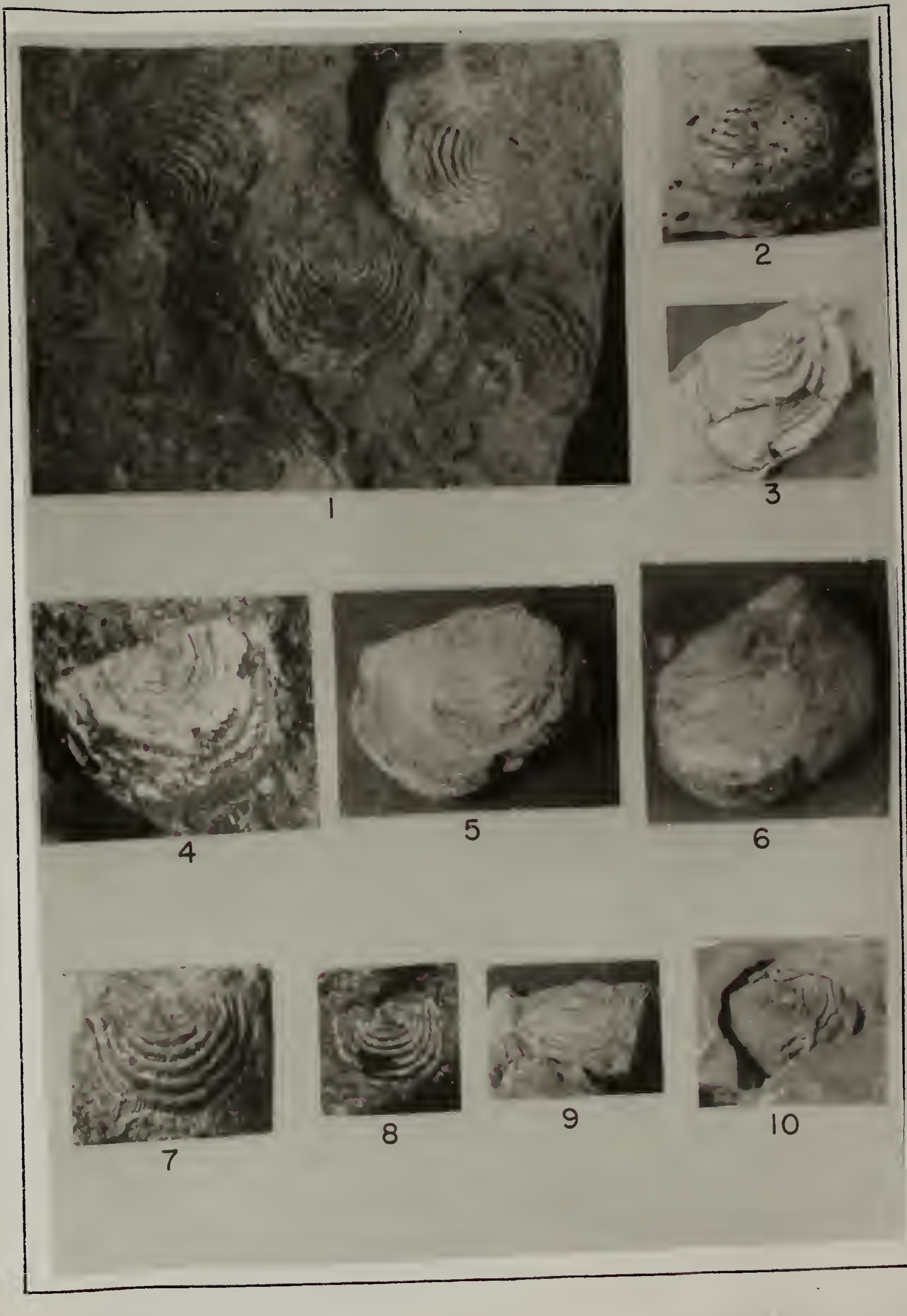


EXPLANATION OF PLATE 15

Figure 1-10 Leptaena rhomboidalis (Wilckens)

1. Several pedicle valves, showing typical concentric rugation; x1. Onondaga Limestone (Moorehouse Member), Y1, Stafford, Genesee Co., N.Y.
2. Exterior of pedicle valve, showing concentric rugae and trail; x1. Onondaga Limestone, P29-2, Swatara Gap, Lebanon Co., Pa.
3. Exterior of pedicle valve; x1.3. Onondaga Limestone (Member A), P1-4, Echo Lake, Monroe Co., Pa.
4. Exterior of pedicle valve; x1.1. Onondaga Limestone (Moorehouse Member), Y15-3, Saugerties, Ulster Co., N.Y.
5. Brachial valve of a complete specimen; x1.3. Onondaga Limestone, P26-12, Schuylkill Haven, Schuylkill Co., Pa.
6. Pedicle valve of the same specimen as 5, showing long trail; x1.3.
7. Exterior of pedicle valve; x1.7. Onondaga Limestone (Moorehouse Member), Y5, Schoharie, Schoharie Co., N.Y.
8. Exterior of another pedicle valve; x1.1. Onondaga Limestone (Moorehouse Member), same locality as 7.
9. Exterior of pedicle valve; x1.3. Onondaga Limestone, P27-4, Auburn, Schuylkill Co., Pa.
10. Internal mold of pedicle valve; x1. Schoharie-Esopus formations, undivided, P24-4, Stony Mountain School, Carbon Co., Pa.

PLATE 15



EXPLANATION OF PLATE 16

Figure 1,2 — Strophodonta (Strophodonta) demissa (Conrad)

1. Exterior of pedicle valve, showing strongly elevated costae on umbo; x1. Onondaga Limestone (Moorehouse Member), Y4, Cherry Valley, Otsego Co., N.Y.
2. Exterior of pedicle valve, showing ornament of individual that lacks elevated costae; x1.1. Onondaga Limestone, P29-2, Swatara Gap, Lebanon Co., Pa.

Figure 3,4 — Megastrophia (Megastrophia) concava (Hall)

3. Exterior of pedicle valve, showing typical costation; x1.3. Onondaga Limestone, P26-12, Schuylkill Haven, Schuylkill Co., Pa.
4. Internal mold of pedicle valve, showing large, flabellate diductor muscle scars; x1.1. Onondaga Limestone, same locality and unit as 3.

Figure 5 — Protoleptostrophia perplana (Conrad). Interior of brachial valve, showing large, bilobed cardinal process; x1.3. Schoharie-Esopus formations, undivided, P19-11, Little Gap, Carbon Co., Pa.

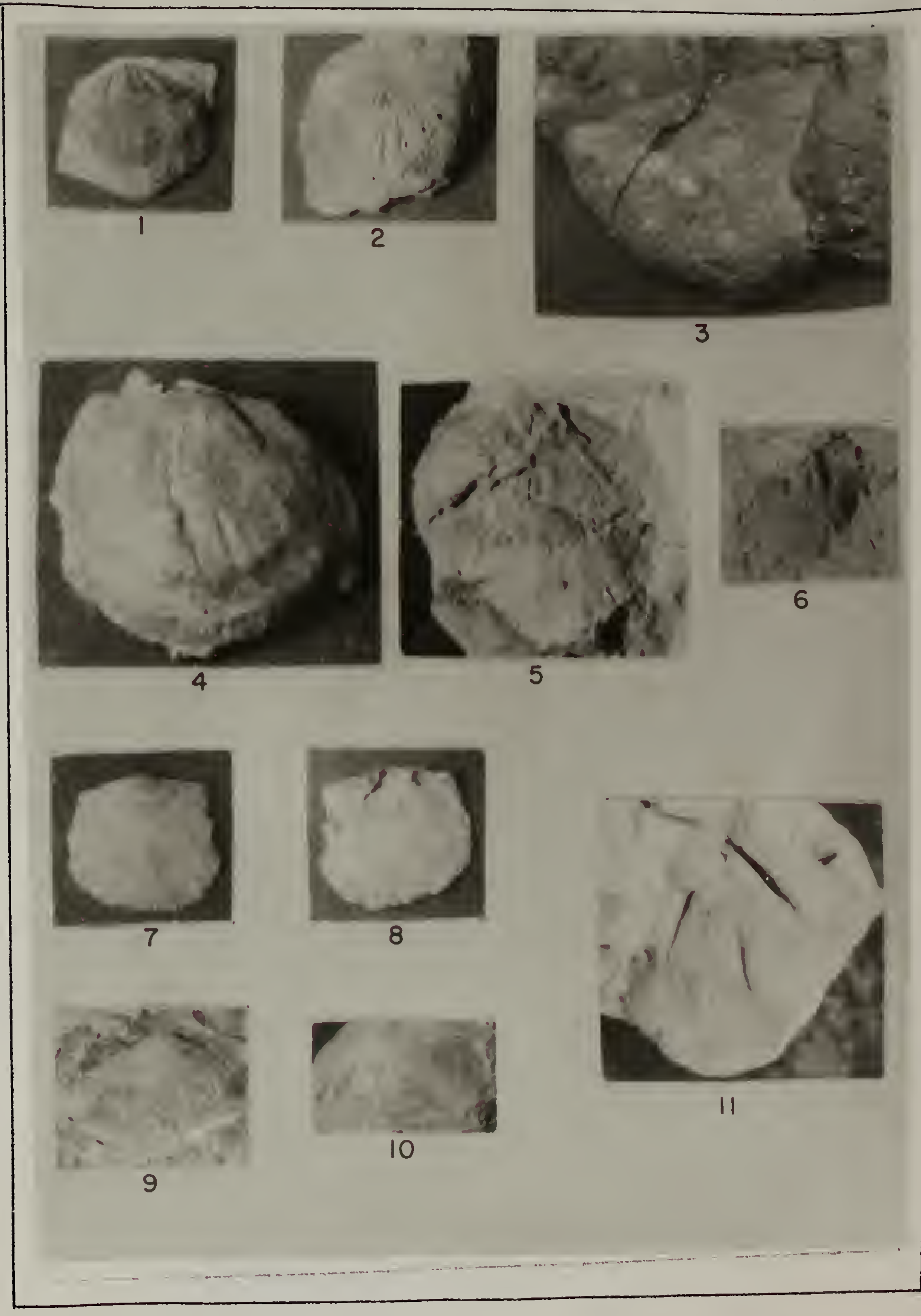
Figure 6 — Douvillina (Douvillina) inaequistriata (Conrad). Internal mold of pedicle valve, showing impressions of diductor scars, muscle-bounding ridges, and lemniscate pallial markings; x1.5. Onondaga Limestone, P22-26, West Bowmans, Carbon Co., Pa.

Figure 7-10 — Schellwienella pandora (Billings)

7. Exterior of brachial valve; x1.5. Needmore Formation (calcareous shale member), P35-2, Lewisburg, Union Co., Pa.
8. Interior of same brachial valve as 7, showing massive socket ridges; x1.5.
9. Exterior of brachial valve, showing typical ornament; x1. Onondaga Limestone, P26-12, Schuylkill Haven, Schuylkill Co., Pa.
10. Internal mold of pedicle valve, showing impressions of short dental plates; x1. Schoharie-Esopus formations, undivided, P19-12, Little Gap, Carbon Co., Pa.

Figure 11 — Hipparionyx proximus (Vanuxem). Internal mold of pedicle valve, showing broad, flabellate diductor scars and smaller, sub-oval adductor scars; x1. Ridgeley Sandstone, P36A, Montoursville, Lycoming Co., Pa.

PLATE 16



EXPLANATION OF PLATE 17

Figure 1 — Devonochonetes (?) lineatus (Vanuxem). Pedicle valve exteriors of several individuals, showing fine costellae; x1.2. Onondaga Limestone (Seneca Member), Y3, Nedrow, Onondaga Co., N.Y.

Figure 2 — Longispina mucronatus (Hall). Interior of brachial valve, showing adductor muscle scars and cardinal process; x1.5. Onondaga Limestone (Echo Lake Member), P1-1, Echo Lake, Monroe Co., Pa.

Figure 3,4 — Anoplia nucleata (Hall)

3. Exterior of pedicle valve, showing small size and smooth surface; x1.3. Needmore Formation (calcareous shale member), P52-12, Newton Hamilton, Mifflin Co., Pa.
4. Exterior of pedicle valve, showing strong convexity; x2. Needmore Formation (calcareous shale member), P36 (float), Montoursville, Lycoming Co., Pa.

Figure 5 — Eodevonaria arcuata (Hall). Internal mold of pedicle valve, showing strong convexity and impression of costellae; x1.6. Schoharie-Esopus formations, undivided, P18, Kunkletown, Monroe Co., Pa.

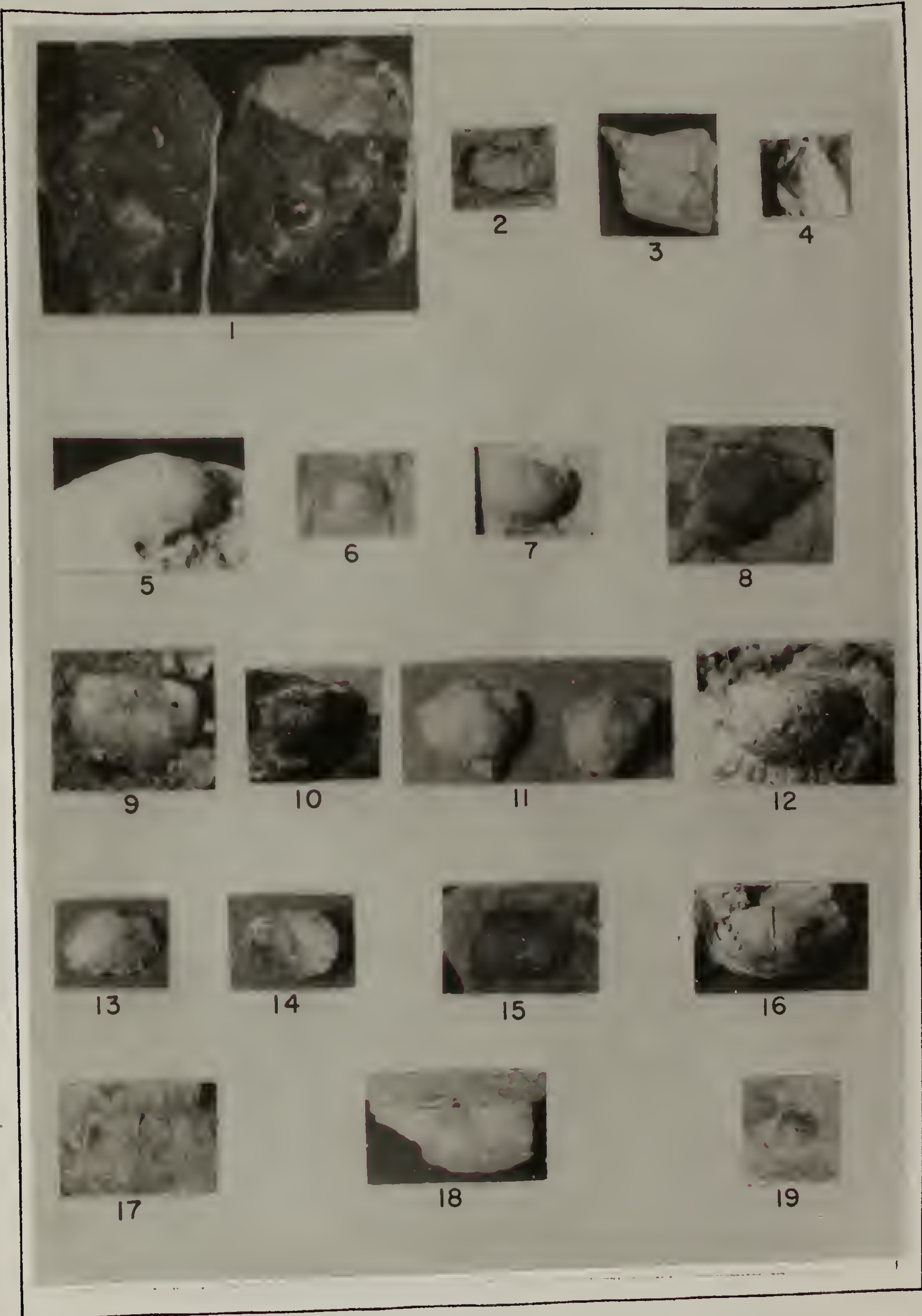
Figure 6-8 — Eodevonaria elymencheri (Boucot and Harper)

6. Internal mold of pedicle valve, showing median septum; x1.2. Onondaga Limestone, P20, Palmerton, Carbon Co., Pa.
7. Internal mold of pedicle valve, showing prominent median septum, and impression of lateral costellae; x1.25. Onondaga Limestone, P22-32, West Bowmans, Carbon Co., Pa.
8. Internal mold of pedicle valve, showing denticulate hinge line; x1.8. Onondaga Limestone, same locality and unit as 7.

Figure 9-18 — Eodevonaria sp.

9. Exterior of silicified pedicle valve; x2. Onondaga Limestone (Echo Lake Member), P1-13, Echo Lake, Monroe Co., Pa.

PLATE 17



10. Exterior of pedicle valve, showing fine costeliae; x1.3. Onondaga Limestone, P28-2, Moyers, Schuylkill Co., Pa.
11. Pedicle valve exteriors of two complete specimens; x1.3. Needmore Formation (calcareous shale member), P31-10, Selinsgrove Junction, Northumberland Co., Pa.
12. Exterior of pedicle valve; x1.5. Needmore Formation (calcareous shale member), P36-12, Montoursville, Lycoming Co., Pa.
13. Pedicle valve exterior of a complete individual; x1.1. Needmore Formation (calcareous shale member), P36-10, Montoursville, Lycoming Co., Pa.
14. Exterior of brachial valve of same specimen as 13, showing deep convexity; x1.1.
15. Internal mold of brachial valve, showing lateral septa and denticulate hinge line; x1.2. Needmore Formation (calcareous shale member), P35-2, Lewisburg, Union Co., Pa.
16. Internal mold of pedicle valve; x1.2. Needmore Formation (calcareous shale member), same locality and unit as 15.
17. Internal mold of pedicle valve; x1.9. Needmore Formation (calcareous shale member), same locality and unit as 15 and 16.
18. View of brachial valve interior and interarea of pedicle valve, showing denticulate hinge line and delthyrium (pedicle valve); x1.3. Needmore Formation (calcareous shale member), same locality and unit as 15, 16, and 17.

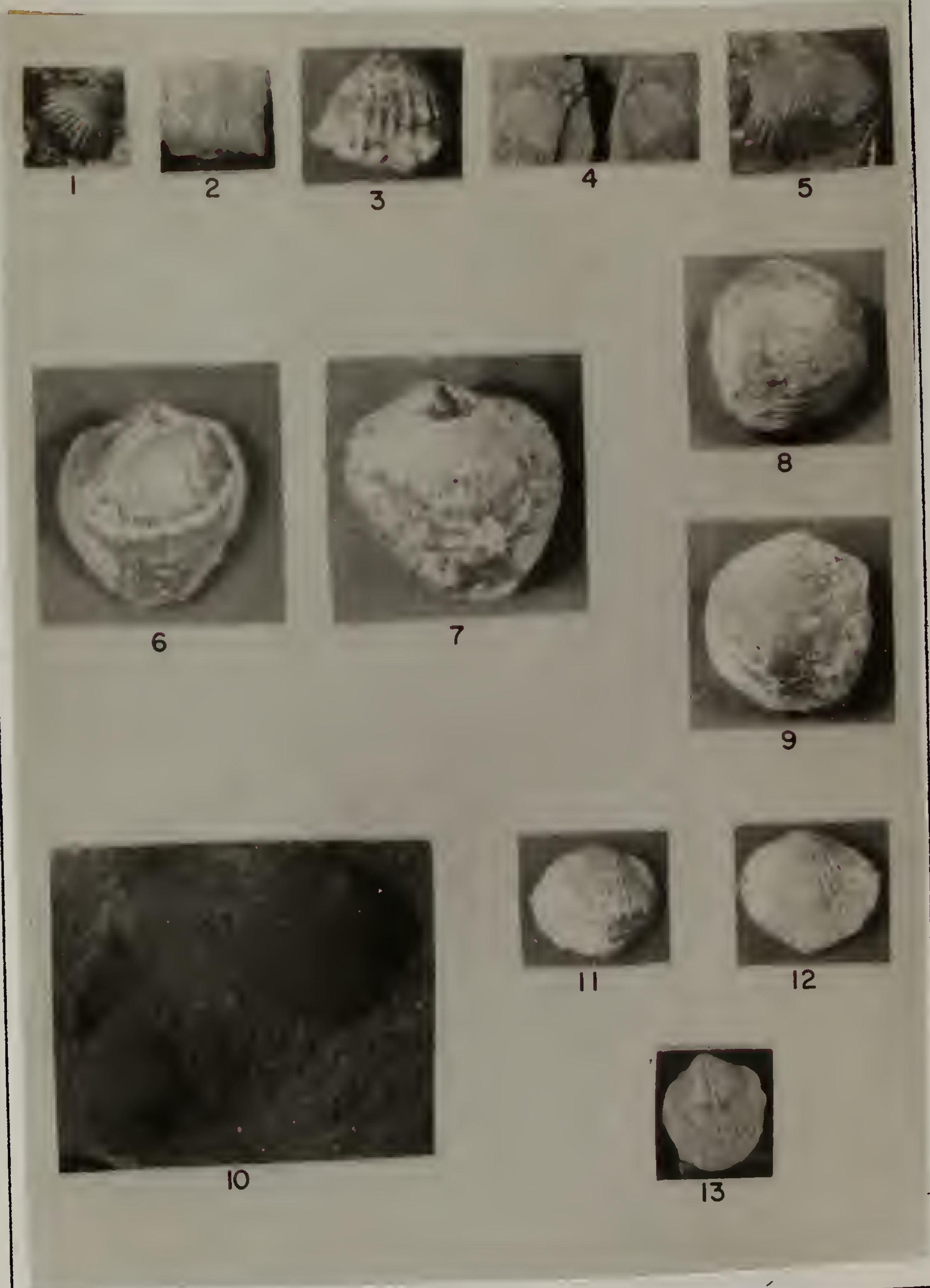
Figure 19 Truncalosia truncata (Hall). Exterior of pedicle valve, showing truncated beak and pustulose spine bases; x2. Needmore Formation (Selinsgrove Limestone Member), P43-67, Old Port, Juniata Co., Pa.

EXPLANATION OF PLATE 18

Figure 1-3 Cupulorostrum tethys (Billings)

1. Exterior of pedicle valve, showing non-bifurcating plications and anterior sulcus; x2. Onondaga Limestone (Echo Lake Member), P1-13, Echo Lake, Monroe Co., Pa.

PLATE 18



2. Exterior of pedicle valve; x1.1. Onondaga Limestone (Edgecliff Member), Y9, Hannacroix, Greene Co., N.Y.
3. Anterior view of pedicle valve, showing non-bifurcating plications; x1.1. Onondaga Limestone (Moorehouse Member), Y5, Schoharie, Schoharie Co., N.Y.

Figure 4 — Leiorhynchus limitare (Vanuxem). Internal molds of two crushed pedicle valves, showing median septum; x1.1. Marcellus Formation, P29, Swatara Gap, Lebanon Co., Pa.

Figure 5 — Leiorhynchus multicostum (Hall). Exterior of pedicle valve, showing shallow sulcus that bears 6 or 7 plications; x1. Marcellus Formation (Cherry Valley Limestone Member), Y4, Cherry Valley, Otsego Co., N.Y.

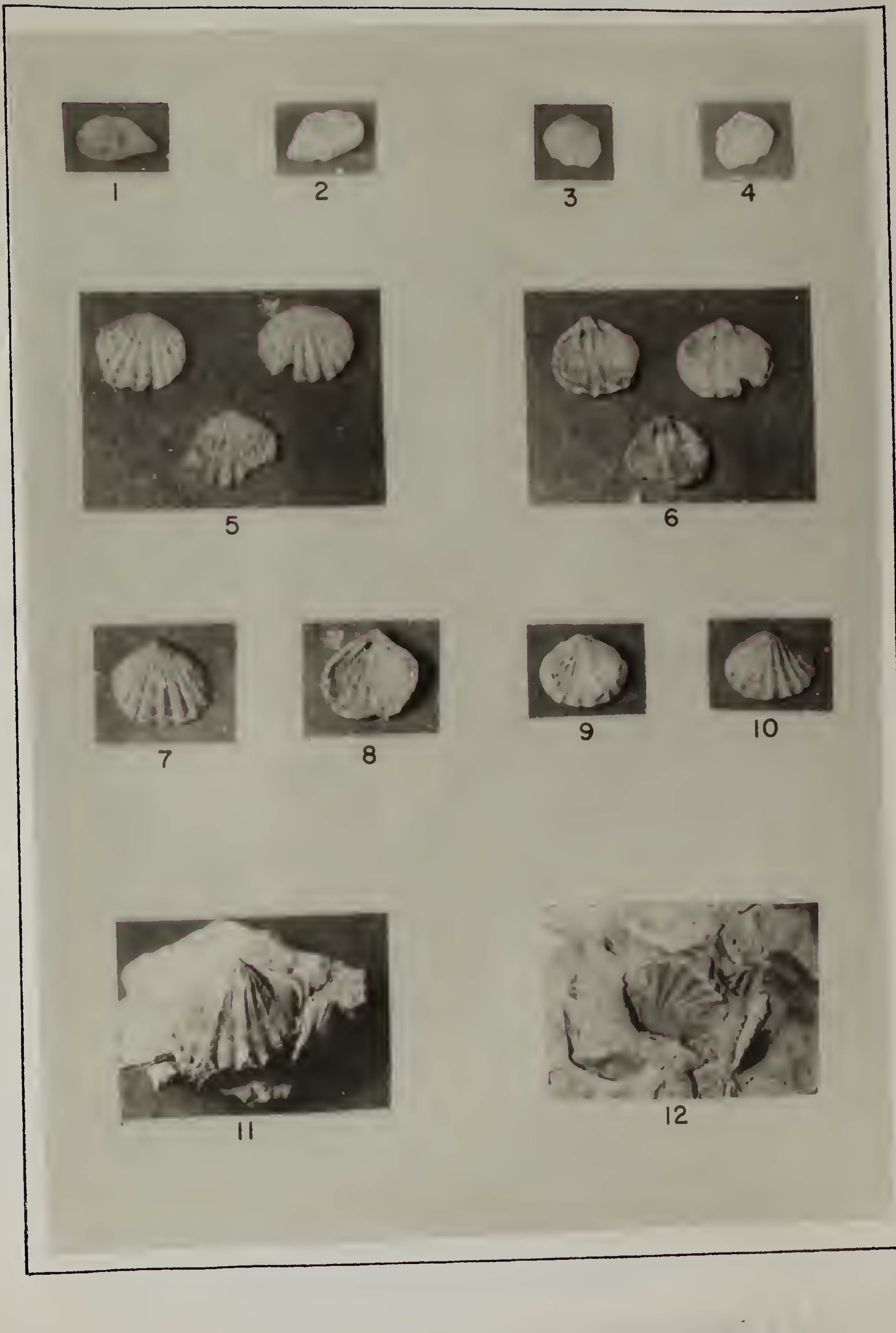
Figure 6-10 — Atrypa reticularis (Linnaeus)

6. Exterior of brachial valve, showing gibbosity, typical costation, and closely spaced growth lines near anterior commissure; x1.1. Schoharie Formation (Saugerties Member), Y13, Catskill, Greene Co., N.Y.
7. Exterior of pedicle valve, showing depressed convexity; x1.2. Same specimen as 6.
8. Exterior of brachial valve, showing finer costation than previous figures; x1.2. Schoharie Formation (Saugerties-Aquetuck members, undivided), Y21, Trilobite Mountain, Orange Co., N.Y.
9. Exterior of pedicle valve; x1.2. Same specimen as 8.
10. Exterior of two brachial valves; x1.4. Jeffersonville Limestone (Brevispirifer zone), K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

Figure 11-13 — Spinatrypa spinosa (Hall)

11. Exterior of brachial valve, showing relatively coarse costae and nodose surface; x1. Onondaga Limestone (Moorehouse Member), Y1, Stafford, Genesee Co., N.Y.
12. Exterior of pedicle valve, showing nodes (spine bases) at intersection of costae and growth lamellae; x1. Same specimen as 11.
13. Exterior of pedicle valve, showing typical costae and nodes; x1.25. Onondaga Limestone (Moorehouse Member), Y5, Schoharie, Schoharie Co., N.Y.

PLATE 19



EXPLANATION OF PLATE 19

Figure 1-10 Coelospira camilla (Hall)

1. Exterior of brachial valve, showing suboval outline; x1.1. Schoharie Formation (Carlisle Center Member), Y11-4, Leeds, Greene Co., N.Y.
2. Exterior of pedicle valve; x1.1. Same specimen as 1.
3. Exterior of brachial valve, showing low median fold; x1.1. Needmore Formation (calcitic shale subfacies), P63-4, Warfordsburg, Fulton Co., Pa.
4. Exterior of pedicle valve, showing sulcus; x1.1. Same specimen as 3.
5. Exteriors of three brachial valves, showing plications and strong growth lamellae; x1.25. Onondaga Limestone, P26-12, Schuylkill Haven, Schuylkill Co., Pa.
6. Interiors of same three brachial valves as 5, showing thick, triangular cardinal processes and deep muscle impressions; x1.25.
7. Pedicle valve exterior; x1.1. Onondaga Limestone, same locality and unit as 5 and 6.
8. Interior view of same pedicle valve as 7, showing long, widely divergent hinge teeth; x1.1.
9. Brachial view of articulated shell; x1.25. Onondaga Limestone, same locality and unit as 5, 6, 7, and 8.
10. Pedicle view of same specimen as 9; x1.25.

Figure 11,12 Leptocoelia flabellites (Conrad)

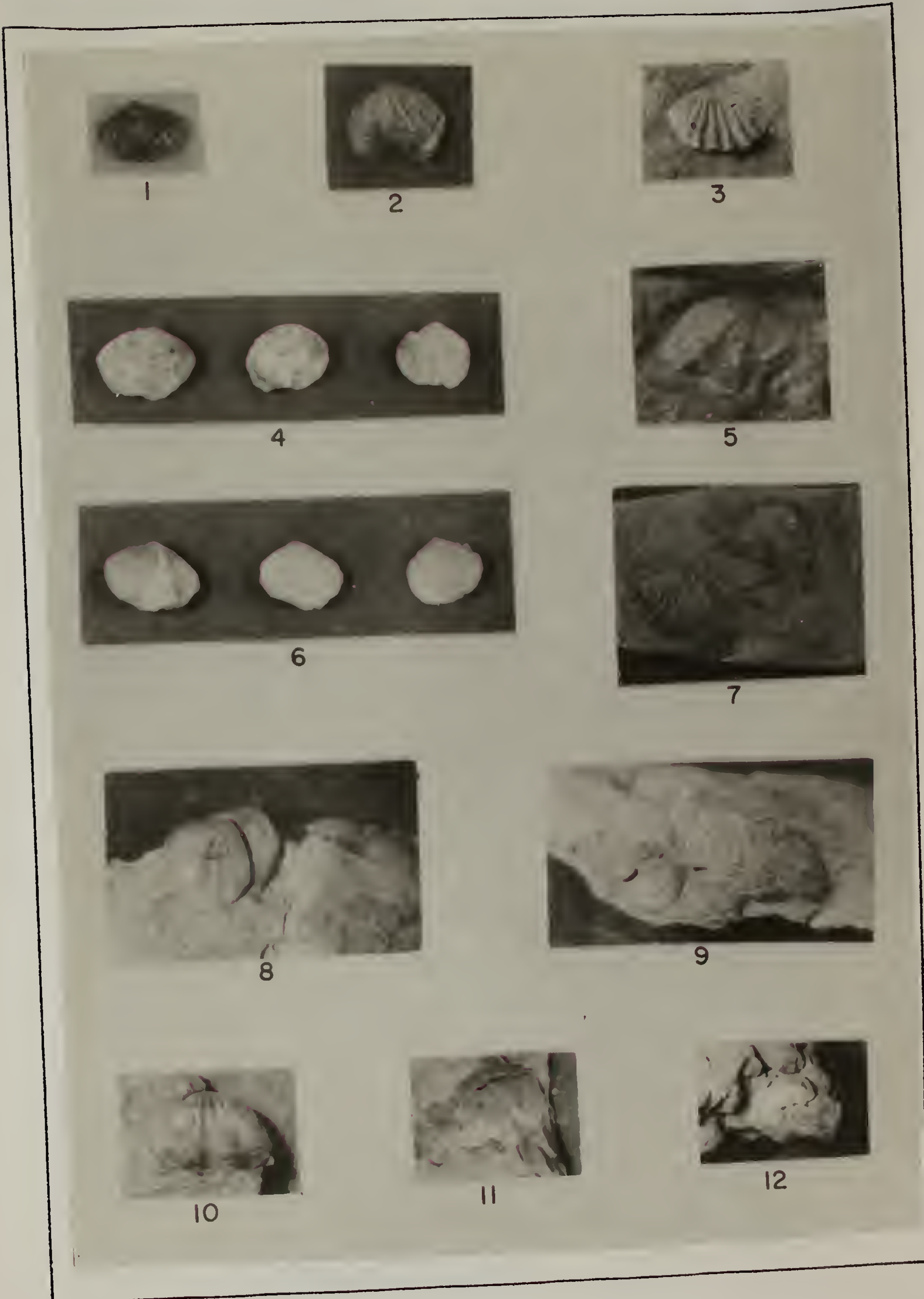
11. Internal mold of pedicle valve, showing strong plications and prominent diductor muscle scars; x1.5. Esopus Formation (Highland Mills Member), Y25, Highland Mills, Orange Co., N.Y.
12. External mold of brachial valve; x1. Schoharie-Esopus formations, undivided, P24-4, Stony Mountain School, Carbon Co., Pa.

EXPLANATION OF PLATE 20

Figure 1-12 Leptocoelina acutiplicata (Conrad)

1. Pedicle view of a pyritized specimen, showing broad sulcus and few lateral plications; x1. Needmore Formation (calcareous shale member), P35-2, Lewisburg, Union Co., Pa.

PLATE 20



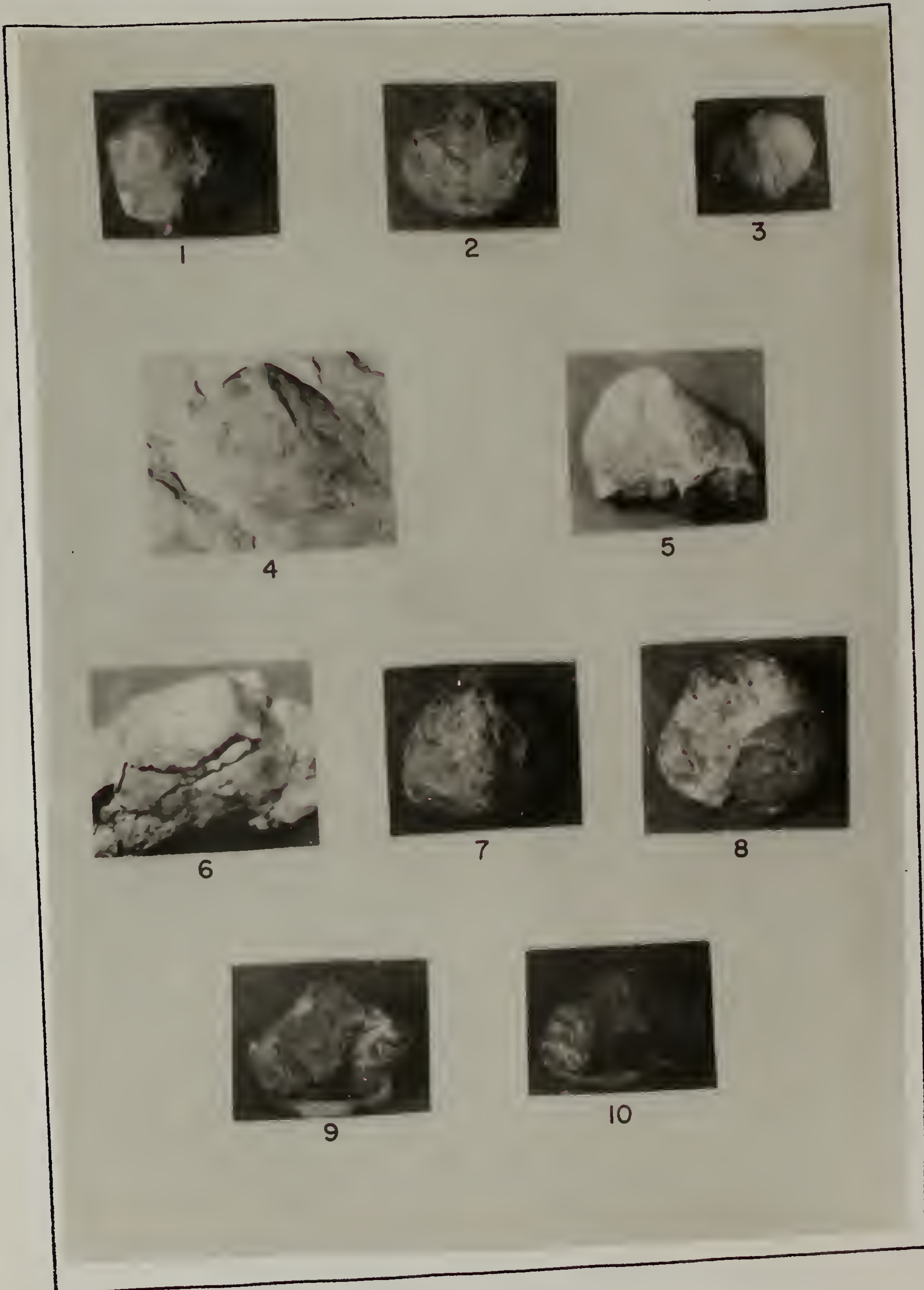
2. Exterior of pedicle valve, showing an abrupt deflection of sulcus at anterior commissure; x1.25. Needmore Formation (calcareous shale member), P52-8, Newton Hamilton, Mifflin Co., Pa.
3. Exterior of brachial valve (somewhat flattened), showing strong plications and distinct growth lamellae; x1. Needmore Formation (Selinsgrove Limestone Member), P58-10, Orbisonia, Huntingdon Co., Pa.
4. Exteriors of three brachial valves; x1.1. Needmore Formation (calcareous shale member), P52-6, Newton Hamilton, Mifflin Co., Pa.
5. Exteriors of pedicle valves; x1.1. Same specimens as 4.
6. Exterior of pedicle valve, showing broad sulcus; x1.1. Needmore Formation (calcareous shale member), P52-9, Newton Hamilton, Mifflin Co., Pa.
7. Several specimens, perhaps in growth position in argillaceous limestone; x1. Needmore Formation (calcareous shale member), P52-12, Newton Hamilton, Mifflin Co., Pa.
8. Cluster of several specimens, probably in growth position; x1. Needmore Formation (calcareous shale member), P35-2, Lewisburg, Union Co., Pa.
9. Another view of same cluster as 8; x1.
10. Exterior of pedicle valve, showing median sulcus and rounded plications on lateral flanks; x1.4. Needmore Formation (calcitic shale subfacies), M2-2, Flintstone, Allegany Co., Md.
11. Internal mold of pedicle valve, showing impressions of teeth; x1. Needmore Formation (calcareous shale member), P35-2, Lewisburg, Union Co., Pa.
12. Exterior of pedicle valve, showing median sulcus and weak plications; x1. Schoharie Formation (Carlisle Center Member), Y17-4, Kingston, Ulster Co., N.Y.

EXPLANATION OF PLATE 21

Figure 1-3 Meristella cf. M. lata (Hall)

1. Dorsal view of a steinkern, showing prominent median septum; x1. Shriver Chert, P35 (float), Lewisburg, Union Co., Pa.
2. Ventral view of the same steinkern as 1, showing strong, longitudinally striate diductor muscle scars and shallow sulcus; x1.

PLATE 21



3. Pedicle view of a smaller steinkern, showing diductor scars and sulcus; x1. Shriver Chert, same locality as 1 and 2.

Figure 4 Meristina nasuta (Conrad). Internal mold of a pedicle valve, showing subtrigonal outline and strong muscle impressions; x0.9. Schoharie-Esopus formations, undivided, P23, Germans, Carbon Co., Pa.

Figure 5-10 Pentagonia unisulcata (Conrad)

5. Pedicle valve, showing broad, flaring sulcus; x1.1. Onondaga Limestone, P28-2, Moyers, Schuylkill Co., Pa.
6. Pedicle valve; x1.2. Onondaga Limestone, same locality and unit as 5.
7. Brachial view of an articulated specimen, showing sharp median fold; x1.1. Onondaga Limestone, same locality and unit as 5 and 6.
8. Pedicle view of the same specimen as 7, showing pentagonal outline and broad sulcus; x1.2.
9. Anterior view of the same specimen as 7 and 8, showing uniplicate anterior commissure; x1.2.
10. Posterior view of the same specimen as 7, 8, and 9, showing narrow depression in brachial fold; x1.2.

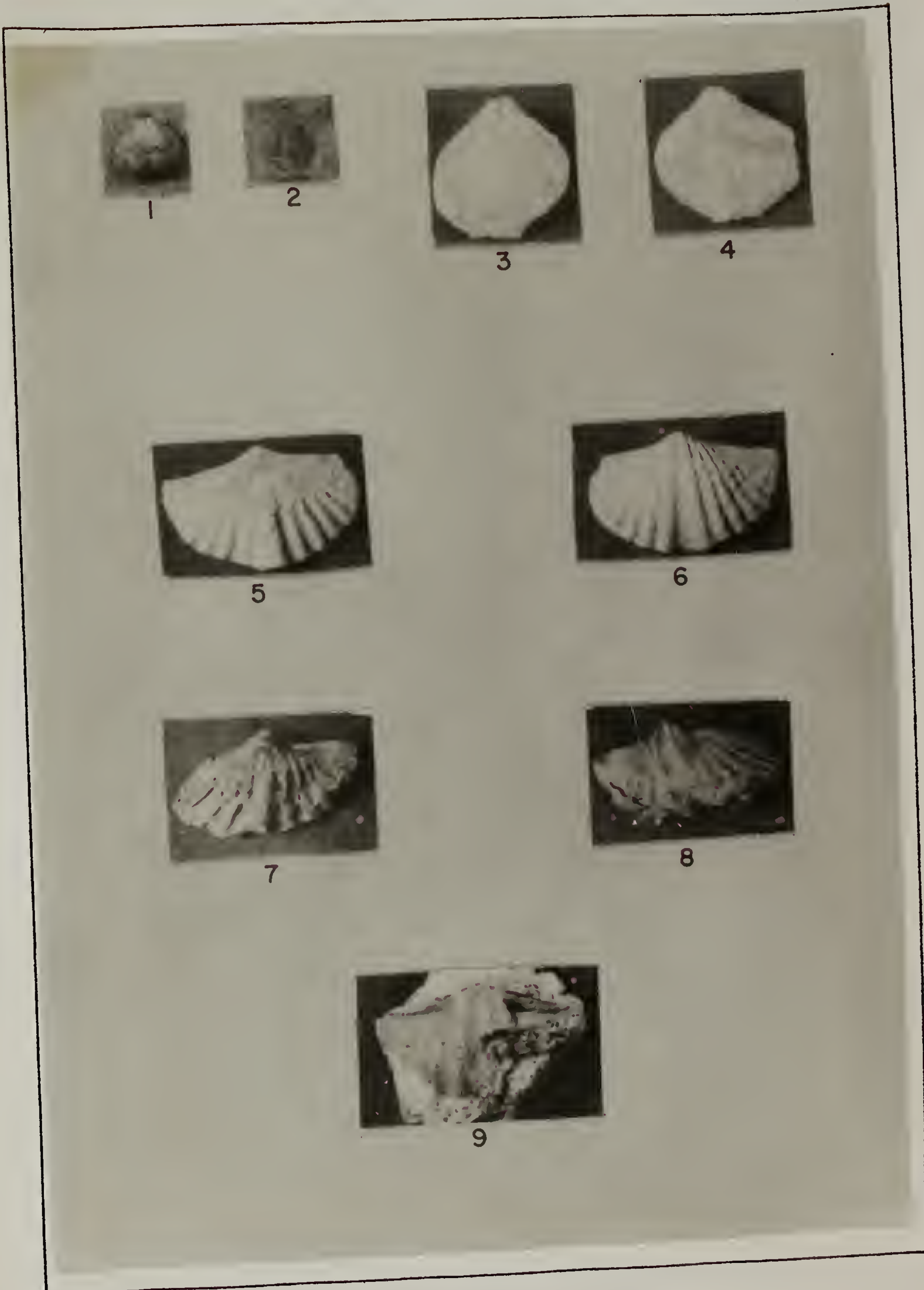
EXPLANATION OF PLATE 22

Figure 1,2 Ambocoelia umbonata (Conrad)

1. Pedicle valve exterior of a complete individual, showing strongly elevated beak and shallow sulcus; x1.4. Needmore Formation (calcitic shale and limestone subfacies), M2-8, Flintstone, Allegany Co., Md.
2. Exterior of pedicle valve, showing shallow sulcus that extends from beak to anterior commissure; x1. Needmore Formation (calcitic shale subfacies), P63-6, Warfordsburg, Fulton Co., Pa.

Figure 3,4 Cyrtinaella biplicata (Hall)

3. Pedicle valve exterior of a complete individual, showing elevated beak and deep sulcus; x1. Onondaga Limestone (Edgecliff Member), Y9, Hannacroix, Greene Co., N.Y.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4. Another view of same individual as 3, showing prominent fold on brachial valve and high, triangular interarea and narrow, convex pseudodeltidium on pedicle valve; x1.

Figure 5-9 Acrospirifer murchisoni (Castelnau)

5. Dorsal view of silicified specimen, showing eight plications of lateral slopes and bald fold; x1. Shriver Chert, P36A, Montoursville, Lycoming Co., Pa.
6. Ventral view of the same specimen as 1, showing plicated lateral slopes and bald sulcus; x1.
7. Dorsal view of a steinkern (distorted); x1.1. Shriver Chert, P37A, Selinsgrove, Snyder Co., Pa.
8. Ventral view of the same steinkern, showing strong diductor muscle impressions; x1.1.
9. Internal mold of a pedicle valve, showing strong muscle impressions and moderately wide triangular interarea; x1.3. Ridgeley Sandstone, P36A, Montoursville, Lycoming Co., Pa.

EXPLANATION OF PLATE 23

Figure 1-7 Acrospirifer duodenaria (Hall)

1. Internal molds of several pedicle valves, showing 6 to 8 plications on each flank; x1. Schoharie-Esopus formations, undivided, P24-4, Stony Mountain School, Carbon Co., Pa.
2. Internal mold of brachial valve, showing fold with median depression; x1.3. Schoharie-Esopus formations, undivided, same locality and unit as 1.
3. Internal mold of pedicle valve, showing broad sulcus; x1.25. Schoharie-Esopus formations, undivided, P22-8, West Bowmans, Carbon Co., Pa.
4. Internal mold of brachial valve, showing narrow, elevated fold; x1.2. Schoharie-Esopus formations, undivided, same locality and unit as 3.
5. Internal mold of pedicle valve, showing impression of muscle scars; x1. Schoharie-Esopus formations, undivided, P19-8, Little Gap, Carbon Co., Pa.
6. Internal molds of several specimens; x1. Schoharie Formation (Saugerties-Aquetuck members, undivided), P7-6, Buttermilk Falls, Monroe Co., Pa.

PLATE 23

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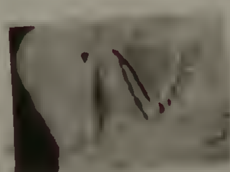

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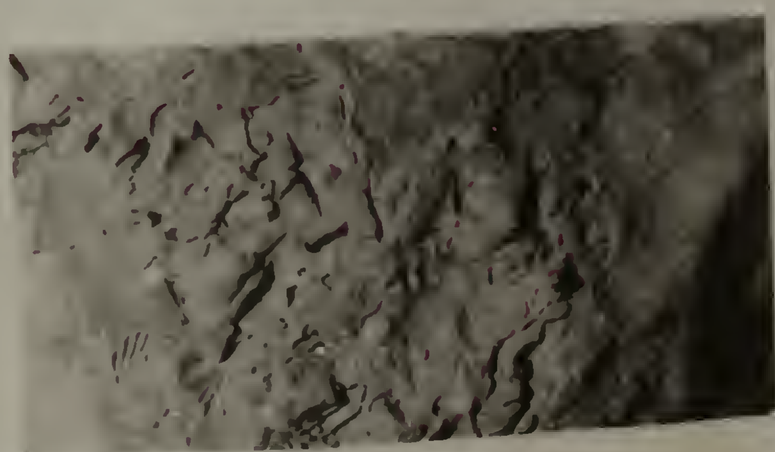


7

7. Slab with many internal and external molds; x1. Schoharie Formation (Saugerties-Aquetuck members, undivided), same locality and unit as 6.

EXPLANATION OF PLATE 24

Figure 1,2 Hysterolites (?) sp.

1. Internal mold of brachial valve (distorted), showing narrow elevated fold and 7 or 8 lateral plications; x1.3. Esopus Formation, P8-1, Brodhead Creek, Monroe Co., Pa.
2. Side view of same internal mold as 1, showing extreme elevation of fold; x1.3.

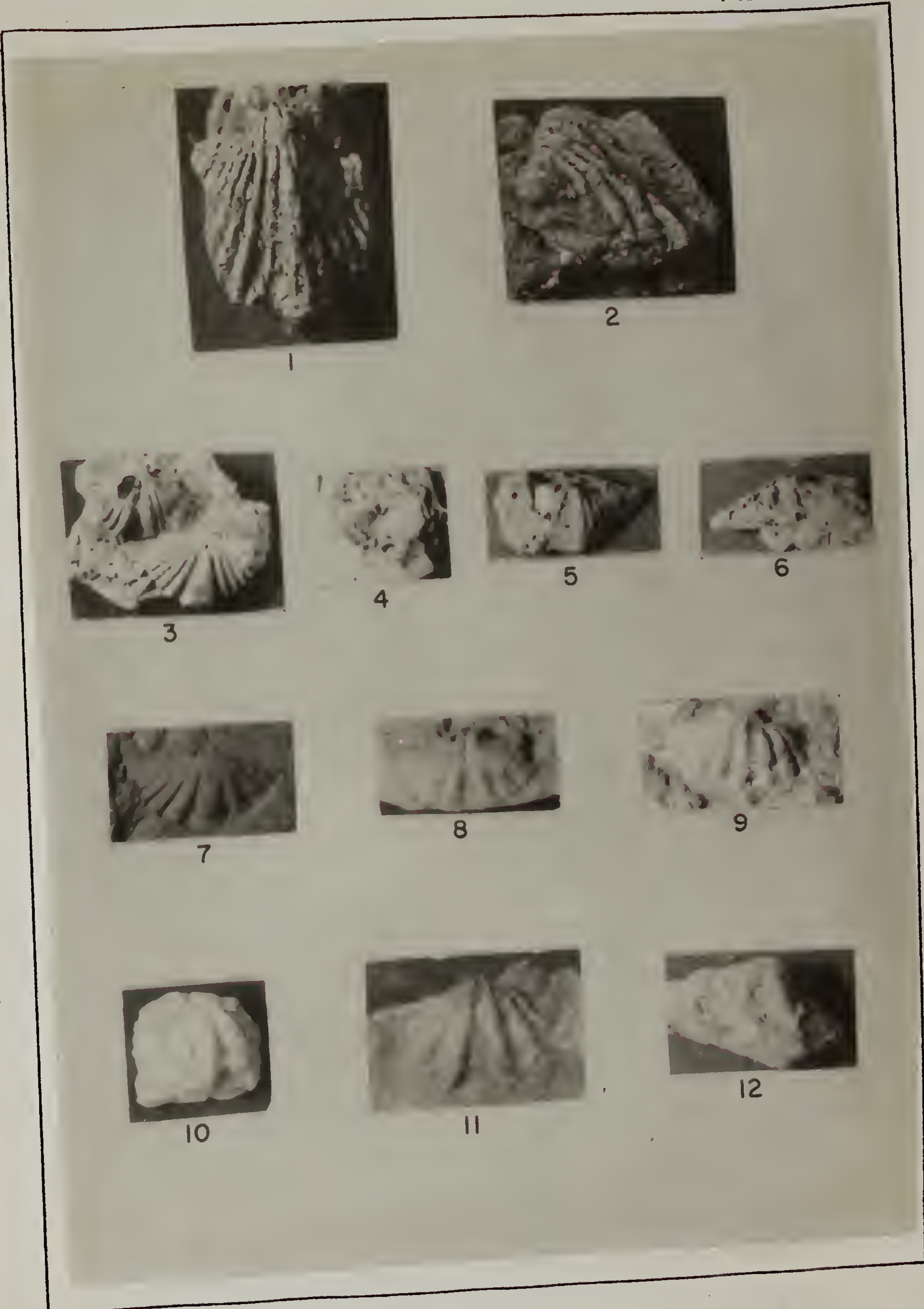
Figure 3-6 Acrospirifer varicosus (Hall)

3. Exterior of silicified pedicle (top) and brachial valves, showing 6 to 8 lateral plications; x1.5. Onondaga Limestone (Echo Lake Member), P1-13, Echo Lake, Monroe Co., Pa.
4. Interior of pedicle valve, showing short dental plates; x1.4. Onondaga Limestone (Echo Lake Member), same locality and unit as 3.
5. Exterior of silicified pedicle valve, showing broad sulcus and about 10 lateral plications; x1.1. Onondaga Limestone (Echo Lake Member), same locality and unit as 3 and 4.
6. Posterior view of same pedicle valve as 3, showing high interarea and impression of dental plates; x1.1.

Figure 7-12 Kozlowskiellina (Megakozlowskiella) raricosta (Conrad)

7. Internal mold of brachial valve, showing fold and 4 or 5 lateral plications; x1. Onondaga Limestone, P22-32, West Bowmans, Carbon Co., Pa.
8. Internal mold of pedicle valve, showing impression of diductor scars in beak area; x1. Onondaga Limestone, same locality and unit as 7.
9. Exterior of pedicle valve; x1. Onondaga Limestone (Nedrow Member), Y9, Hannacroix, Greene Co., N.Y.
10. Exterior of pedicle valve; x1.25. Onondaga Limestone (Nedrow Member), same locality as 9.
11. Exterior of pedicle valve, showing sulcus bounded by elevated plications; x1. Onondaga Limestone (Moorehouse Member), Y6, Berne, Albany Co., N.Y.

PLATE 24



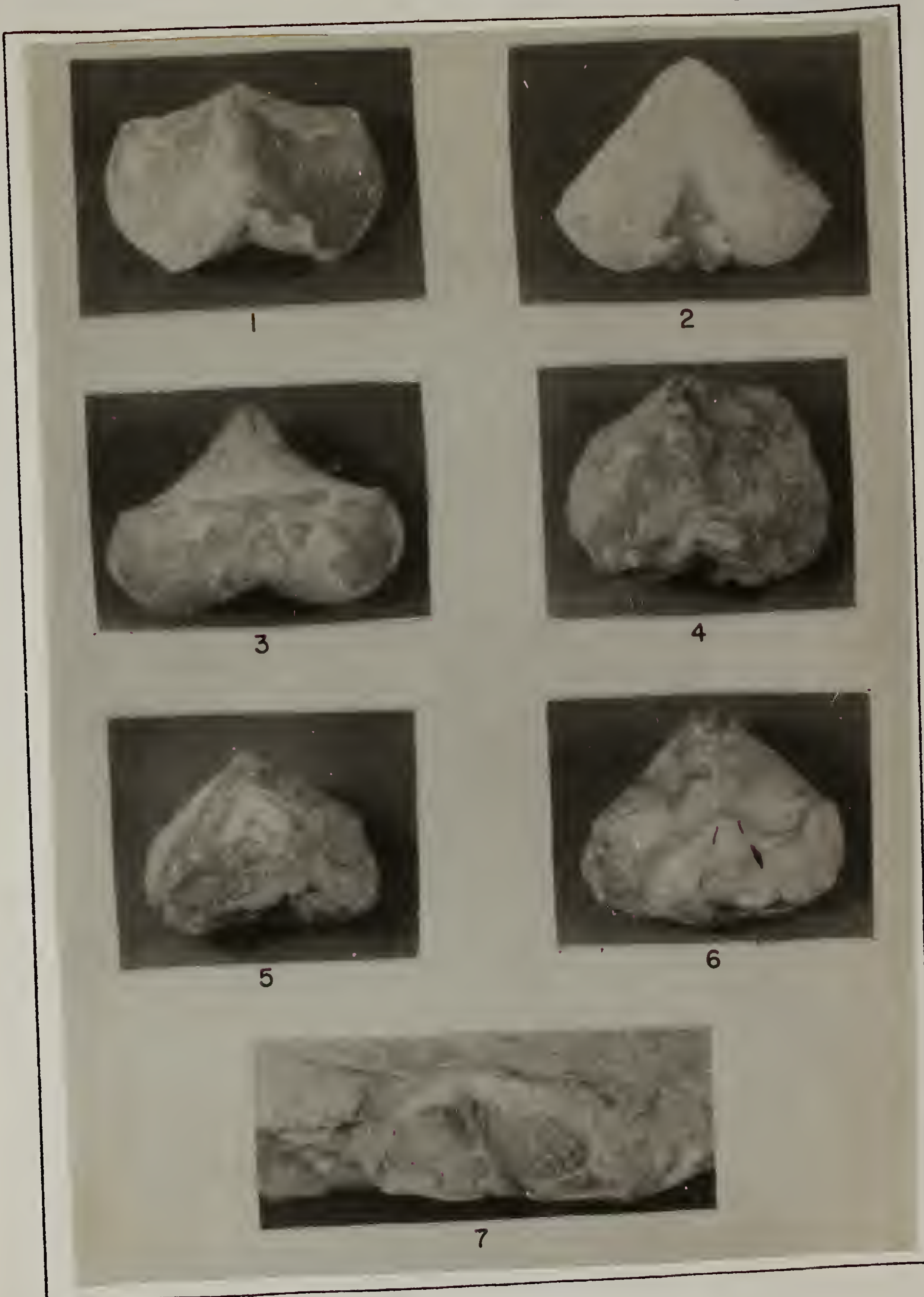
12. Exterior of pedicle valve; x1.1. Needmore Formation (calcareous shale member), P31-10, Selinsgrove Junction, Northumberland Co., Pa.

EXPLANATION OF PLATE 25

Figure 1-7 Paraspirifer acuminatus (Conrad)

1. Exterior of brachial valve, showing smooth, carinate fold and low, wide lateral costae; x1.1. Onondaga Limestone (Moorehouse Member), Y1, Stafford, Genesee Co., N.Y.
2. Anterior view of same specimen as 1, showing sharply carinate profile and smooth, broad sulcus on pedicle valve; x1.1.
3. Posterior view of same specimen as 1 and 2, showing carinate fold on brachial valve and broad sulcus and low interarea on pedicle valve; x1.2.
4. Exterior of brachial valve, showing typical carinate fold; x1.1. Onondaga Limestone (upper part), P27-4, Auburn, Schuylkill Co., Pa.
5. Anterior view of same specimen as 4, showing carinate fold on brachial valve; x1.
6. Posterior view of same specimen as 4 and 5 (partially an internal mold), showing impressions of well-developed dental plates; x1.1.
7. Exterior of pedicle valve, showing broad, smooth sulcus and low, wide lateral costae; x1. Onondaga Limestone (Echo Lake Member), P13-4, Stroudsburg, Monroe Co., Pa.

PLATE 25



EXPLANATION OF PLATE 26

Figure 1-3 Mucrospirifer macra (Hall)

1. Exterior of pedicle valve, showing narrow fold and numerous lateral plications; x1. Schoharie-Esopus formations, undivided, P18, Kunkletown, Monroe Co., Pa.
2. Internal mold of pedicle valve, showing deep sulcus; x1.5. Schoharie-Esopus formations, undivided, same locality as 1.
3. Exterior of pedicle valve, showing deep sulcus and numerous lateral plications; x1.3. Schoharie-Esopus formations, undivided, same locality as 1 and 2.

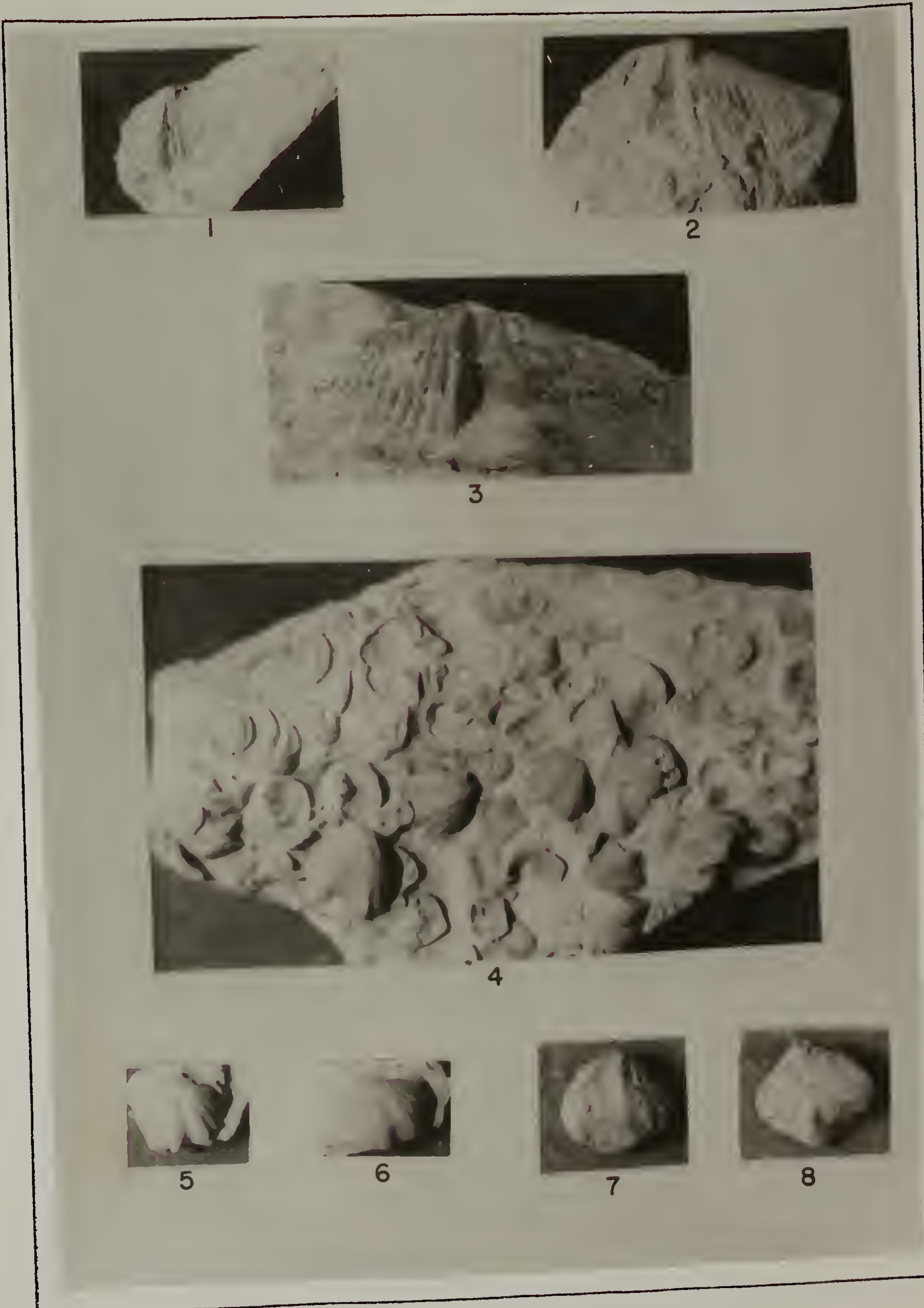
Figure 4-6 Brevispirifer gregarius (Clapp)

4. Slab with many silicified pedicle valves; x1. Jeffersonville Limestone (Brevispirifer zone), K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.
5. Exterior of silicified pedicle valve, showing bald sulcus bounded by strong plications with somewhat narrower plications on flanks; x1. Jeffersonville Limestone (Brevispirifer zone), same locality as 4.
6. Exterior of silicified pedicle valve; x1. Jeffersonville Limestone (Brevispirifer zone), same locality as 4 and 5.

Figure 7-8 Unidentified spiriferinid

7. Exterior of pedicle valve, showing broad, flaring sulcus; x1. Needmore Formation (calcareous shale member), P35-7, Lewisburg, Union Co., Pa.
8. Dorsal view of same specimen as 4, showing prominent fold on brachial valve and high interarea on pedicle valve; x1.

PLATE 26



EXPLANATION OF PLATE 27

Figure 1 — Fimbrispirifer divaricatus (Hall). Exterior of pedicle valve, showing costate sulcus; x1.5. Onondaga Limestone (Edgecliff Member), Y9, Hannacroix, Greene Co., N.Y.

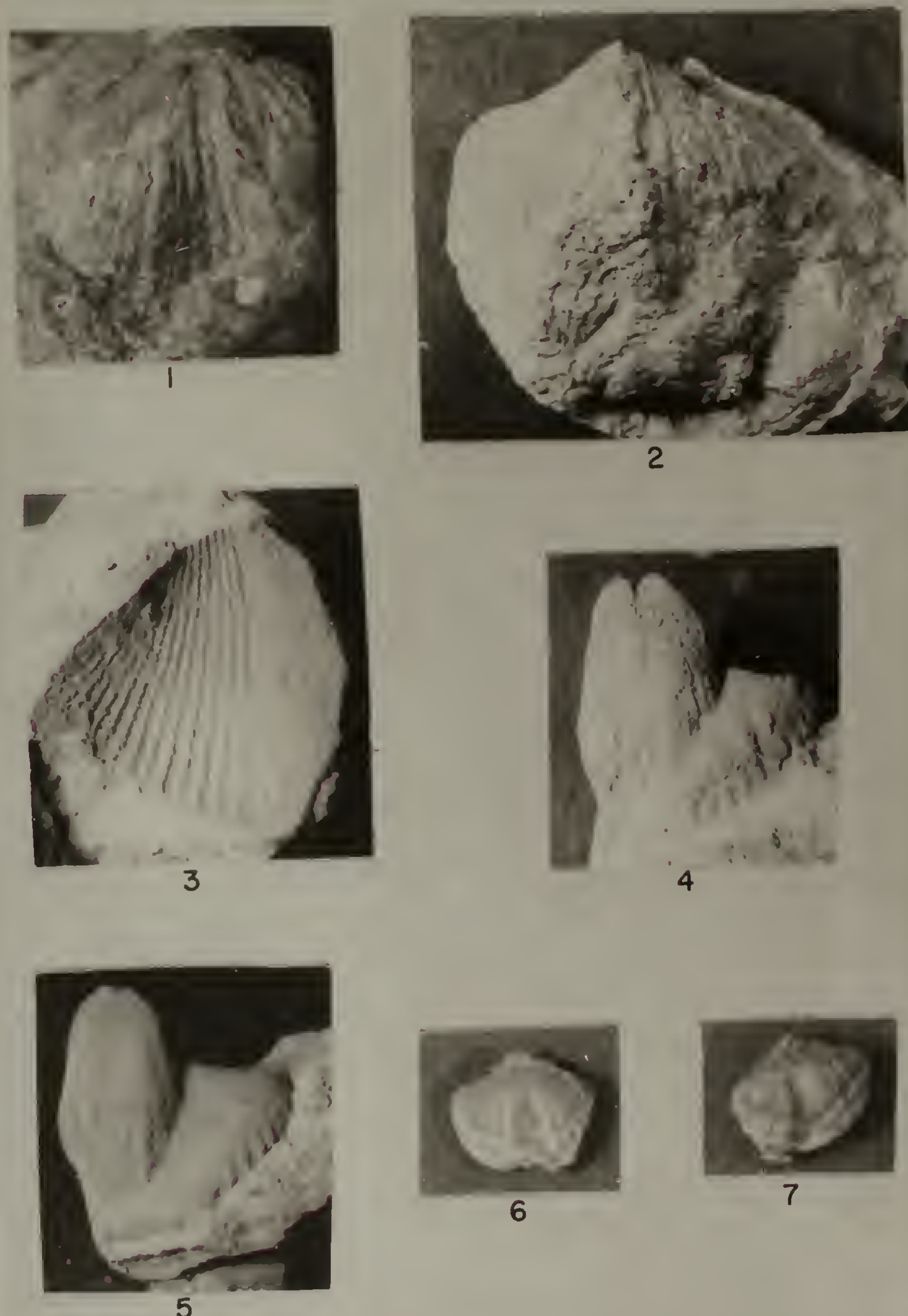
Figure 2-5 — Costispirifer arenosus (Conrad)

2. Internal mold of brachial valve, showing large size and typical lateral costation; x1. Ridgeley Sandstone, P36, Montoursville, Lycoming Co., Pa.
3. External mold of pedicle valve, showing costate sulcus (on right side); x1.2. Ridgeley Sandstone, P36A, Montoursville, Lycoming Co., Pa.
4. Internal mold of pedicle valve, showing massive diductor muscle scars; x1.1. Same individual as 3.
5. Internal mold of pedicle valve, showing diductor muscle scars; x1. Ridgeley Sandstone, same locality as 3 and 4.

Figure 6,7 — Elita fimbriata (Conrad)

6. Brachial view of steinkern, showing bald fold and lateral plications; x1.2. Onondaga Limestone, P26-12, Schuylkill Haven, Schuylkill Co., Pa.
7. Pedicle view of the same steinkern as 6, showing bald sulcus and muscle scars; x1.2.

PLATE 27



EXPLANATION OF PLATE 28

Figure 1-3 Rensselaeria elongata (Conrad)

1. Internal mold of brachial valve, showing impression of large cardinal process; x1. Ridgeley Sandstone, P36A, Montoursville, Lycoming Co., Pa.
2. Internal mold of brachial valve, showing impression of growth lamellae; x1.6. Ridgeley Sandstone, M3, LaVale, Allegany Co., Md.
3. Exterior of pedicle valve, showing rounded costellae; x1. Fossiliferous limestone above Ridgeley Sandstone, P43, Old Port, Juniata Co., Pa.

Figure 4 Amphigenia elongata (Vanuxem). Exterior of pedicle valve, showing strong convexity and widely spaced concentric growth lines; x1. Needmore Formation (Selinsgrove Limestone Member), P43-71, Old Port, Juniata Co., Pa.

PLATE 28

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EXPLANATION OF PLATE 29

Figure 1 Platyceras (Platyceras) dumosum (Conrad). Ventral view of rapidly expanding body whorl, showing stout, hollow spines; x1.3. Onondaga Limestone (Moorehouse Member), Y6, Berne, Albany Co., N.Y.

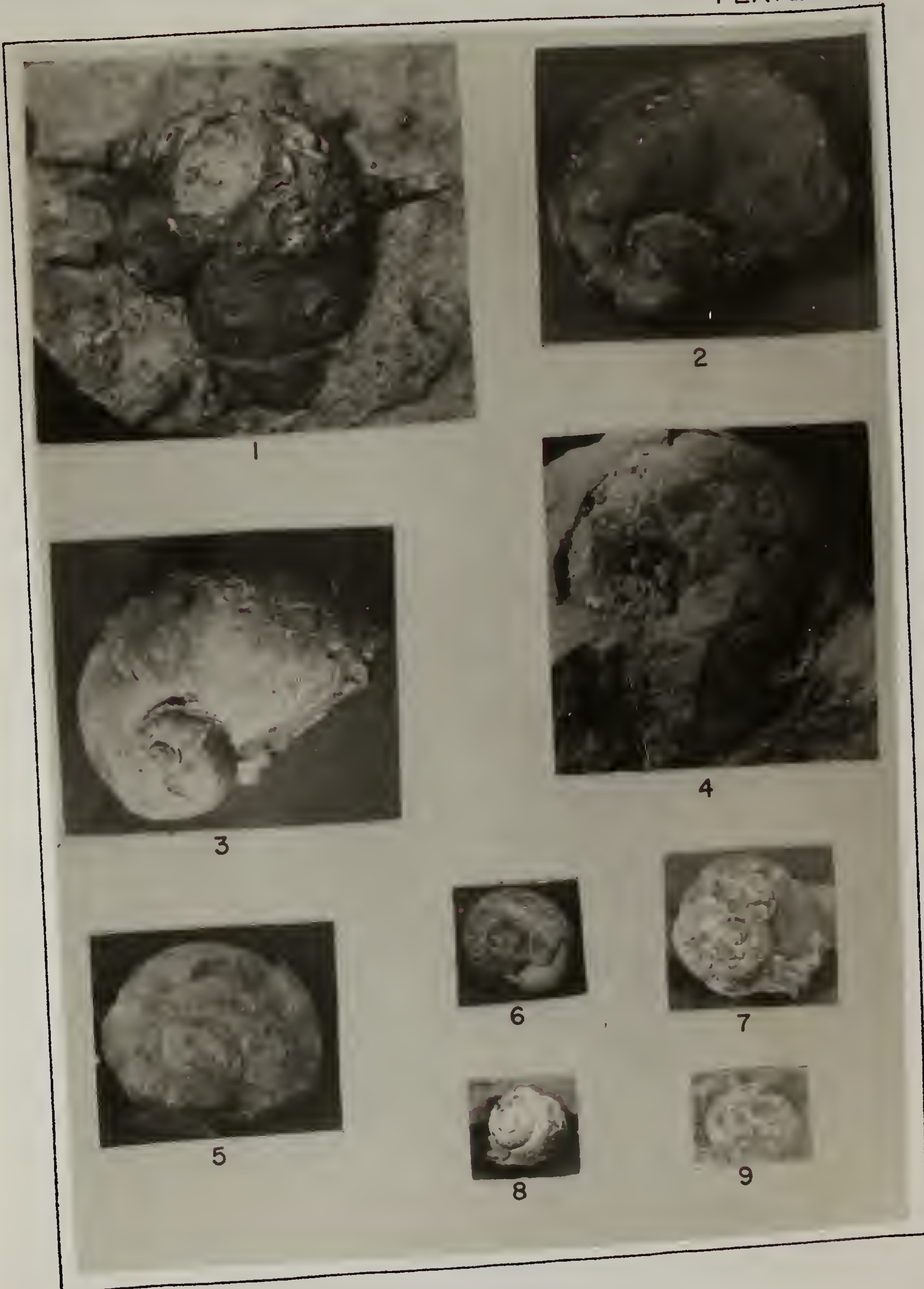
Figure 2-4 Platyceras (Platystoma) ventricosum (Conrad)

2. Apical view of shell, showing dextral coiling and large, ventricose body whorl; x1.1. Shriver Chert (upper part), P37, Globe Mills, Snyder Co., Pa.
3. Apical view of another specimen; x1.3. Shriver Chert (upper part), P41-1, Mt. Pleasant Mills, Snyder Co., Pa.
4. Apical view of internal mold; x1.7. Ridgeley Sandstone, M3, LaVale, Allegany Co., Md.

Figure 5-9 Platyceras (Platystoma) turbinatum (Hall)

5. Apical view of shell, showing dextral coiling and relatively rapidly expanding body whorl (apertural area broken off); x1.3. Onondaga Limestone (Nedrow Member), Y9, Hannacroix, Greene Co., N.Y.
6. Apical view of a smaller specimen; x1.3. Onondaga Limestone (Nedrow Member), same locality as 5.
7. Apical view of a partly broken shell; x1.1. Onondaga Limestone (Nedrow Member), Y13, Catskill, Greene Co., N.Y.
8. Apical view of a small, coarsely crystalline specimen; x1.3. Needmore Formation (Selinsgrove Limestone Member), P52-67, Newton Hamilton, Mifflin Co., Pa.
9. Apical view of another coarsely crystalline specimen; x1.4. Needmore Formation (Selinsgrove Limestone Member), same locality and unit as 8.

PLATE 29



EXPLANATION OF PLATE 30

Figure 1-3 Palaeozygopleura hamiltoniae (Hall).

1. Side view of a pyritized specimen, showing slender, high spire; x1.3. Needmore Formation (calcareous shale member), P61-12, Tyrone, Blair Co., Pa.
2. Fragments of a broken specimen, showing longitudinal costae; x1.4. Needmore Formation (calcareous shale member), P35-6, Lewisburg, Union Co., Pa.
3. Side view of a large specimen; x1. Onondaga Limestone (Moorehouse Member), Y1, Stafford, Genesee Co., N.Y.

Figure 4 Nuculoidea sp. Right valve, showing small size and fine growth lamellae; x1.4. Needmore Formation (calcareous shale member), P52-16, Newton Hamilton, Mifflin Co., Pa.

Figure 5 Praecardium cf. P. multiradiatum (Hall). Part of a valve, showing numerous, flattened costae; x1.2. Needmore Formation (calcitic shale subfacies), M2-7, Flintstone, Allegany Co., Md.

Figure 6 Paracyclas lirata (Conrad). Left valve, showing sharply defined, concentric rugae; x1.4. Onondaga Limestone, P27-2, Auburn, Schuylkill Co., Pa.

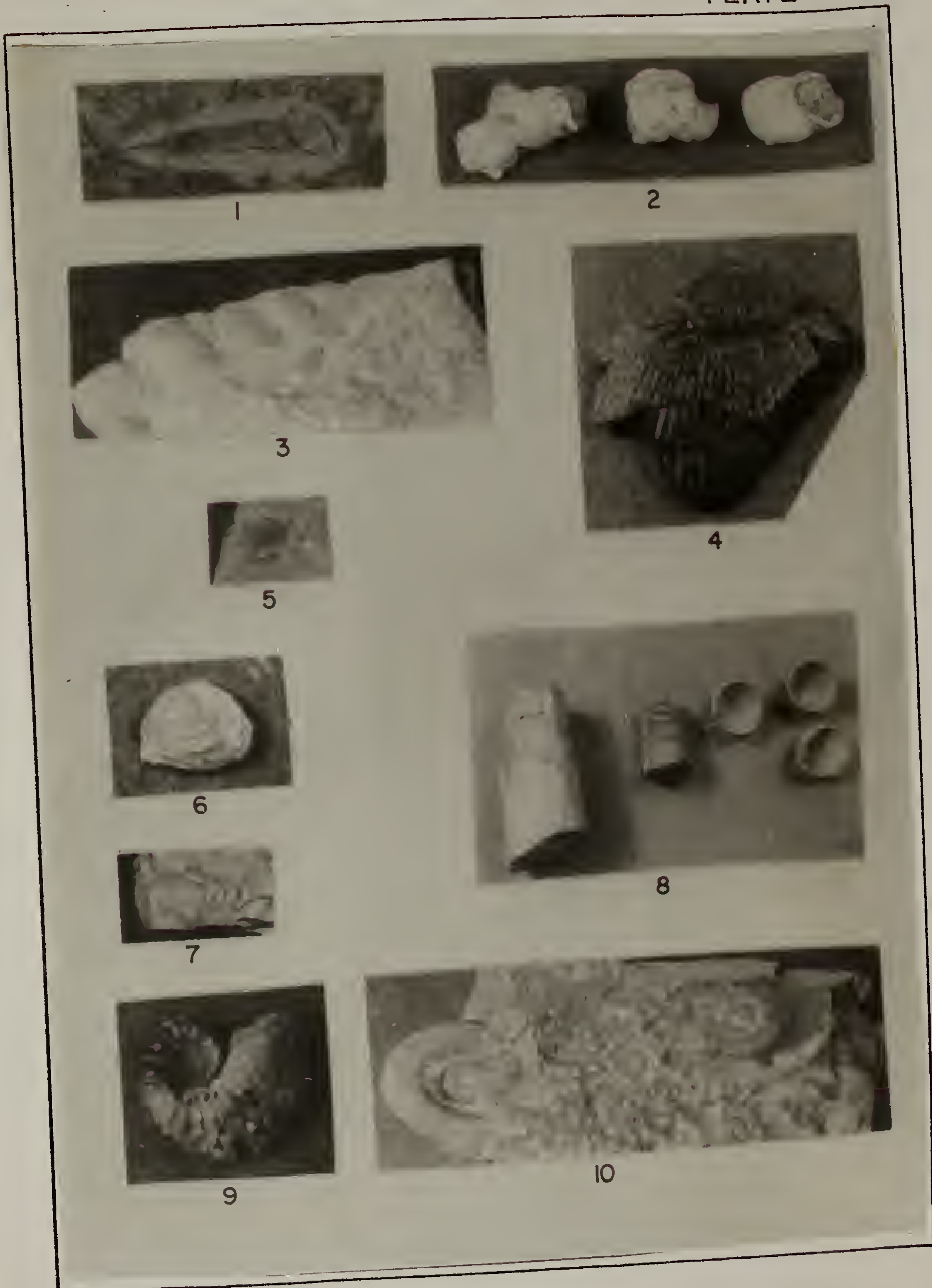
Figure 7 Cypricardinia indenta (Conrad). Left valve, showing elongate outline and strong growth lamellae; x1.3. Onondaga Limestone, P26-12, Schuylkill Haven, Schuylkill Co., Pa.

Figure 8 Michelinoceras subulatum (Hall). Several pyritized fragments of different shells, showing orthoconic shape and dish-like septa with centrally-located siphuncle; x1. Needmore Formation (calcitic shale subfacies), M2-6, Flintstone, Allegany Co., Md.

Figure 9 "Gyroceras" sp. Pyritized shell, showing evolute coiling and well-defined chambers; x1. Needmore Formation (calcareous shale member), P52-16, Newton Hamilton, Mifflin Co., Pa.

Figure 10 Agoniatites (?) sp. Two compressed specimens in black shale, showing evolute coiling; x1. Needmore Formation (calcareous shale member), P52-18, Newton Hamilton, Mifflin Co., Pa.

PLATE 30



EXPLANATION OF PLATE 31

Figure 1 — Proetus (Crassiproetus) crassimarginatus (Hall). Exfoliated pygidium of a large individual, showing typical form and segmentation; x1.3. Onondaga Limestone (Edgecliff Member), Y9, Hannacroix, Greene Co., N.Y.

Figure 2-7 — Dechenella (Dechenella) haldemani (Hall)

2. Cephalon, showing wide brim and distinctive glabellar lobes; x1. Marcellus Formation (Cherry Valley Limestone Member), Y4, Cherry Valley, Otsego Co., N.Y.
3. Pygidium, showing border; x1.5. Marcellus Formation (Cherry Valley Limestone Member), same locality as 2.
4. Pygidium; x1.3. Marcellus Formation (Cherry Valley Limestone Member), same locality as 2 and 3.
5. Pygidium, showing border; x1.3. Marcellus Formation (Cherry Valley Limestone Member), same locality as 2, 3, and 4.
6. Enlargement of same pygidium as 5, showing segmented axial and pleural lobes; x2.1.
7. Pygidium, with border concealed by limestone matrix; x1.6. Marcellus Formation (Purcell Limestone Member), P31-68, Selinsgrove Junction, Northumberland Co., Pa.

Figure 8-10 — Phacops cristata Hall

8. Internal mold of thorax and pygidium (somewhat distorted), showing row of axial spines on thorax; x1.5. Needmore Formation (calcareous shale member), P58-5, Orbisonia, Huntingdon Co., Pa.
9. Thorax, showing row of axial spines; x1.7. Needmore Formation (Selinsgrove Limestone Member), P42-10, Thompsontown, Juniata Co., Pa.
10. Internal mold of cephalon, showing protuberant anterior glabellar lobe and spinous genal angle; x2. Needmore Formation (calcitic shale subfacies), V1, Gainesboro, Frederick Co., Va.

PLATE 31

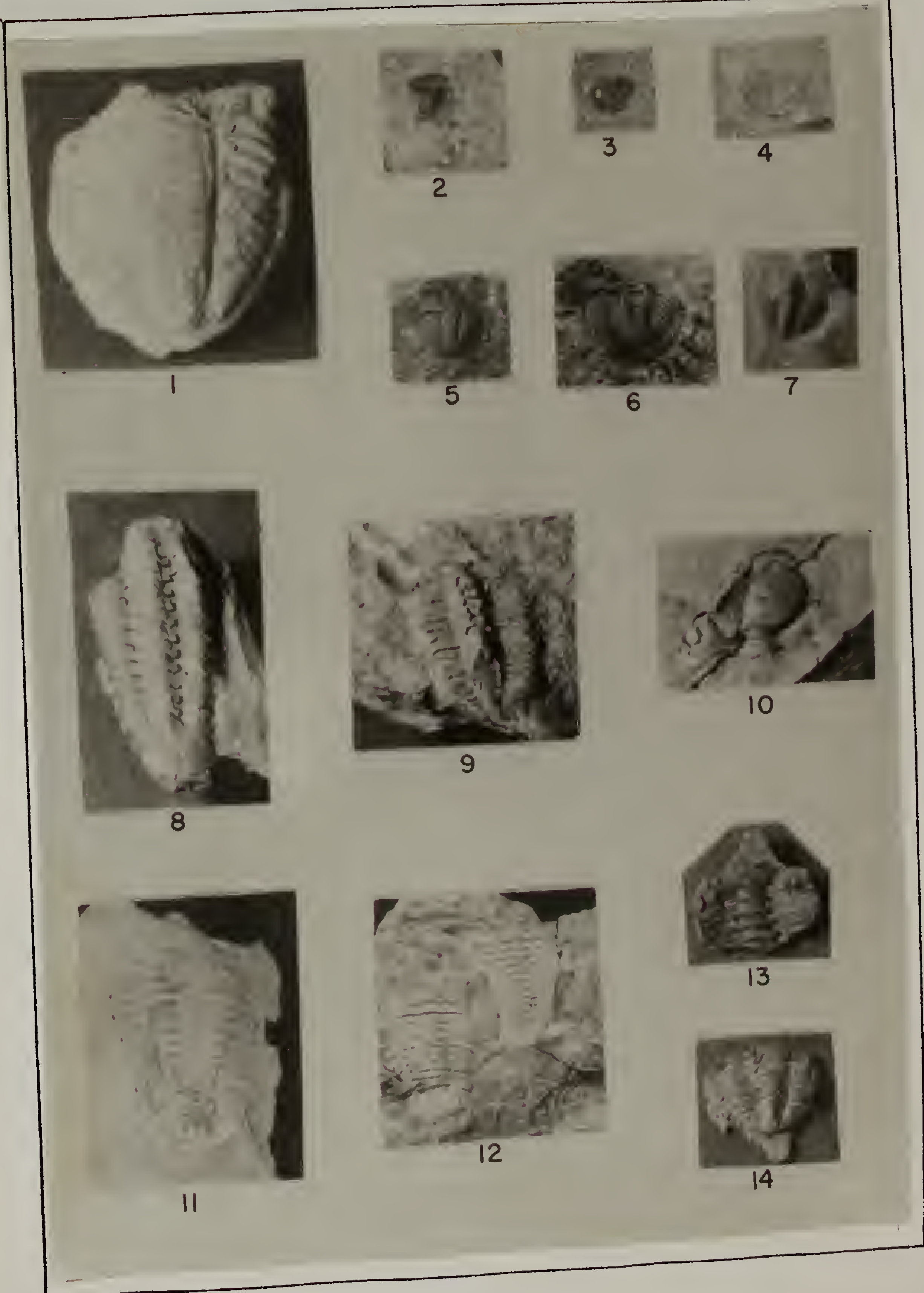


Figure 11-14 Phacops pipa Hall and Clarke

11. Thorax and pygidium; x1.1. Needmore Formation (calcareous shale member), P49-5, Alinda, Perry Co., Pa.
12. Thoraxes and pygidia of two specimens, showing lack of axial thoracic spines; x1.3. Needmore Formation (calcitic shale and limestone subfacies), P63-11, Warfordsburg, Fulton Co., Pa.
13. Internal mold of incomplete cephalon and portion of thorax of a nearly complete, enrolled specimen; x1.4. Onondaga Limestone, P29-2, Swatara Gap, Lebanon Co., Pa.
14. Pygidium and part of thorax; x1.4. Same specimen as 13.

EXPLANATION OF PLATE 32

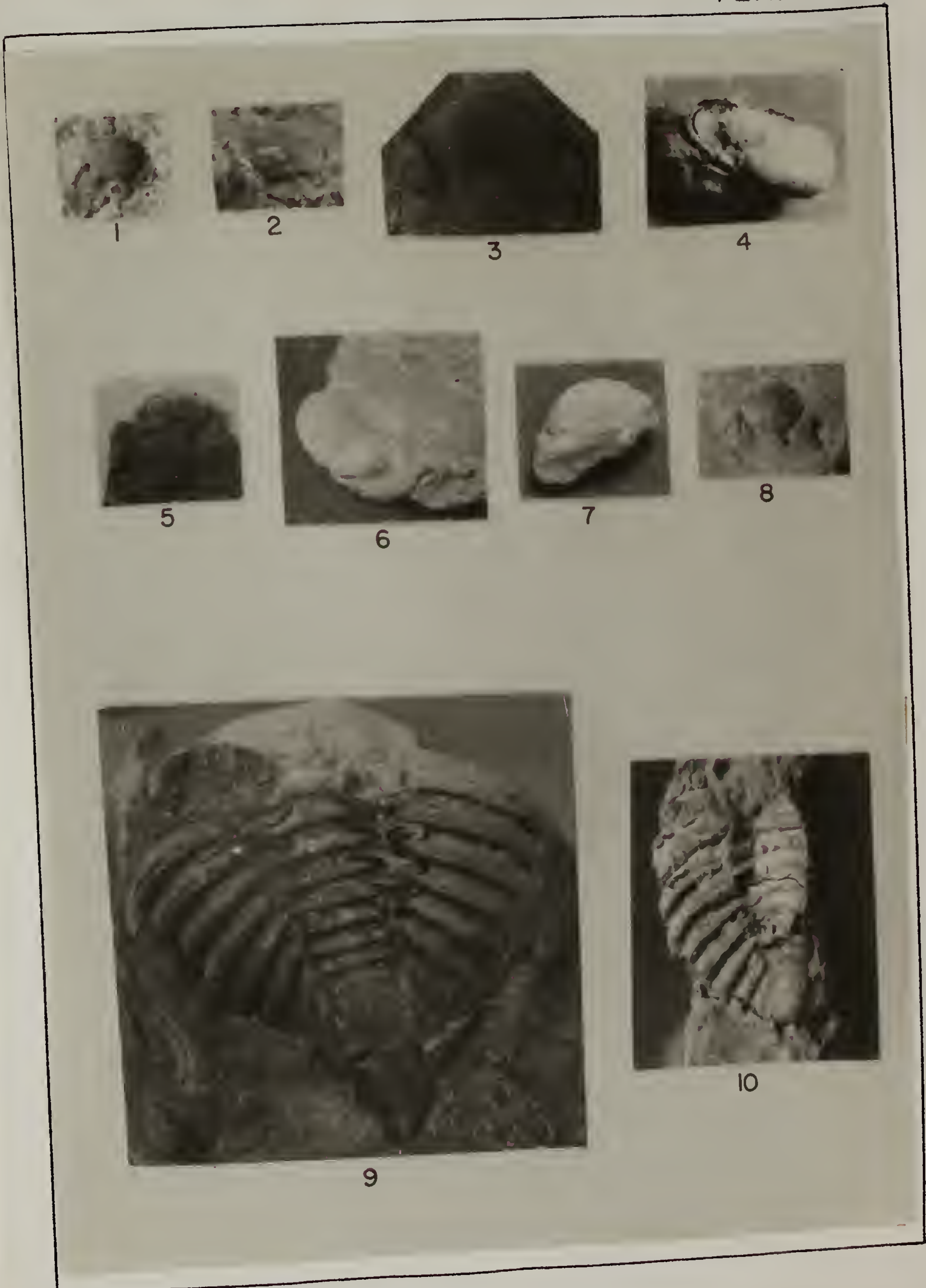
Figure 1-3 Phacops pipa Hall and Clarke

1. Cephalon, showing small size, protuberant anterior lobe of glabella, and short genal spines; x2. Onondaga Limestone (Moorehouse Member), Y5, Schoharie, Schoharie Co., N.Y.
2. Cephalon, showing protuberant anterior lobe of glabella and prominent eyes; x2. Onondaga Limestone (Moorehouse Member), same locality as 1.
3. Larger cephalon, somewhat questionably assigned to this species; x2. Onondaga Limestone (Moorehouse Member), same locality as 1 and 2.

Figure 4-8 Phacops sp.

4. Lateral view of cephalon, showing rounded genal angle; x1.3. Needmore Formation (Selinsgrove Limestone Member), P58-10, Orbisonia, Huntingdon Co., Pa.
5. Cephalon; x1.3. Needmore Formation (calcitic shale and limestone subfacies), P63-6, Warfordsburg, Fulton Co., Pa.
6. Cephalon, showing bulbous frontal lobe; x1. Needmore Formation (calcitic shale subfacies), P63-4, Warfordsburg, Fulton Co., Pa.

PLATE 32



7. Cephalon; x1. Needmore Formation (calcareous shale member), P61-4, Tyrone, Blair Co., Pa.
8. Cephalon, showing eyes and bulbous frontal lobe; x1.1. Needmore Formation (calcitic shale and limestone subfacies), P63-11, Warfordsburg, Fulton Co., Pa.

Figure 9,10 Anchiopella anchiops (Green)

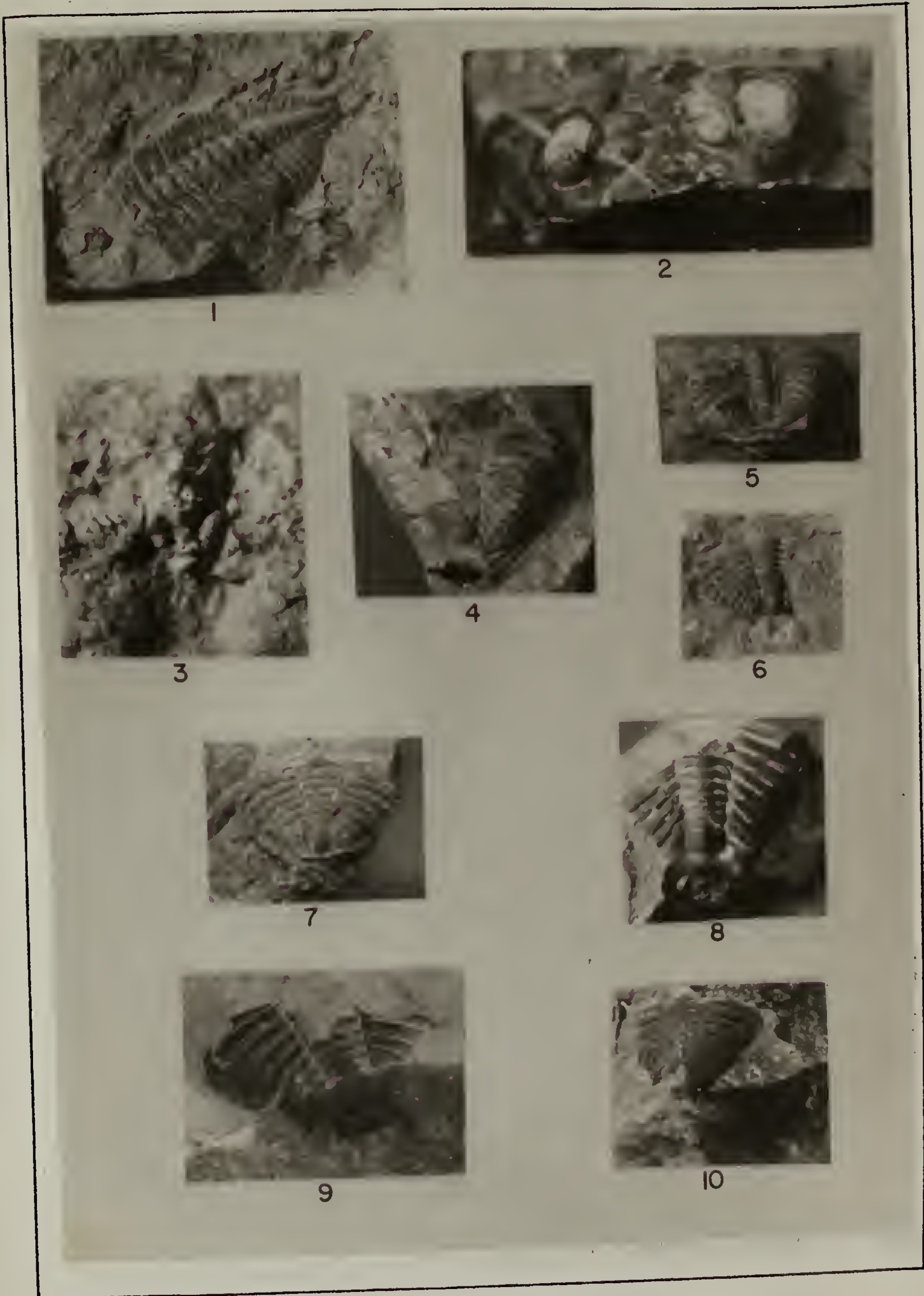
9. Pygidium (exfoliated) of a large specimen, showing stout, upturned caudal spine; x1.3. Schoharie Formation (Saugerties-Aquetuck members, undivided), Y21, Trilobite Mountain, Orange Co., N.Y.
10. Pygidium, showing base of stout caudal spine; x1.2. Schoharie Formation (Saugerties-Aquetuck members, undivided), same locality as 9.

EXPLANATION OF PLATE 33

Figure 1-10 Odontocephalus selenourus (Eaton)

1. Natural cast of a nearly complete specimen, showing equally trilobate thorax and pygidium with eight pleural annulations and two caudal spines; x1.3. Onondaga Limestone, P23, Germans, Carbon Co., Pa.
2. Large, incomplete cephalon, showing prominent, lunate eyes, distinct lateral glabellar lobes, and non-spinous genal angles; x1.3. Needmore Formation (Selinsgrove Limestone Member), P43-67, Old Port, Juniata Co., Pa.
3. Glabella, showing large, bulbous anterior lobe with conspicuous tubercles and smaller, elevated, paired lateral lobes; x1.7. Needmore Formation (Selinsgrove Limestone Member), same locality and unit as 2.
4. Pygidium, showing eight annulations on pleural lobes and bases of two caudal spines; x1.5. Needmore Formation (Selinsgrove Limestone Member), P52-47, Newton Hamilton, Mifflin Co., Pa.
5. Pygidium, showing eight annulations on pleural lobes; x1.4. Needmore Formation (Selinsgrove Limestone Member), same locality and unit as 4.

PLATE 33



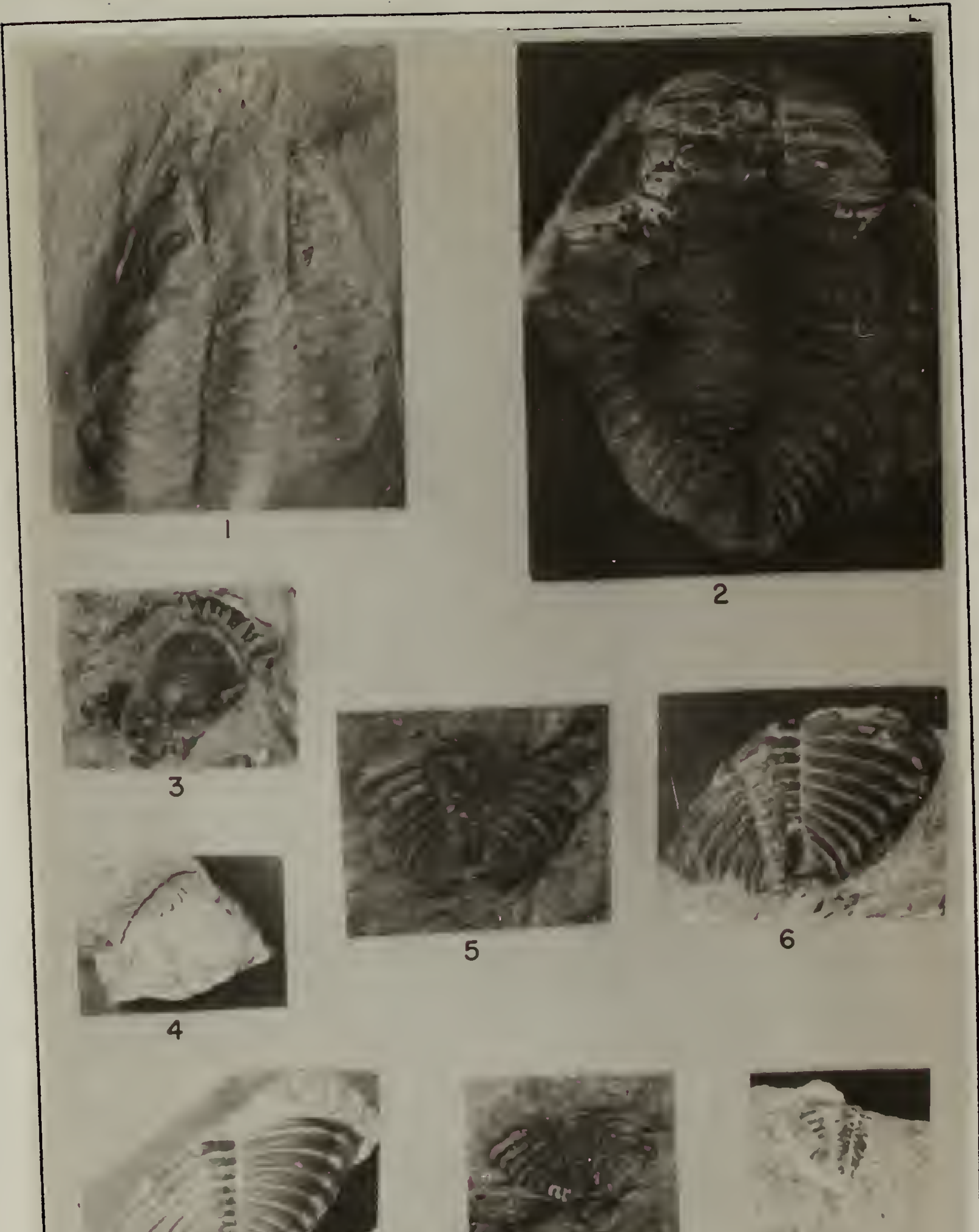
6. Pygidium, showing typical form and bases of two caudal spines; x1. Needmore Formation (Selinsgrove Limestone), same locality and unit as 4 and 5.
7. Pygidium, showing triangular outline and abruptly sloping pleurae; x1.1. Onondaga Limestone (Moorehouse Member), Y15-3, Saugerties, Ulster Co., N.Y.
8. Pygidium, with eight annulations on pleurae and bases of two widely-spaced caudal spines; x1.7. Needmore Formation (Selinsgrove Limestone Member), P43-55, Old Port, Juniata Co., Pa.
9. Pygidium, showing fine medial striations on pleural segments and two caudal spines; x1.3. Onondaga Limestone (Moorehouse Member), Y20, Wawarsing, Ulster Co., N.Y.
10. Pygidium and portion of free cheek; x1. Needmore Formation (Selinsgrove Limestone Member), P53-9, Newton Hamilton, Mifflin Co., Pa.

EXPLANATION OF PLATE 34

Figure 1-8 Odontocephalus aegeria (Hall)

1. Natural cast of cephalon and thorax, showing characteristic "toothed" border, genal spines, and prominent eyes; x1. Needmore Formation (Selinsgrove Limestone Member), P50, Alinda, Perry Co., Pa.
2. Thorax and pygidium of a complete, partially enrolled specimen; x1.5. Needmore Formation (calcitic shale and limestone subfacies), M2-11, Flintstone, Allegany Co., Md.
3. Cephalon, showing "toothed" border; x1.5. Needmore Formation (Selinsgrove Limestone Member), P53-9, Newton Hamilton, Mifflin Co., Pa.
4. Cephalon, showing "toothed" border; x1.2. Needmore Formation (Selinsgrove Limestone Member), P50, Alinda, Perry Co., Pa.
5. Pygidium, showing ten annulations on pleurae; x1.5. Needmore Formation (Selinsgrove Limestone Member), P53-9, Newton Hamilton, Mifflin Co., Pa.
6. Pygidium, with ten annulations (spines not preserved); x1.1. Needmore Formation (Selinsgrove Limestone Member), P30-43, Dalmatia, Northumberland Co., Pa.

PLATE 34



7. Pygidium, showing ten annulations on pleural lobes and obsolete segmentation on posterior end of axial lobe; x1.1. Needmore Formation (Selinsgrove Limestone Member), P52-47, Newton Hamilton, Mifflin Co., Pa.

8. Pygidium; x1. Needmore Formation (Selinsgrove Limestone Member), P53-9, Newton Hamilton, Mifflin Co., Pa.

Figure 9 Odontocephalus bifidus (Hall). Small pygidium, showing six or seven annulations on pleurae and one of the two relatively long, closely-spaced caudal spines; x1.5. Jeffersonville Limestone (Brevispirifer zone), K1, Falls of the Ohio, Louisville, Jefferson Co., Ky.

EXPLANATION OF PLATE 35

Figure 1 Tentaculites gracilistriatus (Hall). Longitudinal section, showing rounded annulations; x30. Needmore Formation (Selinsgrove Limestone Member), P31-52, Selinsgrove Junction, Northumberland Co., Pa.

Figure 2,3 Tentaculites bellulus (Hall)

2. External and internal molds, showing acute annulations; x1.1. Onondaga Limestone (Echo Lake Member), P1-11, Echo Lake, Monroe Co., Pa.

3. External mold of a larger specimen; x1.1. Onondaga Limestone, P25-3, Andreas, Schuylkill Co., Pa.

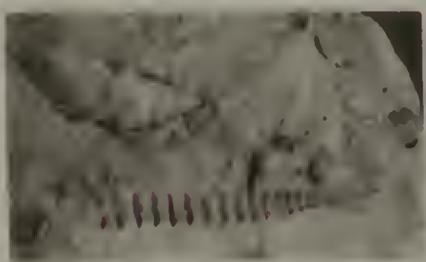
Figure 4,5 Styliolina fissurella (Hall)

4. Many specimens on a limestone slab; x1.25. Needmore Formation (Selinsgrove Limestone Member), P31-52, Selinsgrove Junction, Northumberland Co., Pa.

5. Longitudinal section of an uncrushed specimen (upper left), with trilobite fragment below; x60. Marcellus Formation (Cherry Valley Limestone Member), Y4, Cherry Valley, Otsego Co., N.Y.

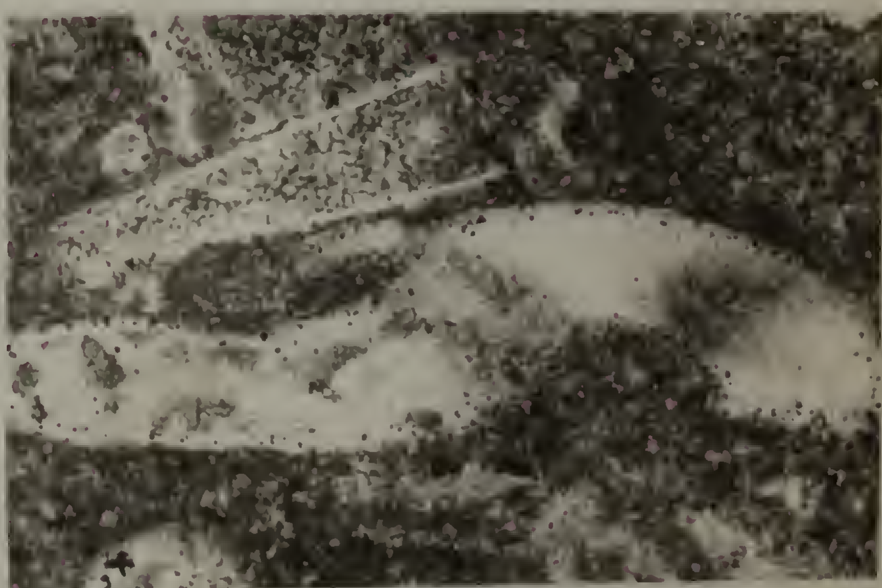
1

2



3

4



5

APPENDIX

ONESQUETHAWAN OUTCROP AND SUBSURFACE LOCALITIES

Introduction

Detailed information concerning all Onesquethawan outcrop and subsurface localities used in compiling data for the present study is given below. (Also see Plate 1.) Outcrop descriptions are based on the observations of the writer and his assistants; deep well data, on the other hand, are entirely from published sources.

The most complete sections of Onesquethawan rocks were measured by one of the following methods: (1) bed by bed measurement with a six-foot tape, (2) use of a five-foot jacob staff, and (3) tape and compass traverse. Except for the insoluble residue percentages and fossil identifications, all unit descriptions are taken directly from field notes. Rock color terms are from the Rock Color Chart (Goddard and others, 1963). Attitude of bedding is shown as follows: N 60° E (strike)/ 45° SW (dip).

The following abbreviations are used in the detailed sections to show fossil abundance: r - rare, unc - uncommon, c - common, a - abundant, va - very abundant, f - flood. These terms are based on visual estimation.

Description of the Localities

New York

Y1 STAFFORD: B. R. DeWitt quarry, on south side of N.Y. Rte. 5, about 1.0 mile east of Stafford, Genesee Co. (7,250 feet south of lat. 43° 00' 00"N, 2,500 feet west of long. 78° 05' 00"W, at an elevation of 875 feet, northwest portion of the Stafford 7-1/2' Quadrangle.) Onondaga Limestone (Clarence and Moorehouse members).

Y2 LEROY: In quarries and waste piles east of Perry Road and north of Gulf Road, between 1.0 and 2.0 miles northeast of LeRoy, Genesee Co. (Northeast and north-central portions of LeRoy 7-1/2' Quadrangle.) Onondaga Limestone (Edgecliff and Moorehouse members).

Y3 NEDROW: On Interstate Rte. 81, south of Nedrow, Onondaga Co. (Northeast portion of South Onondaga 7-1/2' Quadrangle.) Onondaga Limestone (Moorehouse and Seneca members).

Y4 CHERRY VALLEY: On U.S. Rte. 20, 2.0 miles north-northeast of Cherry Valley, Otsego Co. (5,500 feet south of lat. 42° 50' 00"N, 5,500 feet west of long. 74° 42' 30"W at an elevation of about 1,550 feet, west-central part of Sprout Brook 7-1/2' Quadrangle.) The Kalkberg Limestone, Oriskany Sandstone, Esopus Formation, Schoharie Formation, and Onondaga Limestone are exposed in continuous cuts on the south side of the highway west of the roadside rest area. Beds are subhorizontal with attitude of approximately N 75° E/5° S. The upper part of the Union Springs Shale Member, the Cherry Valley Limestone Member, and the lower part of the Chittenango Shale Member crop out along the south side of U.S. Rte. 20 about 1.4 miles to the east. Oriskany, Esopus, and Schoharie Section by Inners.

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
Onondaga Limestone				
Upper members not measured.			15	3
Edgecliff Member				
10. Limestone, thick bedded to massive,				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
med. lt. gray (N6), lt. gray (N7) weathering, medium to coarse grained, cherty, highly fossiliferous. Fossils: Rugose corals (c), Favosites sp. (c), brachiopods (c).	15			
9. Limestone, thin bedded (in beds 1" thick), med. dk. gray (N4), lt. (tannish) gray (N7) weathering, medium grained, somewhat siliceous, highly fossiliferous (fossils silicified). Abrupt disconformable contact with underlying Carlisle Center siltstone. Fossils: Breviphrentis sp. (unc), etc.		3		
Scholarie Formation			42	6
Carlisle Center Member			42	6
8. Siltstone, quartzitic, med. bedded (in beds 3" to 6" thick), lt. gray (N7), yellowish gray (5Y 8/1) weathering, fine grained, slightly calcareous, glauconitic, burrowed, with some thin, shaly partings. Taonurus-markings profuse. Abundant glauconite 5' above base. Unit appears to be somewhat less resistant than underlying unit.	18			
7. Siltstone, quartzitic, thick bedded to massive (in beds 6" to 12" thick), lt. gray (N7), yellowish gray (5Y 8/1) weathering, fine grained, slightly calcareous, glauconitic, burrowed. Profuse Taonurus-markings. Glauconite abundant in 12" bed of siltstone, 14' above base.	20			
6. Siltstone, quartzitic, massive (some poorly defined med. to thick beds, 3" to 12" thick), lt. gray (N7), med. lt. gray (N6) weathering, fine grained with black flint pebbles (3/4" diameter) at base, slightly calcareous, glauconitic, burrowed. Lower 6" contains abundant				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
glauconite. Base of unit contains many peculiar knob-like structures that are related to <u>Taonurus</u>-markings, profuse throughout unit. Disconformity with Esopus.	4	6		
Esopus Formation			18	6
5. Shale, dark gray (N3), med. dark gray (N4) and rusty weathering, fissile, pyritic, burrowed. Breaks into thin fragments 1/2" to 2" long and 1/16" thick. May contain some glauconite. Upper 2' have whitish powder on exposed surfaces (calcium sulfate).	5	6		
4. Shale, siliceous, med. to thick bedded (beds 3" to 24" thick), dk. gray (N3), brownish gray (5YR 4/1) weathering, pyritic, burrowed, with a few beds of siltstone, siliceous, med. to thick bedded (beds 3" to 11" thick), dk. gray (N3), brownish gray (5YR 4/1) weathering, well jointed, sparingly fossiliferous. Fossils: Sponge spicules (?) (va), brachiopods (unc).	4			
3. Siltstone, siliceous, thick bedded (in beds 10" to 12" thick), dk. gray (N3), med. gray (N5) and rusty weathering, very fine grained, slightly calcareous, burrowed, well jointed, sparingly fossiliferous, with interbedded shale, calcareous, thin bedded (beds 1" to 2" thick), dk. gray (N3), med. gray (N5) and rusty weathering. Fossils: <u>Leptocoelia flabellites</u> (unc).	4			
2. Siltstone, highly calcareous, siliceous, med. bedded (in beds 2" to 6" thick), med. gray (N5), lt. (tannish) gray (N7) weathering, fine grained, cherty, dense, fossiliferous, with interbeds of shale,				

	Thickness Unit Ft.	Unit In.	Thickness Total Ft.	Total In.
calcareous, thin bedded (in beds 1" to 2" thick), med. gray (N5), med. lt. gray (N6) and rusty weathering. Chert (in siltstone), dk. gray (N3), occurs as nodules 1" to 2" thick, 3" to 4" long, composes 20% of rock. Vague flaser bedding in siltstone. Abrupt contact with Oriskany. Fossils: Leptocoelia flabellites (unc), unidentified trilobite cephalon (r).	5			
Oriskany Sandstone			2	6
1. Sandstone, calcareous, massive in lower part (bed 1'3" thick) to med. bedded in upper part (beds 2" to 4" thick), med. gray (N5), med. lt. (tannish) gray (N6) weathering, med. to fine grained in lower 6", med. to coarse grained in upper 2', well sorted, fossiliferous. Calcite cemented. Brachiopod molds abundant, most convex up. Fused, disconformable contact with Kalkberg.	2	6		

Y5 SCHOHARIE: Along Schoharie-Cobleskill Road, between Schoharie Hill (on the north) and Round Top (on the south), about 2 miles west of Schoharie village, Schoharie Co. (West-central portion of Schoharie 7-1/2' Quadrangle.) Onondaga Limestone (Moorehouse Member).

Y6 BERNE: In gorge of Fox Creek, just downstream of N.Y. Rte. 43 bridge, Berne, Albany Co. (200 feet north of lat. 42° 37' 30"N, 2,600 feet west of long. 74° 07' 30"W, at an elevation of 980 feet, southeast corner of Gallupville 7-1/2' Quadrangle.) Onondaga Limestone (Moorehouse Member). Section described by Oliver (1956b, pp. 1459-1460).

Y7 THOMPSONS LAKE: North of Thompsons Lake on south side of the secondary road to school No. 5, 0.4 mile west of its junction with N.Y. Rte. 157A, 0.8 mile west of John Boyd Thacher State Park and 1.0 mile north of Thompsons Lake village, Albany Co. (3,750 feet south of lat. 42° 40' 00"N, 1,500 feet east of long. 74° 02' 30"W, at an elevation of 1,345 feet, southeast portion of Altamont 7-1/2' Quadrangle.) Schoharie Formation (Rickard Hill Member), Onondaga Limestone (Edgecliff Member - reef facies). Section described by Oliver (1956a).

Y8 ONESQUETHAW CREEK: Along Onesquethaw Creek, extending from about 1.2 miles east-southeast of Clarksville to foot of Wolf Hill, 1.5 miles northwest of Clarksville, Albany Co. (Central, west-central and northwest portions of Clarksville 7-1/2' Quadrangle.) Esopus Formation, Schoharie Formation (Carlisle Center and Rickard Hill members), Onondaga Limestone (Edgecliff, Nedrow, and Moorehouse members). Type section of the Onesquethaw stage (Cooper, 1942, p. 1733). Section described by Prosser and Rowe (1899, pp. 342-345). (See also Grabay, 1906, pp. 292-295.)

Y9 HANNACROIX: On Roberts Hill Road and in woods to west, 1.5 miles north of Roberts Hill and 1.5 miles southwest of Hannacroix, Greene Co. (Lat. 42° 25' 00"N, 1,750 feet west of long. 73° 50' 00"W, on elevation of 430 feet, west-central portion of Ravena 7-1/2' Quadrangle.) Onondaga Limestone (Edgecliff Member - reef facies, Nedrow and Moorehouse members).

Y10 CATSKILL CREEK: In the gorge of Catskill Creek, about 300 feet east of Mill Pond, 0.1 mile south of Leeds, Greene Co. (811 feet north of lat. 42° 15' 00"N, 5,000 feet east of long. 73° 55' 00"W, at an elevation of about 85 feet A.T., southeast corner of Leeds 7-1/2' Quadrangle.) An anticline in the Glenerie Chert and Esopus Formation is exposed on the south wall of the gorge. Although the complete Esopus can be studied here, the presence of numerous thrust faults that partially repeat the section on the more accessible west limb of the fold renders measurement of the stratigraphic thickness somewhat problem-atical. A few hundred feet upstream from the anticlinal axis, the Schoharie Formation forms the natural dam of Mill Pond. The Onondaga Limestone crops out farther westward along the shores of the pond. Onondaga section by Oliver (1956b, pp. 1449, 1457, 1460; 1962, pp. A16-A17). Schoharie section by Johnsen (1957, pp. 58-61). (See also Johnsen and Southard, 1962, p. A17.) Esopus section (south wall, west limb of anti-cline) by Inners and Waldo.

	Unit Ft.	Unit In.	Total Ft.	Total In.
Schoharie Formation				
Saugerties and Aquetuck members well exposed, but not measured for this study.				
Carlisle Center Member			13	
8. Mudstone, massive, calcareous, med. dk. gray (N4), yellowish gray (5Y 7/2) weathering, glauconitic, pyritic, sandy. Siliceous "black bed" occurs about 5 feet above base. Abrupt but probably conformable contact with underlying Esopus.	13			
Esopus Formation			200	
7. "Laminite bed." Mudstone, laminated, dk. gray (N3), mildly contorted. Laminae consist of very thin (1/64" to 1/16" thick) dk. gray and brownish gray (5YR 4/1) (pyritic) bands, with thin lenticular streaks of quartz. Rather abrupt contact with underlying unit.	15			
6. Mudstone, massive, med. gray (N5) weathering pale olive gray (5Y 5/1), silty, pyritic. <u>Taonurus</u>-markings profuse, many apparent on bedding plane surfaces.	40			
5. Mudstone, massive, med. dk. gray (N4) to dk. gray (N3), pale olive gray (5Y 5/1) weathering, pyritic, strongly burrowed. Intensely cleaved and faulted, with many bedding plane slips and cross faults cemented by calcite veins. Measurement showed thickness of 138 feet for unit. This certainly includes some thickening by thrust faults. Actual stratigraphic thickness probably about	118			
4. Mudstone, massive, med. dk. gray (N4), med. gray (N5) and rusty weathering, silty, vaguely laminated, burrowed. Burrows in upper 2' have				

	Thickness			
	Unit		Total	
	Ft.	In.	Ft.	In.
disrupted bedding laminae to form med. dk. gray blotches (1/16" to 1/8" thick) on weathered surfaces; <u>Taonurus</u> in lower 6". Forms distinct resistant rib on cliff.	2	6		
3. "Fossiliferous bed." Mudstone, massive, calcareous, med. dk. gray (N4), yellowish gray (5Y 7/2) weathering, highly cleaved, fossiliferous. Zone of large (6" to 12"), grayish black (N2), dense, chert nodules about 1'6" from top. Fossils: <u>Leptocoelia flabellites</u> (c), <u>Ambocoelia</u> sp. (unc), etc.	4			
2. Mudstone, massive, dark gray (N3), silty, pyritic, strongly fractured. Pyrite occurs in scattered blebs and nodules up to 2" long, flattened in plane of bedding. Very faint lenticular bedding laminations (1/64" to 1/16" thick) apparent on nearly vertical fractures. Zone of large (6" to 12"), grayish black (N2), dense chert nodules 2' above base. Lower contact with Glenerie Chert apparently gradational and conformable.	20	6		
Glenerie Chert			11	4
1. "Flint beds." Siltstone, med. to thick bedded (beds 2" to 18" thick), grayish black (N2), highly siliceous, very hard, with interbeds of shale, med. bedded (in beds 2" to 6" thick), grayish black (N2), carbonaceous, splintery fractured. <u>Taonurus</u> occurs on bedding plane about 2' below top. Unit is extensively faulted with several wedges overriding each other to the west.	11	4		

Y11 LEEDS: On N.Y. Rte. 23, 0.3 mile east of intersection with Cauterskill Road, 0.25 mile south of Leeds, Greene Co. (Lat. 42° 15' 00"N, 4,000 feet east of long. 73° 55' 00"W, at an elevation of 145 feet, southeast corner of Leeds 7-1/2' Quadrangle.) An anticline in the Esopus and Scholarie formations and Onondaga Limestone, the same structure that occurs in the gorge of Catskill Creek, 0.2 miles to the north, is splendidly exposed here. Measured section is the west limb of the anticline on the east-bound lane of the highway. Section by Inners and Waldo.

	Thickness Unit Ft.	Unit In.	Thickness Total Ft.	Total In.
Onondaga Limestone				
Upper members not exposed.				
Edgecliff Member			38	
10. Limestone, massive, med. lt. gray (N5), lt. gray (N6) weathering, med. fine to med. crystalline, dense, with nodular, med. lt. gray chert. Lower 4 feet lacks chert. Bedding defined by irregular wavy seams generally 2" to 6" apart. A calcarenite composed of comminuted fossils. Lower contact placed at base of first massive limestone bed, top of uppermost tan-weathering argillaceous limestone of Saugerties.	38			
Schoharie Formation			84	2
Saugerties Member			15	
9. Calcareous mudstone (or argillaceous limestone) and crystalline limestone, interbedded. Mudstone, highly calcareous, med. dk. gray (N4), yellowish gray (5Y 7/2) weathering. Limestone, med. gray (N5), lt. gray (N6) weathering, med. fine grained. Beds vary from 3 to 12 inches in thickness. Upper 10 feet gradational into Onondaga, consisting of regular alternations of mudstone (or argillaceous limestone) and crystalline limestone, 2 to 4 inches thick. Pyritic in lower portion. Lower contact at top of thick glauconitic band in				

	Thickness Unit Ft.	In.	Total Ft.	In.
Aquetuck Member. Major slip horizon 5 feet, 3 inches above base. Extensively burrowed. Fossiliferous. Fossils: <u>Mucrospirifer macra</u> (unc), <u>Atrypa reticularis</u> (c), <u>Phacops</u> sp. (unc), favositid corals (c).	15			
Aquetuck Member			46	1
8. Mudstone, massive, calcareous, med. dk. gray (N4), yellowish gray (5Y 7/2) weathering, with med. gray (N5) bands, streaks and blebs that are the result of activity of burrowing organisms. Some purer limestone beds appear in upper part as unit grades into Saugerties Member. Top marked by band of glauconitic mudstone 1.5 feet thick. Upper half is moderately fossiliferous. Fossils: <u>A. reticularis</u> (unc).	34	4		
7. Mudstone, massive, calcareous and siliceous, med. dk. gray (N4) with irregular med. dk. gray and dark brownish gray (5YR 3/1) banding on weathered surfaces. Med. dk. gray weathering bands are siliceous at base and calcareous at top. They vary from 1/16 inch to 1 inch in thickness and are disrupted by burrowing.	11	9		
Carlisle Center Member			23	1
6. Mudstone, massive, calcareous, med. dk. gray (N4), banded med. dk. gray and yellowish gray (5Y 7/2) on weathered surfaces. Thin streaks and blebs of gray mudstone in yellowish gray weathering mudstone (1/8" to 1/4" thick) and vice versa caused by disruption of beds by burrowing organisms. Sandy zone with black flint and clear quartz sand grains and abundant				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
glauconite is 5 feet 6 inches above base. Glauconite also occurs as discontinuous streaks in lower half of unit. Gradational contact with overlying Aquetuck Member.	12	2		
5. "Black bed." Siltstone, massive, siliceous and calcareous, banded grayish black (N2) and dk. brownish gray (5YR 3/1). Laminated, with very thin discontinuous streaks of quartz silt between grayish black and brownish gray weathering laminae. Laminae vary in thickness from 1/16 to 1 inch with black bands apparently more calcareous. Quartz and chert sand, pyrite and glauconite occur at base. Contact with underlying unit is burrowed.	3	11		
4. Mudstone, massive, calcareous, med. (dk.) gray (N4.5), yellowish gray (5Y 8/4) weathering, sandy and pyritic. Coarse sand and small pebbles distributed erratically through unit. One lenticular zone (1 inch thick) 6 inches above base contains scattered, rounded granules of clear quartz and angular granules of black "flint." Glauconite occurs as patches of sand-size grains. Contact with "black bed" marked by occurrence of quartz sand and glauconite. Contact with underlying Esopus is a bedding-slip horizon and appears abrupt, but conformable. Sparingly fossiliferous. Fossils: <u>Coelospira camilla</u> (unc)		7		
Esopus Formation			70	
3. "Laminite bed." Mudstone, laminated, dk. gray (N3), very slightly calcareous. Laminae are very fine (1/64" to 1/16"				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
thick), alternately dark carbonaceous and lt. quartzitic and calcareous. Several bedding-slip horizons marked by quartz-calcite veins. Gradational contact with underlying unit. (Thickness along line of measured section is actually 23 feet, but this probably represents some repetition by faulting. True stratigraphic thickness measured on east limb of fold.)	13			
2. Mudstone, massive, med. dk. gray (N4), fine, sandy, pyritic. Profuse *Taonurus* markings. Moderately cleaved. Weathers to irregular, flattened chips and fragments bounded by cleavage and joint planes.	13	3		
1. Mudstone, similar to Unit 2, but more highly cleaved. Abundant *Taonurus* markings. (A greater thickness of this unit is exposed along the westbound lane.)	44			
Lower part not exposed.				

Y12 CATSKILL: Abandoned thruway exit, southeast side of N.Y. Rte. 23A, about 1.9 miles southwest of intersection of N.Y. Rte. 23A with U.S. Rte. 9W, and about 2.5 miles southwest of Catskill, Greene Co. (4,000 feet south of lat. 42° 12' 30"N, 200 feet west of long. 73° 55' 00"W, at an elevation of 230 feet, east-central part of Cementon 7-1/2' Quadrangle.) Alsen Limestone, Glenerie Chert, Esopus Formation, Schoharie Formation (Carlisle Center Member).

Y13 CATSKILL: Cut on southeast side of N.Y. Rte. 23A, about 2.6 miles southwest of intersection of N.Y. Rte. 23A with U.S. Rte. 9W, and about 3.2 miles southwest of Catskill, Greene Co. (200 feet south of lat. 42° 12' 30"N, 1,700 feet west of long. 73° 55' 00"W, at an elevation of about 180 feet, central portion of Cementon 7-1/2' Quadrangle.) Schoharie Formation (Aquetuck and Saugerties members), Onondaga Limestone (Edgecliff, Nedrow and Moorehouse members).

Y14 WEBBER BRIDGE: On Kaaterskill Creek, underneath the bridge on N.Y. Rte. 23A, 2.9 miles southwest of intersection of N.Y. Rte. 23A with U.S. Rte. 9W, and about 3.5 miles southwest of Catskill, Greene Co. (3,000 feet south of lat. 42° 12' 30"N, 3,200 feet west of long. 73° 55' 00"W, at an elevation of 60 feet, central portion of Cementon 7-1/2' Quadrangle.) Contact of the Onondaga Limestone (Moorehouse Member) and the Marcellus Formation (Bakeoven Shale Member). Locality described by Chadwick (1944, p. 1031).

Y15 SAUGERTIES: On N.Y. Rte. 32, 0.3 mile south of Katsbaan, about 2.0 miles northwest of Saugerties, Ulster Co. (7,000 feet south of lat. 42° 07' 30"N, 3,000 feet west of long. 73° 57' 30"W, at an elevation of about 195 feet, northwest portion of the Saugerties 7-1/2' Quadrangle.) The lower part of the Moorehouse Member and upper part of the Nedrow Member of the Onondaga Limestone crop out on both sides of the highway. Beds strike N30°E and dip about 20°, forming one of a series of north-northeast trending escarpments that mark the outcrop belt of the Onondaga. Section (west side of road) by Inners, assisted by Smith.

	Thickness Unit Ft.	Thickness Unit In.	Total Ft.	Total In.
Onondaga Limestone				
Moorehouse Member			49	
Upper portion not exposed.				
3. Limestone, med. to thick bedded (beds 2" to 12" thick), med. gray (N5), lt. gray (N7) weathering, med. to coarse grained, cherty, fossiliferous. (Beds consist of alternating coarse-grained, fossiliferous calcarenite and med. grained, fossiliferous calcarenite.) Chert, dk. gray (N3), occurs as discontinuous nodular beds up to 6" thick. Base of unit is thin chert band. Fossils: <u>Atrypa reticularis</u> (c), <u>Leptaena rhomboidalis</u> (unc), trilobite fragments (c), rugose corals (c), fenestellid bryozoans (c).	36			

	Thickness Unit Ft. In.	Thickness Total Ft. In.
2. Limestone, med. to thick bedded (beds 2" to 12" thick), med. gray (N5), lt. gray weathering, med. grained, non-cherty, highly fossiliferous. Fossils: Odontocephalus selenourus (c), brachiopods (c), bryozoans (c), rugose corals (c).	13	
Nedrow Member		10
1. Limestone, med. to thick bedded (beds 2" to 12" thick), med. lt. gray (N6), lt. gray (N7) weathering, coarse grained, cherty, fossiliferous. Chert, med. lt. gray to lt. brownish gray (5YR 6/1), occurs as nodules and discontinuous nodular beds. Fossils: Rugose corals (c), brachiopods (c), etc.	10	
Lower portion not exposed.		

Y16 KINGSTON: Ulster Co. Highway Department quarry, on southwest side of U.S. Rte. 209, 0.2 mile west-southwest of U.S. Rte. 209-N.Y. Rte. 28 intersection, west side of Kingston, Ulster Co. (6,250 feet north of lat. 41° 55' 00"N, 3,000 feet east of long. 74° 02' 30"W, at an elevation of 200 feet, east-central portion of Kingston West 7-1/2' Quadrangle.) Onondaga Limestone (Nedrow and Moorehouse members). Section described by Oliver (1962, p. 418).

Y17 KINGSTON: On the Penn Central Railroad, 0.1 mile north of W. O'Reilly Street underpass, about 1.0 mile south of Kingston, Ulster Co. (Lat. 41° 55' 00"N, 2,000 feet west of long. 74° 00' 00"W, at an elevation of 175 feet, southeast quarter of Kingston West 7-1/2' Quadrangle.) The Edgecliff Member of the Onondaga Limestone, the three members of the Schoharie Formation, and the upper portion of the Esopus Formation are folded into an asymetric syncline that is perfectly exposed by a deep railroad cut that crosses the structure transverse to the northeast strike of the beds. Measured section is the west wall of the cut, on the south limb of the syncline. Previously described by Johnsen (1957, pp. 68-72). (See also Johnsen and Southard, 1962, pp. A17-A18.) Section by Inners.

	Unit Ft.	Unit In.	Total Ft.	Total In.
Onondaga Limestone				
Upper members not exposed.				
Edgecliff Member			15	
11. Limestone, massive, med. lt. gray (N6), lt. gray (N7) weathering, med. grained, cherty, fossiliferous. Beds are indistinct, apparently 2" to 3" thick, separated by anastomosing chert seams that weather to tan-brown sand. Chert, med. gray (N4) and vitreous, occurs in nodular beds and discrete masses several inches in diameter that weather out to form jagged surfaces on exposed rock faces. Lower 3' contains scattered nodules of chert, about 2" to 3" in diameter, but is distinctly less cherty than overlying beds. Contact with Schoharie is abrupt but conformable. Fossils: Crinoid fragments (c), rugose corals (c).	15			
Schoharie Formation			217	4
Saugerties Member			43	
10. Limestone, med. bedded, med. gray (N5), lt. gray (N7) weathering, argillaceous, fossiliferous. Beds fused and rather indistinct—2" to 4" thick with wavy interbeds of med. gray, yellowish gray (5Y 7/2) weathering calcareous mudstone. Fossils: Enterolasma sp. (a).	9			
9. Mudstone, calcareous, thick bedded (beds 12" to 24" thick), med. dk. gray (N4), yellowish gray (5Y 7/2) weathering, fossiliferous, with interbeds of limestone, med. bedded (beds 2" to 4" thick), med. gray (N5), lt. gray (N7)				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
weathering, fine grained, fossiliferous. Burrowed. Beds fused. Lower part cleaved, upper 5' more massive, with limestone beds recessed. Fossils: *Stereolasma* sp. (c), favositid corals (c), *Anchiopella anchiops* (c), *Atrypa reticularis* (c), *Eodevonaria* cf. *arcuata* (unc).	34			
Aquetuck Member			43	2
8. Mudstone, calcareous, massive (in beds 6" to 36" thick), med. gray (N5), yellowish gray (5Y 7/2) weathering, with nodules and discontinuous beds (2" to 3" thick) of limestone, fine grained, very tough, med. gray (N5), lt. gray (N7) weathering. Sparingly fossiliferous. Burrowed. Contact with Carlisle Center Member at base of last lt. gray weathering limestone bed (about 3" thick).	43	2		
Carlisle Center Member			131	2
7. Mudstone, calcareous, massive, very tough, med. gray (N5), lt. dusky yellow (5Y 7/4) weathering, burrowed with bedding marked by thin (1/16" to 1/8" thick) med. dark gray (N4) streaks and blebs, fossiliferous. Fossils: Brachiopods (unc).	19	5		
6. Mudstone, calcareous, massive, med. dark gray (N4), yellowish gray (5Y 7/2) weathering, highly cleaved, intensely burrowed with disrupted dark gray (N3) bands (1/16" to 1/8" thick) apparent on surfaces normal to bedding. No *Taonurus* observed. Top marked by rippled bedding surface, probably a result of differential weathering along bedding-cleavage intersections.	57	3		

	Thickness			
	Unit		Total	
	Ft.	In.	Ft.	In.
5. "Black bed." Silstone, very hard, grayish black (N2), dark brownish gray (5YR 3/1) weathering, siliceous, slightly calcareous, pyritic.	1			
4. Mudstone, calcareous, massive, med. dk. gray (N4), yellowish gray (5Y 7/2) weathering, pyritic, sparingly fossiliferous. Crowded with *Taonurus*-markings. Vague yellowish and grayish weathering bands (1/8" to 1/4" thick) apparent on some surfaces. Lower portion highly cleaved. Fossils: *Leptocoelina acutiplicata* (c).	53			
3. Siltstone, med. gray (N5), lt. dusky yellow weathering, calcareous, glauconitic, sandy and argillaceous, fossiliferous. Contains scattered coarse sand grains. *Taonurus*-markings abundant. Sharp contact with overlying, highly cleaved calcareous mudstone of Unit 4. Fused to underlying massive mudstone of the Esopus.		6		
Esopus Formation			92	6
2. Mudstone, massive, dk. gray (N3), sandy, non-calcareous, irregularly cleaved. Crowded with *Taonurus*-markings. Upper part has blocky fracture and appears to be somewhat more massive than lower part.	75	6		
1. "Laminite bed." Mudstone, laminated, dk. gray (N3), rusty weathering, highly cleaved into paper-thin fragments. Laminae consist of alternating brown weathering bands, 1/64" to 1/16" thick, and dk. gray bands, 1/16" to 1/4" thick. Some weathered cleavage fragments have ribbed appearance with brown laminae recessed. Upper contact abrupt.	17			

Lower portion not exposed.

Y18 KINGSTON: On both sides of U.S. Rte. 209, 3.4 miles south of intersection of U.S. Rte. 209 with N.Y. Rte. 28, and about 4.0 miles west-southwest of Kingston, Ulster Co. (750 feet north of lat. 41° 55' 00"N, 2,500 feet east of long. 74° 05' 00"W, at an elevation of 210 feet, central portion of Kingston West 7-1/2' Quadrangle.) Onondaga Limestone (Edgecliff Member).

Y19 STONE RIDGE: Abandoned quarry, northwest side of U.S. Rte. 209, 0.1 mile southwest of intersection of Old Tangore Road and U.S. Rte. 209, and 1.2 miles northeast of Stone Ridge, Ulster Co. (2,750 feet south of lat. 41° 52' 30"N, 500 feet west of long. 74° 07' 30"W, at an elevation of 300 feet, northeast portion of Mohonk Lake 7-1/2' Quadrangle.) Onondaga Limestone (Moorehouse Member).

Y20 WAWARSING: Abandoned quarry, northwest side of U.S. Rte. 209, 0.6 mile north of Wawarsing, Ulster Co. (4,700 feet north of lat. 41° 45' 00"N, 4,000 feet west of long. 74° 20' 00"W, at an elevation of 300 feet, southwest portion of Kerhonkson 7-1/2' Quadrangle.) Onondaga Limestone (Edgecliff and Moorehouse members). Section described by Oliver (1962, p. A19).

Y21 TRILOBITE MOUNTAIN: Exposures along Maple Street and facing Port Jervis Golf Club and also along Erie Railroad to east, about 1.1 to 1.5 miles northeast of Tristates, Orange Co. (Upper part of section located 500 feet south of lat. 41° 22' 30"N, long. 74° 40' 00"W, at an elevation of 540 feet, northwest portion of Port Jervis South 7-1/2' Quadrangle; section extends northeastward along Erie Railroad into Port Jervis North 7-1/2' Quadrangle.) Esopus Formation, Schoharie Formation (Carlisle Center Member, Saugerties-Aquetuck members, undivided), Onondaga Limestone (Edgecliff Member, lower part). Section by Shimer (1905, pp. 222-231) and Johnsen (1957, pp. 86-88).

Y22 TRISTATES POINT: At confluence of Delaware and Neversink rivers, about 1.0 mile south of Port Jervis, 0.6 mile west-southwest of Tristates, Orange Co. (6,500 feet south of lat. 41° 22' 30"N, 8,000 feet west of long. 74° 40' 00"W, at an elevation of 450 feet, north-central portion of Port Jervis South 7-1/2' Quadrangle.) Onondaga Limestone (Moorehouse Member). Section described by Oliver (1956b, p. 1461).

Y23 TRISTATES: Cut through Trilobite Mountain on Interstate Rte. 84, 0.4 mile south of Tristates, Orange Co. (6,750 feet south of lat. 41° 22' 30"N, 5,000 feet west of long. 74° 40' 00"W, at an elevation of 520 feet, north-central portion of Port Jervis South 7-1/2' Quadrangle.) Esopus Formation.

Y24 MONROE: Behind the Monroe Bowl-O-Fun, west side of N.Y. Rte. 17M, 0.3 mile north of intersection of Lakes Road and N.Y. Rte. 17M, Monroe Co. (500 feet south of lat. 41° 20' 00"N, 4,750 feet east of long. 74° 12' 30"W, at an elevation of 620 feet, central portion of Monroe 7-1/2' Quadrangle.) Connelly Conglomerate, Esopus Formation. Locality described by Jaffe and Jaffe (1967, p. F13).

Y25 HIGHLAND MILLS: Cut on Erie Railroad at abandoned railroad station, 0.3 mile east of Highland Mills, Orange Co. (4,250 feet north of lat. 41° 20' 20"N, 750 feet east of long. 74° 07' 30"W, at an elevation of about 500 feet, northwest portion of Popolopen Lake 7-1/2' Quadrangle.) Esopus Formation. Section discussed by Boucot (1959) and Johnsen and Southard (1962, p. A16).

Y26 HIGHLAND MILLS: Cut on New York State Thruway, 8.0 miles north of Interchange 14 and 0.6 mile east of Highland Mills, Orange Co. (5,750 feet north of lat. 41° 20' 00"N, 3,000 feet east of long. 74° 07' 30"W, at an elevation of 520 feet, northwest portion of Popolopen Lake 7-1/2' Quadrangle.) Esopus Formation, Kanouse Sandstone. Section discussed by Boucot (1959) and Johnsen and Southard (1962, p. A14).

Y27 Herdmann No. 1 well (Dome Oil and Gas), Town of Shandaken, Ulster Co. (Rickard, 1969, pl. 12.)

Y28 Gans No. 1 well (United Prod.), Town of Windham, Greene Co. (Rickard, 1969, pl. 11.)

Y29 Lum No. 1 well (N.Y. State Natural Gas Corp.), Town of Worcester, Otsego Co. (Rickard, 1969, pl. 11.)

Y30 J. Skramko No. 1 well (J. C. Benedum et al.), Town of Warren, Herkimer Co. (Rickard, 1969, pl. 11.)

Y31 K. Hirsch No. 1 well (United Prod.), Town of Franklin, Delaware Co. (Rickard, 1969, pl. 12.)

Y32 Clarence C. Lobdell No. 1 well (Bradley Prod. et al.), Town of Columbus, Chenango Co. (Fettke, 1961, pp. 449-465.)

Y33 Doroshenko No. 1 well (N.Y. State Natural Gas Corp.), Town of Eaton, Madison Co. (Rickard, 1969, pl. 11.)

Y34 Frost No. 1 well (Reliance Oil), Town of Marcellus, Onondaga Co. (Rickard, 1969, pl. 11.)

Y35 Richards No. 1 well (Felix and Scissan), Town of Triangle, Broome Co. (Rickard, 1969, pl. 12.)

Y36 Kesselring No. 1 well (N.Y. State Natural Gas Corp.), Town of Van Etten, Chemung Co. (Wiggons, 1959, pp. 1-49; Fettke, 1961, pp. 567-606; Rickard, 1969, pl. 13.)

Y37 Smiley No. 1 well (N.Y. State Natural Gas Corp.), Town of Danby, Tompkins Co. (Rickard, 1969, pl. 13.)

Y38 Sheperd No. 1 well (N.Y. State Natural Gas Corp.), Town of Danby, Tompkins Co. (Rickard, 1969, pl. 13.)

Y39 Fee (Richardson) No. 1 well (N.Y. State Natural Gas Corp.), Town of Nemfield, Tompkins Co. (Rickard, 1969, pl. 13.)

Y40 Grund No. 1 well (N.Y. State Natural Gas Corp.), Town of Enfield, Tompkins Co. (Rickard, 1969, pl. 13.)

Y41 Joe Farkas No. 1 well (Reserve Oil Co.), Town of Lansing, Tompkins Co. (Martens, 1945, pp. 759-766; Fettke, 1961, pp. 551-565.)

Y42 Int. Salt Co. well No. 20, Town of Lansing, Tompkins Co. (Rickard, 1969, pl. 13.)

Y43 Mahaney No. 1 well (Reserve Oil Co.), Town of Ledyard, Cayuga Co. (Rickard, 1969, pl. 13.)

Y44 Shoemaker No. 1 well (United Prod.), Town of Springport, Cayuga Co. (Rickard, 1969, pl. 13.)

Y45 Johnson No. 1 well (Frankfurt Oil), Town of Sennett, Cayuga Co. (Rickard, 1969, pl. 13.)

Y46 Stein No. 1 well (J. C. Benedum), Town of Fayette, Seneca Co. (Rickard, 1969, pl. 11.)

Y47 McDonald No. well (N.Y. State Natural Gas Corp.), Town of York, Livingston Co. (Rickard, 1969, pl. 14.)

Y48 Livonia Salt Shaft (Int. Salt Co.), Town of Livonia, Livingston Co. (Luther, 1894, pp. 259-299.)

Y49 Ellen Collins No. 1 well (Godfrey L. Cabot, Inc.), Town of Erwin, Steuben Co. (Fettke, 1961, pp. 509-521; Rickard, 1969, pl. 12.)

Y50 Roy W. Herringdon No. 1 well (New Penn Development Corp. et al.), Town of Woodhull, Steuben Co. (Fettke, 1961, pp. 491-508.)

Y51 King No. 1 well (Ravening et al.), Town of Wellsville, Allegany Co. (Rickard, 1969, pl. 14.)

Y52 A. Gilbert No. 1 well (Belmont Quad. Drill Corp.), Town of Wirt, Allegany Co. (Fettke, 1961, pp. 441-448.)

Y53 T. H. Sawyer No. 1 well (T. H. Sawyer, Belmont Quad. Drill Corp.), Town of Wirt, Allegany Co. (Fettke, 1961, pp. 437-440.)

Y54 Herdmann No. 1 well (Heiser et al.), Town of Angelica, Allegany Co. (Rickard, 1969, pl. 14.)

Y55 A. Sheldon No. 1 well (Brendel et al.), Town of Allen, Allegany Co. (Fettke, 1961, pp. 429-440.)

Y56 Wolfer No. 1 well (N.Y. State Natural Gas Corp.), Town of Hume, Allegany Co. (Rickard, 1969, pl. 14.)

Y57 Veith No. 1 well (N.Y. State Natural Gas Corp.), Town of Gainesville, Wyoming Co. (Rickard, 1969, pl. 14.)

Y58 Schuelte No. 1 well (Great Lakes Expl.), Town of Bennington, Wyoming Co. (Rickard, 1969, pl. 11.)

Y59 Arcade No. 1 well (K. R. Wilson), Town of Arcade, Wyoming Co. (Fettke, 1961, pp. 415-427.)

Y60 Serial No. 796 well (Iroquois Gas Corp.), Town of Concord, Erie Co. (Fettke, 1961, pp. 373-379.)

Y61 Serial No. 807 well (Iroquois Gas Corp.), Town of Evans, Erie Co. (Fettke, 1961, pp. 365-371.)

Y62 Quinlan No. 1 well (J. Brooke Reed et al.), Town of Olean, Cattaraugus Co. (Fettke, 1961, pp. 401-413.)

Y63 Ryder-Scott No. 1 well (J. Brooke Reed et al.), Town of Allegany, Cattaraugus Co. (Fettke, 1961, pp. 389-400.)

Y64 Hotchkiss No. 2 well (Arkansas Fuel Oil Co.), Town of Randolph, Cattaraugus Co. (Fettke, 1961, pp. 381-387.)

Y65 Kyle Morse No. 1 well (Univ. Delta Drill Co.), Town of Harmony, Chautauqua Co. (Fettke, 1961, pp. 607-622.)

New Jersey

J1 MASHIPACONG ISLAND: On northwest side of N.J. Rte. 521 (the Old Mine Road), about 2.75 miles southwest of Tristates (intersection of Rte. 521 with U.S. Rte. 6) and 1.2 miles southwest of Rock View House, just southeast of Mashipacong Island, Montague Township, Sussex Co. (2,500 feet north of lat. 41° 20' 00"N, 5,500 feet east of long. 74° 45' 00"W, at an elevation of about 425 feet, northwest portion of Port Jervis 7-1/2' Quadrangle.) Onondaga Limestone (Moorehouse Member).

J2 MONTAGUE: On southeast side of N.J. Rte. 521, about 2.1 miles southwest of intersection of Rte. 521 with U.S. Rte. 206 (Montague village) on boundary between Montague and Sandyston townships, Sussex Co. (4,750 feet south of lat. 41° 17' 30"N, 3,000 feet east of long. 74° 50' 00"W, at an elevation of 560 feet, south-central portion of Milford, Pa., 7-1/2' Quadrangle.) Onondaga Limestone (Moorehouse Member).

P1 ECHO LAKE: On southeast side of U.S. Rte. 209, 1.0 mile northeast of Echo Lake and 0.75 mile southwest of Shoemakers, Middle Smithfield Township, Monroe Co. (Top of Onondaga Limestone, 4,000 feet south of lat. 41° 05' 00"N, 1,000 feet east of long. 75° 02' 30"W, at elevation of 500 feet, east-central part of Bushkill 7-1/2' Quadrangle.) Type section of Echo Lake Member (Member D) of the Onondaga Limestone. The Onondaga Limestone is exposed in an abandoned roadside quarry and in a series of cuestas to the southeast that trend northeast-southwest parallel to Walpack Ridge. Members B, C, and D are well exposed. Member A and the Schoharie Formation are largely concealed, so identification and thickness are problematical. The Esopus Formation crops out on the flanks and crest of Walpack Ridge. Total length of described traverse is about 5,000 feet. (See Alvord and Drake, 1971.) Attitude of Onondaga Limestone along U.S. Rte. 209 is N 70° E/ 16° NW. Section by Inners, assisted by Smith.

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
Onondaga Limestone			200±	
Member D (Echo Lake Member)			20	
13. Limestone, med. to thick bedded (in beds 2" to 12" thick), med. gray (N5), lt. gray weathering, siliceous, highly fossiliferous. Consists of fining upward, current-laid deposits —bioskeletal calcirudites to fossiliferous, fine grained calcarenites. Siliceous beds weather spongy. Fossils: "<u>Heterophrentis</u>" sp. B (a), <u>Favosites</u> sp. (c), <u>Eodevonaria</u> sp. (c), <u>Longispina mucronatus</u> (c), <u>Hysterolites varicosus</u> (c), <u>Tentaculites bellulus</u> (c), etc.	20			

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Member C			138	
12. Limestone, massive, med. grained, med. gray (N5), very cherty, fossiliferous. Chert, nodular, black (N1), dense, slightly calcareous; nodules range up to 12" in diameter. (Exposed in abandoned quarry.)	23	8		
11. Limestone, massive, med. gray, med. lt. gray (N6) weathering, cherty, fossiliferous.	15			
10. Limestone, med. bedded to massive, fine to medium grained, med. dk. gray (N4) to med. gray, med. lt. gray weathering, cherty, fossiliferous. Chert, black (N1), dense. Fossils: Rugose corals (c), brachiopods (c).	14			
9. Concealed interval.	12			
8. Limestone, med. to thick bedded (in beds 3" to 12" thick), fine to med. grained, med. dk. gray to med. gray, med. lt. gray weathering, cherty, fossiliferous. Chert, black, dense. A few sparry coquinite beds occur 10 feet above base. Fossils: Rugose corals (c), *Atrypa reticularis* (c), crinoidal debris (a).	13	6		
7. Concealed interval.	30			
6. Limestone, thick bedded (in beds 6" to 18" thick), fine to medium grained, med. dk. gray to med. gray, med. lt. gray weathering, cherty. Chert, black, dense.	30			
Member B			20+	
5. Limestone, med. bedded (in beds 3" to 6" thick), dk. gray (N3), med. gray (N5) weathering, non-cherty, with interbedded shale, calcareous, dark gray. Highly cleaved. (Crops out in bed of Sand Hill Creek.)	20			

	Thickness Unit Ft. In.	Thickness Total Ft. In.
Concealed interval for about 400 feet southeast of Sand Hill Creek.		
Member A (Edgecliff Member)		
4. Limestone, massive, fine grained, med. gray, strongly cleaved, with bedding marked by thin (1/8" to 1/4") seams. A few small chert nodules present. Very fossiliferous. Fossils: Small rugose corals (c), Leptaena rhomboidalis (c), Atrypa reticularis (c), trilobite pygidia (unc).	10±	
Concealed for 2,000 feet further southeast. Several minor folds occur in this interval. (Alvord and Drake, 1971.)		
3. Limestone, massive, fine grained, med. gray, cherty, fossiliferous. Chert, grayish black (N2), dense. Strongly cleaved. (Exposed at north edge of sinkhole where stream flows into cavern.)	20+	
Concealed for 1,000 feet to unpaved road at foot of Walpack Ridge.		
Schoharie Formation		
Most of formation not exposed on traverse.		
Carlisle Center Member (?)		
2. Mudstone, silty, massive, dk. gray, med. gray and rusty weathering, strongly cleaved.		
Esopus Formation		
1. Mudstone, silty, massive, dk. gray, rusty weathering, pyritic. Strongly cleaved. (Forms northwest (dip) slope and crest of Walpack Ridge.)		

P2 MARSHALL CREEK: On both sides of U.S. Rte. 209, about 150 feet south of intersection of that route with U.S. Business

Rte. 209, Marshall Creek, Smithfield Township, Monroe Co. (125 feet south of lat. 41° 02' 30"N, 500 feet west of long. 75° 07' 30"W, at an elevation of 480 feet, southeast portion of East Stroudsburg 7-1/2' Quadrangle.) Onondaga Limestone (Member C).

P3 MARSHALL CREEK: On south side of U.S. Business Rte. 209, about 0.3 mile southwest of Marshall Creek, Smithfield Township, Monroe Co. (750 feet south of lat. 41° 02' 30"N, 1,750 feet west of long. 75° 07' 30"W, at an elevation of 500 feet, southeast portion of East Stroudsburg 7-1/2' Quadrangle.) Onondaga Limestone (Member C).

P4 MARSHALL CREEK: On both sides of U.S. Business Rte. 209, 1.1 miles southwest of Marshall Creek, Smithfield Township, Monroe Co. (3,750 feet south of lat. 41° 02' 30"N, 5,500 feet east of long. 75° 10' 00"W, at an elevation of 600 feet, southeast portion of East Stroudsburg 7-1/2' Quadrangle.) Onondaga Limestone (members C and D, Echo Lake Member).

P5 LAKE VALHALLA ESTATES: At entrance to Lake Valhalla Estates, on north side of U.S. Business Rte. 209, 1.0 mile northeast of the intersection of that route with Pa. Rte. 447 and 2.3 miles southwest of Marshall Creek, Smithfield Township, Monroe Co. (4,500 feet south of lat. 41° 02' 30"N, long. 75° 10' 00"W, at an elevation of 520 feet, southeast portion of East Stroudsburg 7-1/2' Quadrangle.) Onondaga Limestone (members C and D, Echo Lake Member).

P6 EAST STROUDSBURG: On north side of U.S. Business Rte. 209, 0.9 mile northeast of intersection of that route with Pa. Rte. 447 and 0.4 mile northeast of East Stroudsburg borough line, Smithfield Township, Monroe Co. (5,250 feet south of lat. 41° 02' 30"N, 1,000 feet west of long. 75° 10' 00"W, at an elevation of 480 feet, south-central portion of East Stroudsburg 7-1/2' Quadrangle.) Onondaga Limestone (Member B).

P7 BUTTERMILK FALLS: On U.S. Rte. 209 (new), 0.1 mile west of Buttermilk Falls and 2.3 miles south of Marshalls Creek village, Smithfield Township, Monroe Co. (3,600 feet north of lat. 41° 00' 00"N, and 2,200 feet west of long. 75° 07' 30"W, at an elevation of about 400 feet, southeast corner of East Stroudsburg 7-1/2' Quadrangle.) The upper Esopus Formation, Schoharie Formation, and lower Onondaga

Limestone are exposed on both sides of the road. Attitude of bedding is N 80° E/20° S in the Esopus and lower Schoharie and N 80° W/25° S in the upper Schoharie and Onondaga. Buttermilk Falls marks post-glacial course of Marshalls Creek over lower Onondaga beds on strike with exposure in road cut. Previously described by Epstein (1970, pp. 317-318). Section by Inners.

	Thickness Unit Ft.	Unit In.	Thickness Total Ft.	Total In.
Onondaga Limestone				
Upper part not exposed.				
Member A (Edgecliff Member)			30	
9. Limestone, medium to thick bedded (in beds 3" to 12" thick), med. gray (N5), lt. gray (N7) weathering, fine to med. grained, cherty, burrowed, fossiliferous. Appears massive, but beds defined by wavy, dark gray (N3) organic seams are generally 12" or less in thickness. Bedding partings are several feet apart. Chert, grayish black (N2), slightly calcareous, in nodules up to 6" diameter. Chert nodules, more abundant, larger in upper half of exposure. Irregularly cleaved. Contact with Schoharie is abrupt. Fossils: Large crinoid columnals (a), corals (c).	30			
Schoharie Formation			120	
Saugerties-Aquetuck Members, Undivided			52	
8. Siltstone, siliceous, calcareous, massive (beds up to 3' thick), dk. gray (N3), yellowish gray (5Y 7/2) weathering (weathered rind about 1/4' thick on joint surfaces), sandy, burrowed, fossiliferous. Burrows are vertical, generally 1/4" to 1/2" in diameter, up to 6" long, form med. gray (N5) circles on bedding planes. En				

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
echelon tension gashes, subparallel to bedding, are common. Blocky fracture pattern (incipient fractures perpendicular to bedding and spaced 1/4" to 1/2" apart) is distinctive. Unit underlies ridge crest.	16			
7. Siltstone, calcareous, argillaceous, massive (in beds 6" to 24" thick), weathering med. gray (N5) and yellowish gray (5Y 7/2), with abundant nodules of siltstone, siliceous, grayish black (N2). Thoroughly burrowed. Fossiliferous. Fossils: *Acrospirifer duodenaria* (c), etc.	7			
6. Siltstone, calcareous, argillaceous, massive to thick bedded (in beds 6" to 24" thick), med. dk. gray (N4), alternate beds weather med. gray and yellowish gray, burrowed, fossiliferous. Nodules of siliceous, grayish black siltstone (1" to 3" in diameter) scattered parallel to bedding. Burrows are vertical, 1/8" to 1/4" in diameter. Fossils: *Acrospirifer duodenaria* (c), *Anchiopella anchiops* (unc), etc.	29			
Carlisle Center Member			68	
5. Siltstone, calcareous, argillaceous, med. to thick bedded (in beds 4" to 12" thick), med. dk. gray (N4), alternate beds weather med. gray and yellowish gray, rusty stained, pyritic, burrowed, fossiliferous. Burrows are horizontal, *Taonurus* abundant. Discontinuous bed of black (N1) chert about 2" thick, 15 feet below top (observed on east wall of cut), may be "black bed."				

	Thickness Unit Ft. In.	Total Ft. In.
Fossils: Acrospirifer duodenaria (c), Leptocoelina acutiplicata (c).	28	
4. Mudstone, calcareous, massive, dk. gray (N3), weathering med. gray and rusty, pyritic (pyrite in nodules up to 1"), burrowed, fossiliferous, with widely spaced interbeds of mudstone, very calcareous, med. bedded (in beds 2" to 6" thick), dk. gray (N3), weathering yellowish gray (5Y 7/2), burrowed. Taonurus markings profuse. Vague laminations spaced 1/8" to 1/4" apart. Fossils: Leptocoelina acutiplicata (c), Eodevonaria arcuata (unc).	40	
Esopus Formation		106+
3. Mudstone, silty, massive, dk. gray (N3), weathering med. gray (N5), yellowish gray (5Y 7/2), and rusty, pyritic (pyrite in scattered nodules up to 1/2" in diameter), slightly calcareous, fossiliferous. Highly cleaved. Taonurus abundant. Vague lamination (laminae dk. gray and yellowish gray, 1/8" to 1/4" thick) caused by horizontal burrows. Fossils: Leptocoelina acutiplicata (unc).	41	
2. Concealed interval.	30	
1. Mudstone, silty, massive, dk. gray, weathering med. gray and rusty, burrowed, vaguely laminated as in Unit 3. Highly cleaved.	35	
Lower part concealed.		

P8 BRODHEAD CREEK: Along abandoned railroad grade, northeast side of Brodhead Creek, about 0.4 mile west of Minisink Hills, Smithfield Township, Monroe Co. (Base of Esopus approximately 1,000 feet south of lat. 41° 00' 00"N, 5,500 feet west of long. 75° 07' 30"W, at elevation of 380 feet, northeast corner of Stroudsburg 7-1/2' Quadrangle.) The Helderberg Group, Oriskany Group, Esopus Formation, and Schoharie Formation crop out continuously in artificial cuts about 50 feet above Brodhead Creek, where the stream bends south through Godfrey Ridge. The Esopus and Schoharie are also well exposed on bank of Brodhead Creek across from the paper mill. Average attitude of Esopus is N 70° E/45° N. Previously described by White (1882, p. 248) and Swartz and Swartz (1941, p. 1161). Section by Inners.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Schoharie Formation				
Upper portion exposed, but not measured.				
Carlisle Center Member (lower part)			20	
4. Mudstone, calcareous, massive (in beds 12" to 48" thick), med. dk. gray (N4), med. gray (N5) and rusty weathering, Taonurus profuse, fossiliferous, with widely separated interbeds of mudstone, very calcareous, med. bedded (in beds 2" to 6" thick), med. dk. gray (N4), yellowish gray (5Y 6/4) weathering, fossiliferous, recessed. Highly cleaved. Fossils: Leptocoelina acutiplicata (c).	20			
Esopus Formation			216	6
3. Mudstone, silty (with some coarser siltstone beds), massive, very vaguely laminated (laminae, discontinuous 1/16" to 1/2" thick, alternately dk. gray and brown), dk. gray (N3), rusty and grayish black (N2) weathering, burrowed, strongly cleaved. Taonurus markings abundant throughout, but can be best seen 20' above base. Upper 50' slightly calcareous. Fossil hash lens 8' above base.	205			

	Thickness Unit Ft.	In.	Total Ft.	In.
2. Siltstone, calcareous, massive, dk. gray (N3), fossiliferous, grading upward into dk. gray, strongly cleaved, silty mudstone.	10			
1. Sandstone, calcareous, very fine grained, med. dk. gray (N4), fossiliferous, weathers to soft, rusty orange sandrock. Contact with Ridgeley sandstone marked by strongly leached zone. Fossils: Hysterolites (?) sp. (r).	1	6		

Ridgeley Sandstone
Sandstone, massive, lt. gray (N7), med. to coarse grained, quartzose, calcareous, fossiliferous.

P9 BRODHEAD CREEK: In abandoned Slater-Canfield quarry, about 0.1 mile northwest of Delaware, Lackawanna, and Western Railroad tracks that parallel Brodhead Creek and 0.9 mile west of Minisink Hills, Smithfield Township, Monroe Co. (750 feet south of lat. 41° 00' 00"N, 3,500 feet east of long. 75° 10' 00"W, at an elevation of 440 feet, northeast corner of Stroudsburg 7-1/2' Quadrangle.) Schoharie Formation (Saugerties-Aquetuck members, undivided), Onondaga Limestone (Member A, Edgecliff Member, members B and C). Section described by Johnsen (1957, pp. 97-98) and Epstein and Epstein (1967, pp. 79-80).

P10 BRODHEAD CREEK: On north side of Delaware, Lackawanna, and Western Railroad tracks, north side of Brodhead Creek, 0.4 mile east of East Stroudsburg and 1.0 mile west-southwest of Minisink Hills, Smithfield Township, Monroe Co. (1,500 feet south of lat. 41° 00' 00"N, 3,000 feet east of long. 75° 10' 30"W, at an elevation of 400 feet, northwest portion of Stroudsburg 7-1/2' Quadrangle.) Contact of Ridgeley Sandstone and Esopus Formation.

P11 EAST STROUDSBURG: On the Delaware, Lackawanna, and Western Railroad, 0.5 mile south of railroad station, East

Stroudsburg, Monroe Co. (5,000 feet south of lat. 41° 00' 00"N, 5,800 feet west of long. 75° 10' 00"W, at an elevation of about 400 feet, north-central portion of Stroudsburg 7-1/2' Quadrangle.) The Onondaga Limestone crops out on both limbs of an anticlinal fold, overturned to the north, that is splendidly exposed in a long cut at a sharp bend in the railroad. The upper part of the Schoharie Formation forms the core of the anticline. All four members of the eastern Pennsylvania Onondaga can be studied on the north limb. Average attitude of bedding on the north limb is N 50° E/50° S (overturned) and on the south limb, N 60° E/17° S. Previously described by Epstein (1970, pp. 318-320). Section by Inners, assisted by Smith.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Marcellus Formation				
Not exposed in immediate vicinity, but probably directly overlies Unit 11.				
Onondaga Limestone			261	6
Member D (Echo Lake Member)			22	
11. Limestone, massive, coarse grained, med. gray (N5), cherty, extremely fossiliferous (biocalcirudite and biocalcarenite). Numerous calcite veins. Fossils: Small rugose corals (a), <u>Acrospirifer varicosus</u> (c), chonetid brachiopods (a), <u>Tentaculites bellulus</u> (c), etc.	22			
Member C			120	3
10. Limestone, massive, med. grained, med. dk. gray (N4), very cherty, fossiliferous. Chert, grayish black (N2), calcareous. Numerous calcite veins, some en echelon. Slickensides on lower bedding surface (above tuffaceous bed).	8	6		
9. Siltstone, tuffaceous, med. lt. gray (N6), weathering greenish gray (5GY 6/1), micaceous, non-calcareous. Strongly cleaved.	1			

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
8. Limestone, massive, med. grained, med. dk. gray (N4), very cherty, fossiliferous. Chert, grayish black. Numerous calcite veins, many en echelon.	16	11		
7. Limestone, thick bedded, med. to fine grained, med. dk. gray, very cherty, fossiliferous. Chert, grayish black, occurs in discontinuous layers and ragged nodules. About 30% of unit is chert. Many chert veins in upper 15 feet. Calcitic bedding plane slip zone about 20 feet above base.	36	9		
6. Shale and limestone, interbedded. Shale, calcareous, med. dk. gray, highly cleaved. Limestone, thin bedded (in beds about 2" thick), fine to med. grained, med. dk. gray, argillaceous. Sparingly fossiliferous. Cherty rims around some discontinuous limestone nodules.	4	4		
5. Limestone, massive, med. to fine grained, dk. gray (N3.5), cherty, sparingly fossiliferous. Contains calcitic bedding-plane slip zone.	21	7		
4. Limestone, massive, fine to med. grained, med. grained, med. gray (N5), sparingly fossiliferous. Chert, grayish black, calcareous, in discontinuous lenses and nodules. Unit is about 15% chert.	31	2		
Member B			37	4
3. Shale, calcareous, med. dk. gray (N4), highly cleaved, with nodules and discontinuous beds of limestone, med. gray (N5), argillaceous, fossiliferous. Limestone beds and nodule layers are generally 2" to 6"				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
thick and are separated by 3" to 12" of shale. Calcitic bedding plane slip horizon in middle of unit. Fossils: *Atrypa reticularis* (c), rugose corals (c).	37	4		
Member A (Edgecliff Member)			81	11
2. Limestone, med. to thick bedded (in beds 3" to 12" thick), fine grained, med. dk. gray, very cherty, fossiliferous. Fossils: Rugose corals (c).	32	6		
1. Limestone, massive, med. grained, med. gray (N5), lt. gray (N7) weathering, cherty, fossiliferous. Chert, grayish black (N2), calcareous, occurs in ragged nodules up to 6" in diameter, weathers punky. Fossils partly replaced by chert. Highly cleaved. Abrupt contact with Schoharie. Fossils: Large crinoid columns (up to 1-1/2" diameter) (a), rugose corals (c).	49	5		

Schoharie Formation
Saugerties-Aquetuck Members, Undivided
Siltstone, sandy, calcareous, massive, med. dk. gray (N4), sandy, burrowed, highly cleaved.

P12 MINISINK HILLS: Cut on southwest side of Interstate Rte. 80, where highway passes through Godfrey Ridge at Brodhead Creek gap, 0.5 mile west of Minisink Hills, Smithfield Township, Monroe Co. (1,000 feet south of lat. 41° 00' 00"N, 5,000 feet east of long. 75° 10' 00"W, at an elevation of about 400 feet, northeast corner of Stroudsburg 7-1/2' Quadrangle.) Minisink Limestone, Port Ewen Shale, Shriver Chert, and Ridgeley Sandstone. Section described by Epstein, Epstein, Spink, and Jennings (1967, pp. 65-67).

P13 STROUDSBURG: On south side of Interstate Rte. 80 at Pa. Rte. 191 overpass, Stroudsburg, Monroe Co. (5,500 feet south of lat. 41° 00' 00"N, 6,000 feet west of long. 75° 10' 00"W, at an elevation of 425 feet, north-central portion of Stroudsburg 7-1/2' Quadrangle.) Onondaga Limestone (Member C, with tuffaceous siltstone, Member D, Echo Lake Member).

P14 FOXTOWN GAP: On U.S. Rte. 611 on slopes and crest of Godfrey Ridge in Foxtown Gap, just south of Stroudsburg borough line, Foxtown Hill, Stroud Township, Monroe Co. (6,250 feet north of lat. 40° 57' 00"N, 3,500 feet west of long. 75° 10' 30"W, at an elevation of 740 feet, north-central portion of Stroudsburg 7-1/2' Quadrangle.) Ridgeley Sandstone, Esopus Formation, Schoharie Formation, and Onondaga Limestone.

P15 SNYDERSVILLE: In quarry of Eureka Stone Co., southeast side of U.S. Rte. 209, and cuts on both sides of same highway, about 1.5 miles south-southwest of Snydersville, Hamilton Township, Monroe Co. (6,900 feet north of lat. 40° 55' 00"N, 1,400 feet west of long. 75° 17' 30"W, at an elevation of about 580 feet, central portion of Saylorsburg 7-1/2' Quadrangle.) Schoharie Formation, Onondaga Limestone.

P16 HAMILTON SQUARE: On west side of country road, 1.3 miles southwest of Bossardsville and 0.4 mile south of Hamilton Square, Hamilton Township, Monroe Co. (800 feet north of lat. 40° 55' 00"N, 1,000 west of long. 75° 17' 30"W, at elevation of about 620 feet, central part of Saylorsburg 7-1/2' Quadrangle.) Onondaga Limestone. Locality described by White (1882, p. 206).

P17 SAYLORSBURG: On west side of Pa. Rte. 115 in deep rock cut through southwest end of Cherry Ridge, 0.5 mile southeast of Saylorsburg, Monroe Co. (6,500 feet north of lat. 40° 52' 30"N, 5,500 feet east of long. 75° 20' 00"W, at an elevation of about 750 feet, south-central portion of Saylorsburg 7-1/2' Quadrangle.) Schoharie-Esopus formations, undivided, and Palmerton Sandstone have been exposed by recent road construction. Attitude of bedding is N75° E/52° S (overturned). Section by Inners.

	Unit Ft.	Unit In.	Total Ft.	Total In.
Palmerton Sandstone			84	9
Top not exposed.				
13. Sandstone, massive, med. grained, med. lt. gray (N6), moderately sorted, quartzitic.	21			
12. Sandstone, massive, coarse grained, med. lt. gray, poorly to moderately sorted, quartzitic. Three-foot bed of fine grained sandstone in middle.	32			
11. Sandstone, massive, med. to coarse grained, med. lt. gray, moderately well sorted, quartzitic.	10			
10. Sandstone, massive, med. to coarse grained, med. lt. gray, moderately to well sorted, quartzitic. At base several finer beds, 2" to 3" thick.	6	7		
9. Sandstone, massive, med. to coarse grained, med. lt. gray, moderately well sorted, quartzitic.	10	10		
8. Sandstone, thick bedded, with alternating 6" beds of coarse and med. grained sandstone, med. lt. gray, moderately well sorted, quartzitic. Grains angular to moderately rounded.	4	4		
Schoharie-Esopus Formations, Undivided			63	2
7. Sandstone, thick bedded (in beds 6" to 24" thick), very fine grained, with scattered med. to coarse sand grains, very lt. gray (N8), moderately to well sorted, quartzose, fossiliferous. Fossils: Unidentified brachiopods (c).	8	9		
6. Siltstone and sandstone, interbedded. Siltstone, thick bedded, lt. gray (N7), very lt. gray weathering, quartzitic, "chalky." Sandstone, thick bedded, very fine grained, lt. gray, quartzose, somewhat less "chalky" than siltstone. (In 6 beds of about equal thickness.)	3	2		

	Thickness Unit Ft.	In.	Total Ft.	In.
5. Siltstone, thick bedded (in beds 7" to 16" thick), lt. gray, quartzose, "chalky" weathering. Scattered fine sand grains in lower 1 foot.	3			
4. Sandstone, thick bedded, very fine grained, lt. gray, moderately well sorted with scattered sand grains about 1mm. in size, quartzose, fossiliferous. Fossils: Unidentified brachiopods (c).	1	9		
3. Siltstone, med. to thick bedded (in beds 3" to 21" thick, averaging about 10" to 12"), lt. gray (N7) to very lt. gray (N8), weathering (in part) pale yellowish orange (10YR 8/6), quartzose, fossiliferous. Fossils: Acrospirifer duodenaria (c), unidentified brachiopods (unc).	15	3		
2. Siltstone, med. to thick bedded (in beds 2" to 12" thick, averaging 6"), med. gray (N5), strongly leached, weathering rusty and maroon, quartzose and argillaceous. A few beds show Taonurus-markings.	17	9		
1. Siltstone, med. to thick bedded (in beds 3" to 6" thick), med. gray, strongly leached, weathering rusty and yellowish gray (5Y 7/2), quartzose and argillaceous. Fracture cleavage strongly developed. Taonurus-markings common.	13	6		
Base not exposed.				

P18 KUNKLETOWN: In abandoned quarry of Sheesley Minerals Co., 0.3 mile south of Kunkletown, Eldred Township, Monroe Co. (4,000 feet north of lat. 40° 50' 00"N, 3,750 feet east of long. 75° 27' 30"W, at an elevation of about 700 feet, north-central portion of Kunkletown 7-1/2' Quadrangle.) Schoharie-Esopus formations, undivided, and Palmerton Sandstone.

P19 LITTLE GAP: On west side of gap cut by Buckwha Creek between Chestnut Ridge and Stony Ridge, 0.3 mile south of Little Gap Village, Lower Towamensing Township, Carbon Co. (2,000 feet south of lat. 40° 50' 00"N, 4,500 feet east of long. 75° 32' 30"W, at an elevation of 480 feet, east-central portion of Palmerton 7-1/2' Quadrangle.) The Ridgeley Sandstone, Schoharie-Esopus formations, undivided, Palmerton Sandstone, and Onondaga Limestone, as well as the lower part of the Marcellus Formation, are exposed on steep bluffs west of the road. The Palmerton Sandstone is repeated by complex folding. Measurements of Schoharie-Esopus and Palmerton were made at south end of gap on overturned limb of an antiformal fold (Sevon, 1969, p. 131). Average attitude of bedding on this limb is N 75° W/50° S (overturned). Onondaga Limestone crops out in small quarry at north end of gap. Attitude of Onondaga is N 80° E/55° S (overturned?). Previously described by Swartz and Swartz (1941, p. 1153). Section by Inners, assisted by Smith.

	Thickness Unit Ft.	In.	Total Ft.	In.
Marcellus Formation				
Shale, fissile, black (N1) carbonaceous, non-calcareous, rusty weathering.				
Onondaga Limestone			32+	
Top not exposed.				
25. Limestone, massive to thick bedded, fine grained, med. dk. gray (N4) to dk. gray (N3), cherty, argillaceous, highly fossiliferous. Chert occurs in small nodules and discontinuous bands. Weathers shaly. Fossils: _Longispina mucronatus_ (c), _Eodevonaria elymencheri_ (unc), unidentified chonetids (c), etc.	32			
Base not exposed.				
Palmerton Sandstone			151	5
24. Sandstone, massive, med. to coarse grained, conglomeratic, lt. gray (N7), poorly to moderately sorted.	123			

	Unit Ft.	Unit In.	Total Ft.	Total In.
23. Sandstone, fine grained, lt. gray, moderately well sorted, with scattered coarse sand grains.		6		
22. Sandstone, massive, very coarse grained to conglomeratic, lt. gray.	2	9		
21. Sandstone, thick bedded, med. grained, lt. gray, moderately sorted, with scattered pebbles.	1	3		
20. Sandstone, thick bedded, coarse grained, lt. gray, moderately sorted.	4	11		
19. Sandstone, thick bedded, fine grained, lt. gray, well sorted.	2	6		
18. Sandstone, thick bedded, very coarse grained, lt. gray, poorly sorted.	3	1		
17. Sandstone, thick bedded, fine grained, lt. gray, well sorted.	1	4		
16. Sandstone, med. bedded (in beds 2" to 4" thick), fine grained, lt. gray, well sorted.	3			
15. Sandstone, thick bedded, fine grained, lt. gray, well sorted.		8		
14. Sandstone, med. bedded, very coarse grained (average size about 1.5mm.), lt. gray, moderately sorted.		3		
13. Siltstone, medium to thick bedded (in beds 4" to 25" thick), abundant scattered 1mm. sand grains, lt. gray, chalky weathered, with 1" and 3" beds of sandstone, med. coarse grained, lt. gray, moderately sorted. Base of Palmerton drawn below 1" sandstone bed.	8	2		
Schoharie-Esopus Formations, Undivided			86	4
12. Siltstone, med. to thick bedded (in beds 4" to 19" thick, mostly about 12"), with abundant scattered sand grains 1mm. or less in size, lt. gray (N7), chalky weathered, quartzose, fossiliferous.				

		Thickness			
		Unit		Total	
		Ft.	In.	Ft.	In.
	Fossils: *Schellwienella pandora* (unc), *Acrospirifer duodenaria* (unc).	5	10		
11.	Siltstone, thick bedded (in beds 7" to 24" thick), lt. gray to very lt. gray (N8), chalky weathered, quartzose, fossiliferous. Fossils: *Acrospirifer duodenaria* (c), *Protoleptostrophia perplana* (unc).	7	2		
10.	Siltstone, med. to thick bedded (in beds 5" to 13" thick), strongly leached, weathered yellowish gray (5Y 7/2) and maroon, quartzose and argillaceous.	4	0		
9.	Siltstone, thick bedded (in beds 6" to 22" thick), strongly leached, weathered yellowish gray, maroon and rusty, quartzose, argillaceous, fossiliferous. Fossils: *Orbiculoidea* sp. (unc), unidentified brachiopods (unc).	12	3		
8.	Siltstone, thick bedded (in beds 6" to 22" thick), med. dk. gray (N4), strongly leached, weathered yellowish gray and maroon, quartzose and argillaceous.	20	10		
7.	Siltstone, thick bedded (in two beds 12" and 10" thick), leached to med. lt. gray (N6), weathered yellowish gray, quartzose, argillaceous. *Taonurus*-markings abundant.	1	10		
6.	Siltstone, thick bedded (in beds 11" to 22" thick), strongly leached, weathered yellowish gray and rusty, quartzose, argillaceous.	9	7		
5.	Siltstone, thick bedded, leached to med. lt. gray, weathered yellowish gray and rusty, quartzose and argillaceous.	2	2		
4.	Siltstone, med. bedded (in beds 3" to 6" thick), leached to med. lt. gray, weathered yellowish gray, white (N9), and tan, quartzose, argillaceous. Contains vague *Taonurus* markings.	12	5		

	Thickness Unit Ft.	In.	Total Ft.	In.
3. Clay, dk. reddish brown (10R 3/4), hemititic, forms distinct band down slope.		9		
2. Concealed interval. Siltstone float.	9	6		
Ridgeley Sandstone			10+	
1. Sandstone, massive, coarse grained to pebbly, bimodal grain size distribution with modes at 1mm. (coarse sand) and 3 to 4mm. (pebbles).	10			
Base not exposed.				

P20 PALMERTON: Along gravel road at crest of Stony Ridge near entrance to Alliance Sand Co. quarries, 0.2 mile north of Palmerton, Carbon Co. (5,000 feet north of lat. 40° 47' 30"N, 2,000 feet east of long. 75° 37' 30"W, at an elevation of 820 feet, east-central portion of Lehighton 7-1/2' Quadrangle.) Onondaga Limestone, Marcellus Formation. Section of Palmerton Sandstone in sand quarries to east described by Swartz and Swartz (1941, p. 1150).

P21 BOWMANSTOWN: On old Bowmanstown-Palmerton Highway, 0.3 mile southeast of Bowmanstown, Carbon Co. (1,000 feet north of lat. 40° 47' 30"N, 2,500 feet east of long. 75° 40' 00"W, at an elevation of about 480 feet, east-central portion of Lehighton 7-1/2' Quadrangle.) Ridgeley Sandstone, Schoharie-Esopus formations, undivided, and Palmerton Sandstone crop out in steep, rubbly cliffs on east side of road. Attitude of bedding in Schoharie-Esopus is N40° E/45° N. Section by Inners.

	Thickness Unit Ft.	In.	Total Ft.	In.
Palmerton Sandstone				
Upper portion exposed, but not measured.				
5. Sandstone, massive, very lt. gray (N8), moderate red (5R 4/6) mottled, med. coarse grained (0.5 to 1.0mm.), moderately sorted. Contact with				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
underlying Schoharie-Esopus siltstone is poorly exposed, but probably interlayered.	12			
Schoharie-Esopus formations, undivided			43	
4. Siltstone, siliceous, thick bedded (in beds 6" to 24" thick), lt. gray (N7) to white (N9) weathering, rusty stained, fossiliferous. Fossils: *Tentaculites* sp. (unc), unidentified brachiopod fragments (c).	15			
3. Siltstone, med. to thick bedded (in beds 4" to 6" thick), med. dk. gray (N4), rusty weathering, argillaceous and shaly.	3			
2. Siltstone, thick bedded, dk. reddish brown (10R 3/4), sandy, weathers to irregular slabs.		11		
1. Siltstone, med. to thick bedded (in beds 4" to 12" thick), med. dk. gray, rusty weathered, brittle, argillaceous, with abundant *Taonurus* markings. Contact with Ridgeley not exposed.	24			
Ridgeley Sandstone				
Sandstone, massive, lt. gray (N7), coarse grained to conglomeratic, bimodal, highly fossiliferous.				

P22 WEST BOWMANS: In deep cut of Northeast Extension, Pennsylvania Turnpike, through Stony Ridge, 0.2 mile south of West Bowmans, Carbon Co. (1,000 feet north of lat. 40° 47' 30"N, 1,500 feet west of long. 75° 40' 00"W, at an elevation of about 475 feet, central part of Lehighton 7-1/2' Quadrangle.) An unbroken sequence from the New Scotland Formation to the Marcellus Formation has been exposed here by turnpike construction. The New Scotland, Ridgeley, Schoharie-Esopus, Palmerton, and Onondaga crop out in the southern portion of the cut, and the Marcellus Formation in the northern portion. Average attitude of bedding in Onesquethawan rocks is

N 70° E/60° S (overturned). Previously described by Willard (1953, pp. 2299-2302). Section by Inners, assisted by Smith.

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
Marcellus Formation				
Shale, dk. gray (N3), fissile, weathering rusty.				
Onondaga Limestone			42	7
33. Metabentonite, dk. gray (N3), shaly, micaceous, with thin iron-stone interbeds. (Tioga.)		6		
32. Limestone and shale, leached to clay and siltstone with residual chert nodules, weathering grayish orange (10YR 7/4) and dk. yellowish orange (10YR 6/6), beds mostly about 6" thick. Upper 6-7 feet fossiliferous. Fossils: Eodevonaria elymencheri (c), Kozlowskiellina (Megakozlowskiella) raricosta (c), trilobite fragments (unc).	22	5		
31. Shale, micaceous, weathers rusty, fossiliferous.		4		
30. Limestone, leached to clay and siltstone, similar to Unit 32, fossiliferous, burrowed. Fossils: Brachiopods (c), rugose corals (c), crinoid columnals (c).	3	3		
29. Siltstone, micaceous, leached to grayish orange (10YR 7/4), clay shale with mica flakes at top. (Metabentonite?)	1			
28. Limestone and shale, leached to clay, cherty, fossiliferous. Fossils: Leptocoelina acutiplicata (unc), Tentaculites bellulus (unc), unidentified bryozoans (c), trilobite fragments (unc).	8	2		
27. Limestone, med. gray (N5), fine grained, fossiliferous.		2		
26. Shale, med. dk. gray (N4), highly fossiliferous.				

		Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
	Fossils: Leptocoelina acutiplicata (c), Douvillina (Douvillina) inaequistriata (unc), unidentified bryozoans (c).		8		
25.	Shale, poorly exposed.		11		
	Hazard Member			5	2
24.	Limestone, fine grained, grayish red (10R 4/2) weathered, fossiliferous.		5		
23.	Shale, dk. grayish red.		7		
22.	Limestone, silty, dk. grayish red, fine grained.		4		
21.	Shale, silty, dk. grayish red, strongly leached.		7		
20.	Shale, leached to brownish yellow clay.		8		
19.	Shale, med. dk. gray (N4), highly leached, forms dark bank on slope.		7		
18.	Covered interval. Reddish shale float.	2			
	Palmerton Sandstone			110	9
17.	Sandstone, massive, med. coarse grained, lt. gray (N7), moderately well sorted. Grains angular. A few scattered pebbles (about 3 mm.) near top. Pebbles become much more abundant toward base. At top of unit is zone of strongly weathered, carbonaceous stained sandstone which forms sluiceway down hillside. Rusty weathered.	25	6		
16.	Conglomerate, fine gravelly, quartz pebbles up to 1/2", bed indistinct.		7		
15.	Sandstone, quartzose, pebbly to moderately coarse grained, lt. gray (N7), pebble beds discontinuous and grade into coarse sandy beds. Bedding, massive, indistinct.	50			
14.	Sandstone, quartzose, massive, med. coarse grained, med. lt. gray (N6), lower part mottled with hematitic stains. Bedding becomes evident in				

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
lower part, thick beds up to 1 foot or more in thickness.	24			
13. Sandstone, quartzose, thick bedded (in beds 6" to 27" thick), med. coarse grained, med. lt. gray (N6). Upper bed has reddish hematitic stains. Lower bed grades down into fine sandy siltstone.	7			
12. Siltstone, sandy, med. lt. gray.		8		
11. Sandstone, quartzose, med. coarse grained, med. lt. gray.		9		
10. Siltstone, quartzose, sandy, med. lt. gray, rusty weathering, fossiliferous.	1	7		
9. Sandstone, quartzose, med. coarse grained, med. lt. gray, fossiliferous.		8		
Schoharie-Esopus Formations, Undivided			42	9
8. Siltstone, quartzose, thick bedded (in beds 6" to 18" thick), med. lt. gray (N6), rusty stained, sandy, fossiliferous. Fossils: Tentaculites sp. (unc), Mucrospirifer macra (unc), Acrospirifer duodenaria (c).	12			
7. Siltstone, thick bedded, med. gray (N5), burrowed (Taonurus markings), fossiliferous.	2	4		
6. Siltstone, argillaceous, thick bedded (in beds 5" to 20" thick), med. dk. gray (N4), rusty and shaly weathering.	3	5		
5. Siltstone, sandy, dk. reddish brown (10R 3/4) weathered, soft, hematitic.		7		
4. Siltstone, argillaceous, med. to thick bedded (in beds 4" to 20" thick), med. dk. gray, rusty weathered, Taonurus markings abundant.	14	5		
3. Siltstone, argillaceous, thin to thick bedded (in beds 2" to 6" thick), med. dk. gray, rusty and tan weathered.	6	9		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
2. Siltstone, argillaceous, leached to white and rusty clay punk. Contact with Ridgeley abrupt.	3	3		
Ridgeley Sandstone			10+	
1. Sandstone, quartzose, massive, very coarse grained to conglomeratic, lt. gray (N7), bimodal sorting, fossiliferous. Very pebbly in upper few feet, with pebbles up to 1/2" in diameter. A 1" bed of finer grained sandstone at top. Fossils: Costispirifer arenosus (a), etc.	10+			

P23 GERMANS: In active (west) and inactive (east) quarries of the Refractories Sand Co., Germans, Penn Township, Carbon Co. (West quarry - 4,000 feet north of lat. 40° 45' 00"N, 1,000 feet east of long. 75° 45' 00"W, at an elevation of about 680 feet; east quarry - 5,000 feet north of lat. 40° 45' 00"N, 3,500 feet east of long. 75° 45' 00"W, at an elevation of 680 feet; southwest portion of Lehighton 7-1/2' Quadrangle.) Schoharie-Esopus formations, undivided, Palmerton Sandstone, Onondaga Limestone.

P24 STONY MOUNTAIN SCHOOL: On crest of low ridge, 0.4 mile east-northeast of Stony Mountain School and 1.3 miles southwest of Germans, East Penn Township, Carbon Co. (2,000 feet north of lat. 40° 45' 00"N, 3,800 feet west of long. 75° 45' 00"W, at an elevation of about 700 feet, southeast corner of Nesquehoning 7-1/2' Quadrangle.) At site of measured section, the Ridgeley and Palmerton sandstones form projecting ledges for a short distance along top of ridge, with the Schoharie-Esopus siltstone exposed in the intervening swale. Attitude of Ridgeley is N 67° E/56° S (overturned). Few fossils were observed in the Schoharie-Esopus here, but a large fauna was collected along strike 500 feet to the northeast. Section by Inners, assisted by Smith.

	Thickness Unit Ft.	Unit In.	Thickness Total Ft.	Total In.
Palmerton Sandstone			39	
Upper part concealed.				
11. Sandstone, quartzose, massive, very coarse grained to pebbly, med. lt. gray (N6), moderately sorted, grains angular. Appears unbedded. A few scattered brachiopod molds present.	36			
10. Siltstone, quartzose, med. gray (N5).		2		
9. Sandstone, quartzose, coarse grained, med. lt. gray.	1			
8. Siltstone, quartzose, med. gray.		5		
7. Sandstone, quartzose, coarse grained (average size about 2mm.), med. lt. gray.		6		
6. Siltstone, quartzose, med. gray, fossiliferous.		8		
5. Sandstone, quartzose, coarse grained, med. lt. gray.		2		
Schoharie-Esopus Formations, Undivided			22	6
4. Siltstone, quartzose, thick bedded, med. dk. gray (N4) to med. gray (N5) weathered, occurs as rubble zone with a few outcropping ledges. Hemitite bed, 6" thick, dark reddish brown (10R 3/4) weathered, about 7 feet above base. Sparingly fossiliferous. Fauna listed below collected 500 feet east on strike. Fossils: Leptocoelia flabellites (c), Acrospirifer duodenaria (c), Leptaena rhomboidalis (unc), etc.	22	6		
Ridgeley Sandstone			12	
3. Conglomerate, quartzose, massive, coarse grained, lt. gray (N7) to white (N9), poorly sorted, pebbles up to 1/2" in diameter, average grain size of matrix 1-2mm., highly fossiliferous (brachiopod valves, convex up).	3			

	Unit Ft.	Unit In.	Total Ft.	Total In.
2. Sandstone, quartzose, massive, very coarse grained (average grain size about 2mm.), lt. gray (N7). Pebbles not as abundant as in Unit 3. Very coarse pebbly layer at base. Replete with brachiopod molds, convex up.	3			
1. Conglomerate, quartzose, massive, coarse grained, lt. gray, with several pebbly conglomeratic beds, grains angular, pebbles rounded. Numerous brachiopod molds, convex up.	6			
Lower part concealed.				

P25 ANDREAS: In quarries of Refractories Sand Co., 0.75 mile south of Andreas, West Penn Township, Schuylkill Co. (Composite section based on exposures of Onondaga Limestone in abandoned sand pit, 4,000 feet south of lat. 40° 45' 00"N, 200 feet west of long. 75° 47' 30"W, at elevation of about 740 feet, and of Palmerton Sandstone, in active quarry about 2,000 feet to northeast, northeast corner of New Tripoli 7-1/2' Quadrangle.) Schoharie-Esopus, Palmerton and Onondaga are extensively exposed in several plunging folds that control quarry operations (Sevon, 1969, pp. 133-136). Section by Inners, assisted by Smith.

	Unit Ft.	Unit In.	Total Ft.	Total In.
Onondaga Limestone			45	
3. Limestone, argillaceous, fossiliferous, thoroughly leached to dusky yellow (5Y 6/4), silty claystone, with interbeds of shale, micaceous, fossiliferous, at top. Brownish-red (10R 4/2) weathered limestone at base may represent Hazard Member. Contact with Palmerton is abrupt. Fossils: Leptaena rhomboidalis (unc), rugose corals (unc), etc.	45			

	Thickness Unit Ft. In.	Thickness Total Ft. In.
Palmerton Sandstone		48
2. Sandstone, massive, med. to coarse grained, with a few conglomeratic lenses (max. pebble size about 6mm.), lt. gray (N7). Contact with underlying Schoharie-Esopus partially concealed, but probably interlayered.	48	
Schoharie-Esopus formations, undivided		15
1. Siltstone, quartzitic, med. to thick bedded (in beds 4" to 12" thick), lt. gray (N7) to white (N9), chalky weathering, fossiliferous.	15	
Base not exposed.		

P26 SCHUYLKILL HAVEN: In Delago's quarry (abandoned), at right angle bend in road about 0.7 mile northeast of Schuylkill Haven and 1.1 miles west of Adamsdale, North Manheim Township, Schuylkill Co. (3,500 feet north of lat. 40° 37' 30"N, 4,500 feet east of long. 76° 10' 00"W, at an elevation of about 520 feet, southeast corner of Pottsville 7-1/2' Quadrangle.) The Bloomsburg Formation, Bossardsville (= Tonoloway) Limestone, Keyser Limestone, Decker (?) Formation, Ridgeley Sandstone, and Onondaga Limestone (lower part) are exposed in abandoned quarry and in cuts on the Penn Central Railroad to the north. Upper part of Onondaga crops out in small quarry hole in woods several hundred feet east of main quarry. Attitude of Ridgeley is N 80° E/44° S. Previously described (except Onondaga) by Swartz and Swartz (1941, pp. 1133-1136) and Cleaves (1939, pp. 128-129). Section by Inners, assisted by Smith.

	Thickness Unit Ft. In.	Thickness Total Ft. In.
Onondaga Limestone		42±
13. Limestone, med. bedded, fine grained, dk. gray (N3), siliceous, bituminous, highly fossiliferous. Weathers somewhat shaly. Poorly exposed in old		

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
quarry hole east of Delago's quarry. Fossils: Unidentified chonetid brachiopods (c).	20±			
Concealed interval of unknown thickness.				
12. Shale, calcareous, med. to thick bedded (in beds 4" to 12" thick), med. gray (N4), highly fossiliferous, with interbedded limestone, argillaceous, med. bedded (in beds 3" to 5" thick), fine grained, med. gray (N5), highly fossiliferous. Fossils: Heterophrentis simplex (c), Fenestrellina sp. (a), Levenia lenticularis (unc), Leptaena rhomboidalis (unc), Megastrophia (Megastrophia) concava (c), Schellwienella pandora (unc), Atrypa reticularis (c), Coelospira carnilla (unc), Elita fimbriata (unc), Cypricardinia indenta (unc), unidentified platycerid gastropods (c).	8			
11. Concealed interval (old haul road).			14	
Ridgeley Sandstone			4	
10. Sandstone, conglomeratic, massive, lt. gray (N7), bimodal, moderately sorted, sparsely fossiliferous. Pebbles, mostly quartz, well rounded, up to 1/2" in diameter, most abundant in upper 1'8". Contact with underlying Decker (?) Formation abrupt. Fossils: Spiriferinid brachiopods (molds, r). Cleaves (1939, p. 129) reports Costispirifer arenosus, Acrospirifer murchisoni, and Rensselaeria marylandica (i.e., R. elongata).	4			
Decker (?) Formation			18	11
9. Sandstone, med. bedded (in two beds 2-1/2" thick), fine grained, med. lt.				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
gray (N6) to pale greenish yellow (10Y 8/2), tan weathered, quartzose.		5		
8. Shale, pale greenish yellow (10Y 8/2) with thin lenses of sandstone, burrowed.	1	1		
7. Sandstone, thin to med. bedded (in beds 1" to 6" thick), fine grained, med. lt. gray to greenish gray (5GY 6/1), tan weathered, quartzose to shaly, with interbedded shale, thin to med. bedded (in beds 1/2" to 5" thick), greenish gray.	3	5		
6. Covered interval.	5			
5. Sandstone, mostly thin bedded (in beds 1/2" to 3" thick), fine grained, med. lt. gray to greenish gray, rusty speckled, quartzose to shaly, interbedded with shale, thin bedded (in beds 1" or less thick), greenish gray. Some bedding planes and joints are coated by thin film of black manganese oxide.	2	2		
4. Sandstone, thick bedded, med. grained, greenish gray, rusty speckled, quartzose.		11		
3. Sandstone, med. bedded (in beds 2-1/2" to 5" thick), fine grained, greenish gray tan weathered, quartzose to shaly, with thin bed of shale, sandy, greenish gray 5" above base. Lower sandstone bed has ripple marks on upper surface.	1	6		
Fault?				
2. Sandstone, thin to thick bedded (in beds 1" to 6" thick), fine grained, greenish gray, rusty and tan weathered, shaly fossiliferous, with interbedded shale and mudstone, sandy, thin to med. bedded (in beds 1/2" to 4" thick), greenish gray, fossiliferous. Fossils: *Leperditia* sp. (c).	1	10		

	Thickness Unit Ft.	In.	Total Ft.	In.
1. Sandstone, mostly thin bedded (in beds 1" to 3" thick), fine grained, lt. gray (N7) to greenish gray (5GY 6/1), tan and rusty weathered, current laminated, burrowed, interbedded with shale, thin to med. bedded (in beds 1/8" to 5" thick), med. gray (N5) to greenish gray, rusty weathered, calcareous in part, burrowed. A 1" bed of fine grained, rusty weathered sandstone with abundant Cupulorostrum sp. at base.	2	7		

Keyser Limestone

Limestone, thin bedded (in beds 1/2" to 2" thick), med. dk. gray (N4), argillaceous to sandy, highly fossiliferous, with some interbedded shale, calcareous. Fossils: Ostracodes (a), brachiopods (c), corals (c).

P27 AUBURN: Along dirt road on east side of Schuylkill River, 0.5 mile southeast of Auburn, Schuylkill Co. (4,500 feet north of lat. 40° 35' 00"N, 150 feet west of long. 76° 05' 00"W, at an elevation of 500 feet, north-central portion of Auburn 7-1/2' Quadrangle.) The Onondaga Limestone here occurs above the Bloomsburg "Red Beds" with only a foot or so of conglomeratic sandstone (Ridgeley?) intervening. Attitude of the Onondaga is N 69° E/17° NW, and of the upper Bloomsburg, N 69° E/26° NW. Previously described by Swartz and Swartz (1941, p. 1132). Section by Inners.

	Thickness Unit Ft.	In.	Total Ft.	In.
Marcellus Formation				
Black shale not exposed, but probably present in low area north of knoll formed by limestone beds of Unit 4. A short distance farther north along road, fine to				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
med. grained, yellowish weathering quartz sandstone crops out. Stratigraphic separation between sandstone and limestone not measured, but cannot be more than a few tens of feet.				
Onondaga Limestone			24+	
Upper part concealed.				
4. Limestone, med. to thick bedded, fine grained, med. gray (N5) to med. dk. gray (N4), argillaceous, fossiliferous. No well defined shale partings. Beds break up into irregular elongate blocks. Fossils: Paraspirifer acuminatus (unc), Atrypa reticularis (c), Leptaena rhomboidalis (unc), unidentified bryozoans (c), small rugose corals (unc).	5			
3. Limestone, massive, fine grained, med. dk. gray, argillaceous, burrowed (rusty markings), fossiliferous. Fossils: P. acuminatus (unc), small rugose corals (unc).	1	2		
2. Limestone and shale, interbedded. Mostly float with a few well defined beds of limestone. Limestone, med. to thick bedded, fine grained, med. gray (N5), argillaceous, highly fossiliferous. Shale, calcareous, med. dk. gray (N4), brownish weathering, platy to irregular fracture. Fossils: Megastrophia (Megastrophia) concava (c), Coelospira camilla (c), Longispina mucronatus (c), Kozlowskiellina (Megakozlowskiella) raricosta (unc), Lichenalia sp. (unc), Palaeozygopleura hamiltoniae (unc), Paracyclas lirata (unc), etc.	10			

	Thickness Unit Ft.	In.	Total Ft.	In.
1. Concealed interval. Float of calcareous shale.	8			
Ridgeley (?) Sandstone				
Sandstone, quartzose, conglomeratic, poorly sorted (bimodal grain size distribution). Not exposed, but presence is indicated by relatively sparse float.	1			
Bloomsburg Formation				
Shale and sandstone, red with some green beds. Immense thickness exposed along road and railroad to south.				

P28 MOYERS: In an old, abandoned quarry hole, 2.7 miles east of Rock and 0.5 mile south of Moyers, Wayne Township, Schuylkill Co. (1,500 feet north of lat. 40° 32' 30"N, 200 feet west of long. 76° 15' 00"W, at an elevation of 750 feet, east-central portion of Swatara Hill 7-1/2' Quadrangle.) Bedding in the Onondaga Limestone strikes N 70° E and dips 35° N into the Pine Grove Syncline of Wood and Kehn (1968). Section by Inners.

	Thickness Unit Ft.	In.	Total Ft.	In.
Marcellus Formation				
Shale, fissile, grayish black (N2), noncalcareous. Float.				
Onondaga Limestone			38	
2. Limestone, thin to thick bedded (in beds 1" to 10" thick), fine grained, med. dk. gray (N4) to med. gray (N5), brownish gray (5YR 4/1) weathered, argillaceous, fetid, fossiliferous, interbedded with shale, thin bedded (in beds 1" to 3" thick), med. dk. gray (N4),				

	Thickness Unit Ft. In.	Thickness Total Ft. In.
calcareous, fossiliferous. Some dk. gray (N3) calcareous shale and shaly limestone poorly exposed at top. Fossils: Pentagonia unisulcata (c) (in lower 2 feet), Atrypa reticularis (c), Leptaena rhomboidalis (c), Megastrophia (Megastrophia) concava (c), Eodevonaria elymencheri (c), unidentified chonetids (a), etc.	20	
1. Float crop of shale and limestone (shale predominant) with upper few feet exposed. Shale, non-fissile, med. dk. gray (N4), calcareous, fossiliferous. Limestone, med. bedded, fine grained, med. dk. gray, brownish gray weathered, fossiliferous. Contact with underlying Bloomsburg Formation is concealed, but can be located within a few feet. (A few fragments of coarse grained to pebbly, lt. gray (N7), moderately sorted sandstone were found in the vicinity of the contact, but their local derivation could not be verified.)	18	
Bloomsburg Formation		
Sandstone, med. bedded, fine grained, mod. greenish yellow (10Y 7/4), blocky fracture, interbedded with shale, thick bedded, mod. greenish yellow, sandy. Underlying beds concealed.	8	

P29 SWATARA GAP: On south-bound lane of Interstate Rte. 81, 0.5 mile northwest of Swatara Gap, Swatara Township, Lebanon Co. (5,500 feet south of lat. 40° 30' 00"N, 2,000 feet east of long. 76° 32' 30"W, at an elevation of about 550 feet, northeast portion of Indiantown Gap 7-1/2' Quadrangle.) The Bloomsburg Formation (with upper green sandstone member), Onondaga Limestone, Marcellus Formation, and Montebello Sandstone Member of the Mahantango Formation are splendidly exposed on both sides of a deep rock cut. Attitude of Onondaga is N 56° E/86° NW, and of upper Bloomsburg, N 59° E/86° NW. This is the best locality for observing the disconformity between the Onondaga Limestone and the Bloomsburg Formation. Section by Inners.

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
Marcellus Formation			50±	
Shale, fissile, dk. gray (N3) to black (N1), carbonaceous, silty toward top. Sparingly fossiliferous, containing *Styliolina fissurella* and *Leiorhynchus limitare*. Contorted and shiny at base.	50±			
Shale, grayish yellow (5Y 8/4), soft, abounds in pyrite.		1		
Shale, black (N1), carbonaceous, crushed.	1			
Onondaga Limestone			22	9
10. Metabentonite (?), yellowish gray (5Y 8/1), rusty weathering. Contains abundant very fine quartz, mica, and pyrite.		5		
9. Clay, in three beds 11", 20" and 10" thick, tan to brownish (leached limestone) with interbeds of shale, in beds 2" to 6" thick, lt. gray (N7), shiny.	4	1		
8. Limestone, fine grained, med. gray (N5) to med. dk. gray (N4), argillaceous, highly fractured and cleaved, fossiliferous. Fossils: Unidentified chonetid brachiopods (c).	1	11		
7. Covered interval, float of shale and limestone.	1			
6. Metabentonite (?), yellowish gray (5Y 8/1), tan to rusty weathering, fine sandy, containing abundant quartz and biotite.	1	7		
5. Shale, weathering brown and rusty, calcareous, fossiliferous. Upper part denser, with thin, rusty, hematitic streaks.				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Fossils: Unidentified chonetid brachiopods (c).	2	5		
4. Limestone, med. to thick bedded, fine grained, med. gray (N5) to med. dk. gray (N4), fossiliferous. More strongly weathered than underlying units. Weathered to olive brown silty clay, in part. Fossils: Unidentified brachiopods (c) and rugose corals (c).	6			
3. Limestone, massive, fine grained, med. gray to med. dk. gray, med. lt. gray (N6) weathering, argillaceous, fossiliferous.	2			
2. Limestone, med. bedded (in beds to 6" thick), fine grained, med. dk. gray to dk. gray (N3), med. lt. gray weathering, argillaceous, fossiliferous, with interbeds of shale, in beds 2" to 4" thick, med. dk. gray, calcareous, fossiliferous. Small nodules (to about 2" in diameter) in lower few feet are phosphatic. Fossils: *Leptaena rhomboidalis* (unc), *Strophodonta (Strophodonta) demissa* (unc), *Atrypa reticularis* (c), *Hysterolites* (?) sp., *Phacops pipa* (unc), unidentified bryozoans (c) and small rugose corals (c).	3			
1. Conglomerate, poorly sorted, polymict, consisting mostly of rounded quartz pebbles 5 to 10mm. in diameter, but with some chert, etc., pebbles up to 25mm. (largest pebble is about 150mm. in max. length).		4		
Bloomsburg Formation				
Sandstone, med. to thick bedded, fine grained, lt. greenish gray (5GY 7/1), vuggy at top, barren.	50±			

	Thickness Unit Ft.	In.	Total Ft.	In.
Shale and sandstone, interbedded, dominantly red, with a few greenish gray beds.				

P30 DALMATIA: On east side of Susquehanna River, along Penn Central Railroad, 1.2 mile south of Dalmatia, Northumberland Co. (5,000 feet north of lat. 40° 37' 30"N, 1,500 feet west of long. 76° 55' 00"W, at an elevation of about 400 feet, south-central portion of Dalmatia 7-1/2' Quadrangle.) Contact of Needmore Formation and Ridgeley Sandstone crops out at milepost 121. Except for a few feet at the top of the Selinsgrove Limestone Member, the Needmore is completely exposed. Exposures are on north limb of Dalmatia Anticline. Attitude of bedding is about N 70° E/60° S, and of pervasive fracture cleavage, about N 75° E/90°. Previously described by White (1883, pp. 369-372). Section by Inners, assisted by Fletcher.

	Thickness Unit Ft.	In.	Total Ft.	In.
Marcellus Formation				
Sandstone, massive to shaly, fine grained, med. gray (N5), tan weathering, and shale, sandy, med. gray, with about 25 feet of black (N1) shale at base.				
Contact between Marcellus and underlying Selinsgrove Limestone not exposed.				
Needmore Formation			118	1
Selinsgrove Limestone Member			58	10
57. Limestone and shale, interbedded. Limestone, thick bedded, med. dk. gray (N4), argillaceous. Shale, dk. gray (N3), calcareous.	2			
56. Limestone and shale, interbedded (in two beds 3" and 12" thick), fine grained, med. dk. gray, argillaceous, fossiliferous. Shale, dk. gray, calcareous. Insoluble residue (ls.), 28.6%.				

	Description	Unit Ft.	Unit In.	Total Ft.	Total In.
	Fossils: <u>Ambocoelia umbonata</u> (c), <u>Odontocephalus</u> sp. (unc).	3	3		
55.	Limestone, massive, fine grained, med. dk. gray, pyritic, argillaceous. Insoluble residue, 22.0%.	1	7		
54.	Limestone and shale, interbedded. Limestone, thick bedded (beds poorly defined), fine grained, med. dk. gray, pyritic, argillaceous, fossiliferous. Shale, med. dk. gray, calcareous. Insoluble residue (ls.), 9.7%. Fossils: <u>Odontocephalus</u> sp. (unc).	6			
53.	Limestone and shale, in two 2" beds. Limestone, fine grained, med. dk. gray, argillaceous. Shale, med. dk. gray, calcareous.		4		
52.	Limestone and shale, interbedded. Limestone, med. to thick bedded (in six beds 2" to 6" thick), fine grained, med. dk. gray, argillaceous, sparingly fossiliferous. Shale, in six beds 3" to 7" thick, med. dk. gray, calcareous. Insoluble residue (ls.), 11.1%. Fossils: Small brachiopods (c) near top.	4	2		
51.	Limestone and shale, interbedded. Limestone, med. bedded (in beds 1" and 2" thick), fine grained, med. dk. gray, argillaceous. Shale, deeply weathered, calcareous.		6		
50.	Shale, med. dk. gray, calcareous.		4		
49.	Limestone, med. bedded (in beds about 2" thick, separated by thin shale partings), fine grained, med. dk. gray, argillaceous, fossiliferous. Insoluble residue, 8.3%. Fossils: <u>Odontocephalus aegeria</u> (c).	4			
48.	Limestone and shale, interbedded. Limestone, med. bedded (in two beds				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
2" and 1" thick), fine grained, med. dk. gray. Shale, fissile, dk. gray, calcareous.		10		
47. Limestone, massive, fine grained, med. dk. gray, argillaceous, fossiliferous. Mineralization (calcite) along prominent joint. Fossils: Small brachiopods (c).	1	7		
46. Limestone and shale, interbedded. Limestone, med. to thick bedded, fine grained, med. dk. gray, argillaceous, sparingly fossiliferous in upper 1" bed. Shale, med. dk. gray, calcareous. Insoluble residue (ls.), 10.7%. Fossils: Unidentified trilobite and brachiopod fragments (c).	2	3		
45. Shale and limestone, interbedded. Limestone, med. bedded, fine grained, med. dk. gray, argillaceous. Shale, med. dk. gray, calcareous.	2	2		
44. Limestone and shale, interbedded. Similar to Unit 45.	1	9		
43. Limestone and shale, interbedded. Limestone, med. bedded, fine grained, med. dk. gray, argillaceous, fossiliferous. Shale, dk. gray, calcareous, fossiliferous. Fossils: O. aegeria (c), unidentified small rugose corals (r).	1	9		
42. Shale and limestone, interbedded. Limestone, med. bedded, fine grained, med. dk. gray. Shale, fissile, dk. gray, weathering rusty, calcareous. 10" bed of shale in middle. Insoluble residue (ls.), 11.8%. Fossils: Palaeozygopleura hamiltoniae (unc).	2	2		

	Unit Ft.	Unit In.	Total Ft.	Total In.
41. Limestone, fine grained, med. dk. gray, argillaceous, fossiliferous. Fossils: Small brachiopods (unc).		10		
40. Shale, fissile, dk. gray, calcareous, with 1/4" limestone bed in middle.	1	11		
39. Shale and limestone, interbedded. Shale, med. dk. gray, calcareous, fossiliferous. Limestone, med. to thick bedded, fine grained, med. dk. gray, shaly.	1	6		
38. Limestone, massive, fine grained, med. dk. gray, argillaceous, fossiliferous.	1			
37. Shale, med. dk. gray, calcareous.		5		
36. Limestone, massive, fine to med. grained, med. gray (N5), argillaceous, pyritic, highly fossiliferous. Insoluble residue, 33.0%. Fossils: Atrypa reticularis (c), Coelospira camilla (?) (a), unidentified small rugose corals (r).	1	8		
35. Shale, med. dk. gray, calcareous, rusty stained.		2		
34. Limestone, fine grained, med. dk. gray, argillaceous, sparingly fossiliferous.		2		
33. Shale, med. dk. gray, calcareous.		5		
32. Limestone, with thin shale interbeds. Limestone, thick bedded, similar to Unit 34. Fossils: Unidentified brachiopods (unc).	5			
31. Limestone and shale, interbedded. Limestone, med. to thick bedded, fine grained, med. dk. gray, argillaceous, fossiliferous. Shale, med. dk. gray, calcareous, fossiliferous. Insoluble residue (ls.), 24.2%. Fossils: Levenea sp. (c), unidentified chonetid brachiopods (c).	3	5		

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
30. Shale, med. dk. gray, calcareous, fossiliferous, with 1" band of limestone about 2" above base. Fossils: *Ambocoelia umbonata* (c).		6		
29. Limestone, massive, fine grained, med. dk. gray, argillaceous, fossiliferous. Fossils: *A. umbonata* (va).		9		
28. Shale, med. dk. gray, calcareous, highly fossiliferous at base, burrowed. Fossils: Unidentified brachiopod and trilobite fragments (a).	1			
27. Limestone, pyritic, similar to Unit 29. Fossils: *A. umbonata* (unc).	1	3		
26. Shale, med. dk. gray, calcareous, pyritic, sparingly fossiliferous.	1			
25. Limestone and shale, interbedded. Similar to Unit 31. Insoluble residue (ls.), 20.9% Fossils: *Levenea* sp. (unc), *Atrypa reticularis* (unc), *Ambocoelia umbonata* (unc), *Odontocephalus* sp. (unc).	2	4		
24. Limestone, massive, fine grained, med. dk. gray, argillaceous, pyritic, sparingly fossiliferous.		10		
Calcareous Shale Member			32	9
23. Shale, med. dk. gray, calcareous, pyritic, fossiliferous. Fossils: *Palaeozygopleura hamiltonia* (unc).	1	4		
22. Limestone, fine grained, med. dk. gray, very argillaceous.		3		
21. Shale, med. dk. gray, calcareous, fossiliferous. Fossils: *Levenea* sp. (unc), *Leptocoelina acutiplicata* (unc), *Orbiculoidea media* (unc).	1	8		

	Description	Unit Ft.	Unit In.	Total Ft.	Total In.
20.	Limestone, similar to Unit 22, fossiliferous. Fossils: Atrypa reticularis (unc), Ambocoelia umbonata (unc).		3		
19.	Shale, similar to Unit 21.	1	2		
18.	Limestone, fine grained, med. dk. gray, sparingly fossiliferous.		1		
17.	Shale, med. dk. gray, tan weathering, calcareous, highly fossiliferous. Fossils: A. reticularis (c), A. umbonata (c), L. acutiplicata (unc), unidentified rugose corals (c).	1	11		
16.	Limestone, fine grained, med. dk. gray, argillaceous.		4		
15.	Shale, med. dk. gray, pale olive (10Y 6/2) weathering, fossiliferous, with thin bed of fine grained, med. gray (N5) limestone in middle. Insoluble residue (ls.), 14.9%. Fossils: Small brachiopods (unc).	5	4		
14.	Limestone, med. bedded (in two beds separated by thin shale partings), med. dk. gray, tan weathering, very argillaceous.		10		
13.	Shale, med. dk. gray, calcareous, sparingly fossiliferous.		11		
12.	Limestone, fine grained, med. dk. gray, very argillaceous, fossiliferous.		4		
11.	Shale, med. dk. gray, calcareous, fossiliferous. Fossils: Leptocoelina acutiplicata (unc).	1	1		
10.	Limestone, similar to Unit 12. Insoluble residue, 21.5%.		3		
9.	Shale, similar to Unit 11.	2	8		
8.	Shale, med. dk. gray, calcareous, fossiliferous, with thin bed of fine grained, med. gray (N5) limestone. Insoluble residue (ls.), 65.8%.		7		

	Unit Ft.	Unit In.	Total Ft.	Total In.
7. Limestone, fine grained, med. dk. gray, very argillaceous, fossiliferous. Fossils: Unidentified brachiopod fragments (unc).	1	7		
6. Shale, med. dk. gray, tan weathering, calcareous, fossiliferous. Fossils: Palaeozygopleura hamiltoniae (unc).	1	6		
5. Shale, similar to Unit 6.	2	8		
4. Shale, dk. gray, slightly calcareous, silty, fossiliferous in upper 4 feet. Fossils: L. acutiplicata (c), Orbiculoidea media (c).	8			
Beaverdam (?) Shale Member			26	6
3. Shale, dk. gray (N3) to grayish black (N2), rusty weathering, silty, calcareous in part, splintery fracture.	25			
2. Shale, dk. gray, sandy, with small phosphatic concretions.		6		
1. Clay, tan weathering, phosphatic (?), sandy, fossiliferous. Disconformable contact with Ridgeley. Fossils: Panenka sp. (r), etc.	1			
Ridgeley Sandstone				
Sandstone, massive, fine to med. grained, lt. gray (N7), cherty, slightly calcareous, fossiliferous.				

P31 SELINSGROVE JUNCTION: On east side of Susquehanna, along Penn Central Railroad, about 0.3 mile south of Selinsgrove Junction, Northumberland Co. (2,000 feet north of lat. 40° 47' 30"N, 3,000 feet west of long. 76° 50' 00"W, at an elevation of about 420 feet, west-central portion of Sunbury 7-1/2' Quadrangle.) Needmore Formation crops out on both limbs of eastward-plunging Shade Mountain Anticline along railroad and Pa. Rte. 147. Shriver chert wraps around nose of fold in bed of Susquehanna. Needmore-Marcellus contact and the Tioga Metabentonite are clearly exposed. This is the type locality of the Selinsgrove Limestone Member and also the best locality for observing the Purcell Limestone Member of the Marcellus Formation in central Pennsylvania. Previously described by White (1883, p. 360) and Willard (1932). Section (crest and south limb of anticline) by Inners.

	Thickness Unit Ft.	Thickness Unit In.	Total Ft.	Total In.
Marcellus Formation				
Shale, grayish black (N2) to black (N1), non-calcareous, intensely cleaved and contorted.				
Purcell Limestone Member			33	9
71. Shale, dk. gray (N3), tan weathering, calcareous.	5			
70. Limestone, fine grained, dk. gray, dense, argillaceous.		6		
69. Shale, dk. gray, calcareous.	1	2		
68. Limestone, massive, fine grained, dk. gray, argillaceous, fossiliferous. Fossils: Dechenella haldemani (c).	2			
67. Shale, fissile, dk. gray, calcareous in part. Zone of rusty weathering calcareous concretions 22" below top. Sparingly fossiliferous.	14	8		
66. Limestone, fine grained, dk. gray, argillaceous, fossiliferous. Weathers with rusty specks. Fossils: D. haldemani (c), unidentified gastropod and nuculoid bivalve (unc).		5		
65. Shale, dk. gray, pale olive (10Y 6/2) weathering, calcareous.	10			
64. Shale, fissile, grayish black (N2), rusty weathering. Lower 50' is calcareous and contains numerous discontinuous lenses of grayish black, highly argillaceous and silty limestone.	250			
63. Limestone, fine grained, dk. gray (N3), very silty, containing abundant mica flakes.		8		

	Unit Ft.	Unit In.	Total Ft.	Total In.
62. Limestone and shale, interbedded. Limestone, fine grained, dk. gray, silty, somewhat laminated. Shale, grayish black, calcareous, silty.		10		
61. Shale, grayish black, calcareous, silty.		9		
60. Limestone, fine grained, dk. gray, silty, with laminations.		2		
59. Shale, grayish black, calcareous, silty, weathering rusty due to presence of pyrite. Few thin beds of dk. gray, silty limestone at base.	1	5		
58. Limestone, thin bedded, fine grained, dk. gray, silty, pyritic with grayish black shale partings. One bed has distinct med. dk. gray (N4), finely bioclastic band at base. Insoluble residue, 23.5%.		10		
Needmore Formation			135+	
Selinsgrove Limestone Member			56	6
57. Metabentonite, weathering rusty tan, pyritic, micaceous, slightly calcareous, with thin beds of shale, laminated, med. dk. gray (N4), calcareous, highly fossiliferous, with abundant juvenile brachiopods. (Tioga B.)		4		
56. Limestone, med. bedded, fine grained, dk. gray (N3), med. lt. gray (N6) weathering, argillaceous, with grayish black (N2) shale partings. Unit rusty stained on surface due to leaching of overlying bentonite.		9		
55. Shale, grayish black, calcareous.		3		
54. Limestone, thick bedded, fine grained, dk. gray, argillaceous, with grayish black shale partings.	1	5		
53. Limestone and shale, interbedded. Limestone, fine grained, dk. gray, weathering med. lt. gray (N6), argillaceous, with numerous calcite veins. Shale, grayish black, calcareous.		5		

	Unit Ft.	Unit In.	Total Ft.	Total In.
52. Limestone, thick bedded, fine grained, dk. gray, with grayish black shale parting between two beds. Fossiliferous. Insoluble residue (ls.), 9.6%. Fossils: Small brachiopods (a, in limestone), Styliolina fissurelia (a, in black shale).	1	5		
51. Metabentonite and shale. Metabentonite, med. gray (N5), weathering yellowish gray (5Y 7/2), non-calcareous (leached), silty and micaceous---8" thick. Shale, 4" thick, grayish black, calcareous, composed of myriads of tiny brachiopods, occurs below metabentonite. (Tioga A.)	1			
50. Limestone, massive, fine grained, med. dk. gray, weathering lt. gray (N7), argillaceous, with thin band of limestone, grayish black, bituminous, highly fossiliferous, at base. Insoluble residue, 10.3%. Fossils: Small juvenile brachiopods (f).	1			
49. Limestone and shale, interbedded. Limestone, fine grained, med. dk. gray, argillaceous. Shale, grayish black, calcareous.		8		
48. Limestone, fine grained, med. dk. gray, argillaceous.		7		
47. Limestone and shale, interbedded. Limestone, med. bedded, fine grained, dk. gray to med. dk. gray, argillaceous, with some beds containing a few brachiopods. Shale, grayish black, calcareous. Insoluble residue (ls.), 9.8%.	3	9		
46. Limestone, massive, fine grained, med. dk. gray, argillaceous, with abundant pyrite.	1	5		

Thickness

	Thickness Unit Ft.	In.	Total Ft.	In.
45. Limestone and shale, interbedded. Limestone, med. to thick bedded, fine grained, med. dk. gray, weathering lt. gray, pyritic, argillaceous, sparingly fossiliferous, a few small brachiopods being the only fossils present. Shale, dk. gray, calcareous. Insoluble residue (ls.), 20.4%.	5	2		
44. Limestone, med. bedded, fine grained, dk. gray, in two beds (4" and 2" thick) separated by thin shale parting, argillaceous. Contains some small brachiopods.		6		
43. Limestone and shale, interbedded. Limestone, thick bedded, fine grained, med. dk. gray, pyritic, argillaceous. Shale, dk. gray, calcareous, with upper 3" bed containing a few small brachiopods.	1	9		
42. Limestone and shale, interbedded. Limestone, thin bedded, fine grained, dk. gray, pyritic, argillaceous, containing trilobite fragments. Shale, dk. gray, calcareous. Insoluble residue (ls.), 25.7%.		8		
41. Limestone, fine grained, med. dk. gray, pyritic, argillaceous, with scattered trilobite fragments. Insoluble residue, 13.0%.		6		
40. Limestone and shale, interbedded. Limestone, thick bedded, fine grained, med. dk. gray to dk. gray, pyritic, argillaceous, sparingly fossiliferous. Shale, dk. gray, calcareous. Insoluble residue (ls.), 11.8%.	1	10		
39. Shale, dk. gray, calcareous.		6		
38. Limestone and shale, interbedded. Limestone, thick bedded, fine grained, med. dk. gray, pyritic, argillaceous.				

	Thickness Unit Ft.	In.	Total Ft.	In.
Shale, dk. gray, calcareous, occurring as thin partings. Insoluble residue (ls.), 8.8%.	2	5		
37. Shale, dk. gray, calcareous.		3		
36. Limestone and shale, interbedded. Limestone, thin to med. bedded, fine grained, med. dk. gray, pyritic, argillaceous, fossiliferous. Shale, dk. gray, calcareous. Insoluble residue (ls.), 10.1%. Fossils: Odontocephalus aegeria(c).	1	5		
35. Limestone, fine grained, med. dk. gray, argillaceous, fossiliferous, containing trilobite fragments.		9		
34. Limestone and shale, interbedded. Limestone, med. bedded, fine grained, med. dk. gray to dk. gray, argillaceous, fetid, sparingly fossiliferous. Shale, dk. gray, calcareous, occurs as thin partings.	2	2		
33. Limestone, fine grained, med. dk. gray, argillaceous, pyritic, fossiliferous, containing trilobite fragments. Insoluble residue, 10.6%.		6		
32. Shale, dk. gray, calcareous.		2		
31. Limestone, fine grained, med. dk. gray, argillaceous, pyritic.	1	5		
30. Limestone and shale, interbedded. Limestone, med. to thick bedded, fine grained, med. dk. gray, argillaceous, pyritic. Shale, in beds about 3" thick, dk. gray, calcareous.	2	11		
29. Limestone and shale, interbedded. Limestone, med. bedded, fine grained, med. dk. gray, argillaceous. Shale, in beds about 1" thick, dk. gray, calcareous.	3	8		
28. Limestone and shale, interbedded. Limestone, med. to thick bedded, fine grained, med. dk. gray,				

	Unit Ft.	Unit In.	Total Ft.	Total In.
argillaceous, pyritic, fossiliferous. Shale, dk. gray, calcareous.	3	4		
27. Limestone, massive, fine grained, med. dk. gray, weathering lt. gray (N7), argillaceous, fossiliferous. Fossils: Small rugose corals and brachiopods (unc).	1	2		
26. Limestone, similar to Unit 27. Insoluble residue, 10.9%. Fossils: <u>Phacops pipa</u> (unc), unidentified brachiopods (unc).	1	8		
25. Shale, banded med. dk. gray (N4) and black (N1), calcareous.		5		
24. Limestone and shale, interbedded. Limestone, thin bedded, fine grained, med. dk. gray, argillaceous, sparingly fossiliferous. Shale, dk. gray, calcareous. Calcite and quartz mineralization along joint planes. Fossils: Unidentified brachiopods (unc), crinoid fragments (unc).	3	10		
23. Limestone and shale, interbedded. Limestone, med. to thin bedded, fine grained, med. dk. gray, argillaceous, pyritic, sparingly fossiliferous. Shale, dk. gray, rusty weathering, calcareous. Insoluble residue (ls.), 26.1%. Fossils: Small unidentified brachiopods (unc).	2			
22. Limestone, fine grained, med. dk. gray, very argillaceous, fossiliferous. Insoluble residue, 22.5%. Fossils: Small unidentified brachiopods (unc).		8		
21. Shale, dk. gray, calcareous.		4		
20. Limestone, fine grained, med. dk. gray, lt. gray weathering, argillaceous.		2		
19. Shale, dk. gray, calcareous, fossiliferous.		7		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
18. Limestone, similar to Unit 20, fossiliferous. Insoluble residue, 19.6%. Fossils: *Ambocoelia umbonata* (unc), unidentified small brachiopods (c).		7		
17. Shale, med. dk. gray, calcareous, rusty stained. In middle of unit is a 1-1/2" layer of grayish black (N2), glittery, pyritic shale.	1			
16. Limestone, fine grained, med. gray (N5), lt. gray weathering, very argillaceous, sparingly fossiliferous. Insoluble residue, 31.7%. Fossils: *A. umbonata* (unc), unidentified small brachiopods (c).	1	2		
Calcareous Shale Member			78+	
15. Concealed interval.	10			
14. Limestone, fine grained, med. dk. gray, lt. gray (N7) weathering, very argillaceous.		4		
13. Shale, med. gray (N5), weathering lt. gray, calcareous, with a few thin argillaceous limestone beds.	4			
12. Limestone, similar to Unit 14, fossiliferous. Fossils: Unidentified brachiopods (unc).		6		
11. Shale, med. gray, calcareous, extremely fossiliferous. Numerous horizontal, rusty-weathering *lebenspuren*. Fossils: Unidentified brachiopods (c) and ostracodes (c).	1	8		
10. Limestone, fine grained, med. dk. gray (N4), argillaceous, very fossiliferous. Fossils: *Kozlowskiellina (Megakozlowskiella) raricosta* (r), unidentified brachiopods (c) and ostracodes (c).		10		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
9. Shale, med. gray, calcareous, very fossiliferous. Fossils: Leptocoelina acutiplicata (c), etc.	1	3		
8. Limestone, similar to Unit 10.		3		
7. Shale, med. gray, calcareous, fossiliferous.	4			
6. Limestone, fine grained, med. dk. gray, lt. gray weathering, highly argillaceous, fetid, fossiliferous. Fossils: L. acutiplicata (c).		6		
5. Shale, med. gray, calcareous, very fossiliferous. A 4" bed of very argillaceous limestone, with numerous L. acutiplicata, lies 10 feet above base. (Bed is discontinuous.) Insoluble residue (ls.), 42.6%. Fossils: L. acutiplicata (va), Orbiculoidea media (c).	18			
4. Limestone, fine grained, med. dk. gray, weathering yellowish gray (5Y 7/2), argillaceous, fossiliferous. Fossils: L. acutiplicata (unc).		5		
3. Shale, med. gray, rusty stained, splintery, calcareous, fossiliferous. Zone of med. dk. gray (N3), very argillaceous limestone nodules at 9 feet above base. Insoluble residue (ls.), 78.4%. Fossils: L. acutiplicata (c).	12			
2. Shale, med. gray, calcareous, highly fractured (splintery).	25			
1. Concealed to top of Shriver chert in bed of Susquehanna River.	?			

Shriver Chert

Limestone, very siliceous, and chert, med. to thick bedded, med. dk. gray, brownish and tan weathering, tough, fossiliferous.

P32 DANVILLE: In gutter and shallow cuts on west side of road to rest home, 0.2 mile north of U.S. Rte. 11 and 0.5 mile east of Danville, Montour Co. (13,000 feet south of lat. 41° 00' 00"N, 3,750 feet west of long. 76° 35' 00"W, at an elevation of 530 feet, north-central portion of Shamokin 15' Quadrangle.) Needmore Formation.

P33 DANVILLE: On road between Ridgeville and U.S. Rte. 11, 0.25 mile north of U.S. Rte. 11 and 2.1 miles east of Danville, Montour Co. (12,250 feet south of lat. 41° 00' 00"N, 3,500 feet east of long. 76° 35' 00"W, at an elevation of 600 feet, northeast portion of Shamokin 15' Quadrangle.) Mandata Shale, Shriver Chert, and Needmore Formation (lower part). Section described by Cleaves (1939, p. 125).

P34 FISHING CREEK: About 500 feet north of very sharp bend in unpaved road that parallels Fishing Creek, about 1.7 miles north of Bloomsburg and 1.5 miles west of Light Street, Mt. Pleasant Township, Columbia Co. (4,000 feet south of lat. 41° 02' 30"N, 1,750 feet east of long. 76° 27' 30"W, at an elevation of 520 feet, south-central portion of Bloomsburg 7-1/2' Quadrangle.) Keyser (?) Limestone, Marcellus Formation. (Needmore Formation apparently faulted out.) Section described by White (1883, p. 219).

P35 LEWISBURG: In borrow pit on west side of U.S. Rte. 15 and in road cut immediately to south, 2.0 miles north of Lewisburg, Union Co. (1,000 feet south of lat. 41° 00' 00"N, 1,200 feet east of long. 76° 52' 30"W, at an elevation of 480 feet, northwest corner of Northumberland 7-1/2' Quadrangle.) The Beaverdam Shale and calcareous shale members crop out in the borrow pit, and the Selinsgrove Limestone Member in the cut on U.S. Rte. 15. Since a wide covered interval separates the two exposures, it is possible that the thickness measured for the calcareous shale member is far in excess of the actual stratigraphic thickness. The Shriver Chert and Helderberg Group are exposed along the highway to the northeast of the Needmore shale pit, while the Marcellus black shale is worked for borrow in another pit to the south. Attitude of bedding is N80°E/25°S. Section by Inners.

	Thickness Unit Ft.	In.	Total Ft.	In.
Marcellus Formation				
Shale, dk. gray (N3) to black (N1), fissile, carbonaceous. Contact between Marcellus Formation and underlying Selinsgrove Limestone approximately exposed in borrow pit to southwest of measured section.				
Needmore Formation			189	
Selinsgrove Limestone Member			34+	
11. Limestone and shale, interbedded. Limestone, med. to thick bedded, med. gray (N5) to med. dk. gray (N4), lt. gray (N7) weathered, argillaceous, sparingly fossiliferous. Several solid ledges exposed. Shale, pale olive (10Y 6/2) weathered, subfissile, calcareous, mostly float. Near contact with Marcellus Formation limestone contains abundant crystals of barite about 1/8" long (at north end of borrow pit to southwest).	34+			
Calcareous Shale Member			155?	
10. Shale, pale olive (10Y 6/2) to lt. olive gray (5Y 6/1) weathered, calcareous, float, with several ledges of med. dk. gray, argillaceous limestone near top.	38			
9. Covered interval, probably mostly shale.	44?			
8. Shale, lt. olive gray (5Y 6/1) weathered, calcareous, fossiliferous. Fossils: *Ambocoelia umbonata* (unc), *Palaeozygopleura hamiltoniae* (r).	1			
7. Limestone, fine grained, med. dk. gray, argillaceous, fossiliferous. Fossils: *A. umbonata* (c), unidentified spiriferinid (r), *Odontocephalus* sp. (r), small rugose corals (r).		2		
6. Shale, deeply leached, highly calcareous, fossiliferous.				

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
Fossils: *A. umbonata* (c), *Levenea* sp. (c).	3			
5. Mostly covered, scattered outcrops of lt. gray (N7) weathered, calcareous shale.	30			
4. Shale, thin bedded to fissile, med. gray (N5), strongly weathered, calcareous, fossiliferous with abundant horizontal burrows. Fossils: *Leptocoelina acutiplicata* (c).	12			
3. Limestone, fine grained, med. dk. gray (N4), argillaceous, pyritic, sparingly fossiliferous. Fossils: *L. acutiplicata* (unc).		2		
2. Shale, subfissile, med. gray (N5), weathering olive gray (5Y 5/1), calcareous, highly fossiliferous, very strongly burrowed. Fossils: *L. acutiplicata* (a), *Coelospira camilla* (unc), *Eodevonaria* sp. (c), *Anoplia nucleata* (r), *Orbiculoidea media* (unc), small rugose corals (c).	12			
Beaverdam Shale Member				
1. Shale, subfissile to fissile, med. dk. gray (N4) to dk. gray (N3), noncalcareous, sparingly fossiliferous, containing some rounded, dk. gray (N3), slightly calcareous concretions. Burrowed. Fossils: *L. acutiplicata* (c), *Orbiculoidea media* (r).	15			
Shriver Chert				
Chert and siliceous limestone, strongly leached, weathered tan-brown, fossiliferous.				

P36 MONTOURSVILLE: In abandoned sandstone quarry of the Lycoming Silica Sand Co., off Fairview Drive, eastern boundary of Montoursville borough, Lycoming Co. (650 feet north of lat. 41° 15' 00"N, 4,500 feet east of long. 76° 55' 00"W, at an elevation of about 580 feet, southeast portion of Montoursville North 7-1/2' Quadrangle.) The Beaverdam Shale Member, calcareous shale member, and lower 13 feet of the Selinsgrove Limestone Member are exposed here above deeply decomposed Ridgeley Sandstone. The lower part of the Marcellus Formation crops out in a shale borrow pit immediately to the north. Exposure is located along the Needmore outcrop belt that parallels the Allegheny Front on the north flank of the Bald Eagle Mountain Anticline. Attitude of beds is about N 90° E/35° N. Ridgeley Sandstone described by Cleaves (1939, p. 123). Needmore section by Inners, assisted by M. Inners.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Marcellus Formation				
Shale, dk. gray (N3) to black (N1), carbonaceous, largely non-calcareous, with some large (4' in diameter), limy septarian concretions about 50 feet above base. Contact with Selinsgrove Limestone concealed.				
Needmore Formation			115±	
Selinsgrove Limestone Member			32±	
34. Concealed interval. (Large float blocks of limestone are present at south edge of Marcellus borrow pit.)	20±			
33. Limestone and shale, interbedded. Limestone, dk. gray (N3), bituminous, extremely fossiliferous, containing floods of small juvenile brachiopods. Shale, dk. gray, calcareous.	5			
32. Limestone, in two thick beds (separated by thin shale parting), fine grained, med. gray (N5), weathered lt. gray (N7), argillaceous.	1	9		
31. Shale, med. dk. gray (N4), calcareous.		9		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
30. Limestone, fine grained, med. gray (N5), weathered lt. gray (N7).		5		
29. Shale, dk. gray, calcareous.	1			
28. Limestone, med. bedded (with thin shale partings), fine grained, med. lt. gray (N5.5), weathered pale olive (10Y 6/2), argillaceous, wavy bedded.	3			
27. Limestone, massive, fine grained, med. lt. gray (N5.5), argillaceous, fossiliferous. Fossils: <u>Odontocephalus aegeria</u> (c).		9		
26. Limestone, fine grained, med. lt. gray (N5.5), pale olive (10Y 6/2) weathered, argillaceous, with numerous veins of coarse calcite. Forms large load cast in underlying shale. Not observed elsewhere, but contact between Unit 27 and Unit 25 appears on inaccessible slope to west.	0–1			
Calcareous Shale Member			67	4
25. Shale, pale olive weathered, calcareous.	2	6		
24. Limestone, fine grained, med. dk. gray (N4), weathered lt. gray (N7), argillaceous, containing abundant trails.		7		
23. Shale, med. dk. gray, weathered med. lt. gray (N6) and pale olive, calcareous.	6	8		
22. Limestone, med. bedded (in two beds separated by thin shale parting), med. dk. gray, weathered pale olive, argillaceous.		10		
21. Shale, with a few thin to med. bedded marlstone interbeds. Shale, med. dk. gray, calcareous. Marlstone, fine grained, med. dk. gray (very calcareous mudstone).	3	5		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total in.
20. Shale, very thinly bedded, med. dk. gray, calcareous, fossiliferous, with numerous thin calcite seams. Fossils: <u>Leptocoelina acutiplicata</u> (unc).	14			
19. Marlstone, med. dk. gray, calcareous and argillaceous, grades into shale to west.		7		
18. Shale, very thinly bedded, pale olive weathering, calcareous, sparingly fossiliferous. Fossils: <u>Eodevonaria</u> sp. (unc.)	6			
17. Shale and marlstone, interbedded. Shale, pale olive weathering, calcareous, fossiliferous. Marlstone, med. dk. gray, sparingly fossiliferous.	3	2		
16. Shale, laminated, med. dk. gray, calcareous, containing rusty weathering burrows.	4	4		
15. Marlstone, fine grained, dk. gray, weathered med. lt. gray (N6).		10		
14. Shale, thin bedded, med. dk. gray, lt. gray (N7) weathering, calcareous, with numerous pyrite nodules 1" or more in length.	1	2		
13. Shale, very thinly laminated, black (N1), slightly calcareous, highly bituminous, fossiliferous. Contains thin calcite veins parallel to bedding. Strong crenulation parallel to strike. Fossils: <u>L. acutiplicata</u> (unc).	1	7		
12. Shale, with interbeds of limestone. Shale, med. dk. gray, calcareous, upper 6" black like Unit 13, but not laminated. Limestone, med. gray, highly argillaceous, extremely fossiliferous (occurs in two beds, 2" thick, near top).				

	Unit Ft.	Unit In.	Total Ft.	Total In.
Fossils: L. acutiplicata (a), Orbiculoidea media (c), Eodevonaria sp. (unc).	5	6		
11. Marlstone, med. dk. gray, weathering med. lt. gray, almost massive in places, but breaks up into shaly fragments on weathering.		9		
10. Shale, thin bedded, med. gray, highly calcareous, intensely burrowed, fossiliferous. Fossils: L. acutiplicata (c).	3	11		
9. Marlstone, med. gray, weathering med. lt. gray.		4		
8. Shale, med. dk. gray, calcareous, pyritic, intensely burrowed, darker toward top. Fossils: Anoplia nucleata (r).	7	6		
7. Limestone, fine grained (crystalline), med. gray, fossiliferous, discontinuous. Fossils: L. acutiplicata (c).		2		
6. Shale, med. dk. gray (N4), weathering med. gray (N5), calcareous.		4		
5. Marlstone, fine grained, med. dk. gray, weathers to sublaminated fragments, discontinuous.		2		
4. Shale, med. dk. gray, calcareous, intensely burrowed, highly fossiliferous. Fossils: L. acutiplicata (a), Eodevonaria sp. (a).	2	8		
3. Marlstone, med. dk. gray, discontinuous.		4		
Beaverdam Shale Member			16	1
2. Shale, thin bedded, med. dk. gray (N4), med. gray (N5) weathering, calcareous, containing some small dk. gray (N3), slightly calcareous (probably phosphatic) concretions.				

	Thickness Unit Ft. In.	Total Ft. In.
Numerous thin calcite veins present.	16	
1. Sandstone, med. grained, rusty and dk. gray weathered, quartzose, slightly calcareous.		1

Ridgeley Sandstone
Sandstone, massive, fine to coarse grained, very lt. gray (N8) to white (N9), deeply weathered and friable, quartzose, highly fossiliferous.
Fossils: Costispirifer arenosus (c), etc.

P36 A MONTOURSVILLE: In active quarry of the Lycoming Silica Sand Co. between Montoursville and Williamsport, north of U.S. Rte. 220 on west side of Loyalsock Creek, about 0.5 mile west of Montoursville, Lycoming Co. (Lat. 41° 15' 00"N, 3,500 feet east of long. 76° 57' 30"W, at an elevation of 620 feet, south-central part of Montoursville North 7-1/2' Quadrangle and north-central part of Montoursville South 7-1/2' Quadrangle.) Shriver Chert (upper part) and Ridgeley Sandstone.

P37 GLOBE MILLS: Along banks and in bed of small stream, 0.7 mile east of Globe Mills and 0.75 mile northwest of Kraemer, Middlecreek Township, Snyder Co. (6,400 feet north of lat. 40° 47' 50"N, 5,700 feet west of long. 77° 00' 00"W, at an elevation of 490 feet, west-central portion of Freeburg 7-1/2' Quadrangle.) Shriver Chert, Needmore Formation.

P37 A SELINSGROVE: Cut on U.S. Rte. 522, 0.2 mile north of intersection of that route with Broad Street, Selinsgrove, Snyder Co. (6,250 feet north of lat. 40° 47' 30"N, 1,250 feet east of long. 76° 52' 30"W, at an elevation of 500 feet, west-central portion of Sunbury 7-1/2' Quadrangle.) Shriver Chert.

P38 KISSIMMEE: On road leading north from U.S. Rte. 522 at Hassinger's Church, about 1.5 miles west of Middleburg and 0.5 mile south of Kissimmee, Franklin Township, Snyder Co. (1,750 feet south of lat. 40° 47' 30"N, 500 feet west of long. 77° 05' 00"W, at an elevation of 620 feet, southwest portion of

Middleburg 7-1/2' Quadrangle.) Tonoloway Limestone, Helderberg Group, Shriver Chert and Needmore Formation (lower part).

P39 KISSIMMEE: In bed of stream just north of sharp bend in country road about 1,500 feet north of U.S. Rte. 522, 3.5 miles west of Middleburg and 1.9 miles southwest of Kissimmee, Franklin Township, Snyder Co. (3,450 feet south of lat. 40° 47' 30"N, 2,500 feet east of long. 77° 07' 30"W, at an elevation of 640 feet, southwest portion of Middleburg 7-1/2' Quadrangle.) Needmore Formation.

P40 TROXELVILLE: On west side of Beaver Springs-Troxelville Road, 0.4 mile south-southeast of Troxelville, Adams Township, Snyder Co. (2,000 feet north of lat. 40° 47' 30"N, 1,600 feet east of long. 77° 12' 30"W, at an elevation of 630 feet, central portion of Beavertown 7-1/2' Quadrangle.) Ridgeley Sandstone (upper part), Needmore Formation (part of calcareous shale member).

P41 MT. PLEASANT MILLS: Along secondary road at east end of Lime Ridge, 0.2 mile north of Mt. Pleasant Mills, Snyder Co. (6,200 feet north of lat. 40° 421 30"N, 5,000 feet west of long. 77° 00' 00"W, at an elevation of 590 feet, northwest portion of Richfield 7-1/2' Quadrangle.) Upper part of the Shriver Chert and lower part of the Needmore Formation (deeply weathered) crop out on the west side of the road. Locality lies on south flank of the Shade Mountain Anticline. Bedding attitude at north end of cut is N62° E/54° S. Beds at south end have been rotated to a north dip by slope creep. Section by Inners.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Needmore Formation				
Upper portion not exposed.				
Calcareous Shale and Beaverdam Shale Members, Undivided			60+	
2. Shale, strongly leached, clayey, weathering lt. tan, fossiliferous. Contact with Shriver marked by tan and dk. brown earthy masses. Actual contact not exposed, but can				

	Thickness Unit Ft. In.	Thickness Total Ft. In.
be approximately located by digging. Fossils: Orbiculoidea media (unc), Leptocoelina acutiplicata (unc).	60	

Shriver Chert

1. "Chert," white (N9) and tan weathering, dense, strongly leached, fossiliferous. Fossils: Platyceras (Platystoma) ventricosum (c), large spiriferinid brachiopods (unc).

P42 THOMPSONTOWN: On west side of road that parallels Delaware Creek, 1.5 miles north of Thompsontown, Juniata Co. (600 feet north of lat. 40° 35' 00"N, 3,500 feet east of long. 77° 15' 00"W, at an elevation of 550 feet, northwest portion of Millerstown 7-1/2' Quadrangle.) The upper part of the calcareous shale member and the Selinsgrove Limestone crop out here, but the upper and lower contacts are concealed. Attitude of bedding is N65° E/45° S. A small drag fold occurs in the upper part of the Selinsgrove. (See Willard, 1939, p. 148.) Section by Inners.

	Thickness Unit Ft. In.	Thickness Total Ft. In.
Marcellus Formation		
Shale, fissile, black (N1), non-calcareous. Exposed in borrow pit on hillside to south.		
Concealed interval.		
Needmore Formation		112+?
Selinsgrove Limestone Member		95 ?
19. Limestone and shale, interbedded. Limestone, thick bedded (in beds mostly between 4" and 12" thick), fine grained, med. gray (N5) to med. dk. gray (N4), argillaceous, sparingly fossiliferous. Shale, thin bedded (in beds mostly about 2" thick), dk. gray		

		Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
	(N3), calcareous. Only a few limestone ledges exposed, as interval is largely covered by thick growth of honeysuckle. Thickness measurement unreliable. Fossils: A few small brachiopods observed in middle ledges.	73±			
18.	Limestone, with shale interbeds. Limestone, thick bedded, fine grained, med. dk. gray, argillaceous, sparingly fossiliferous. Shale, thin bedded, dk. gray, calcareous. Burrowed. Fossils: Small brachiopods (unc) and trilobite fragments (unc).	2	5		
17.	Concealed interval with thin shale at base.	2	10		
16.	Limestone, fine grained, med. dk. gray, argillaceous.		6		
15.	Limestone, with shale interbeds. Limestone, thick bedded, similar to Unit 16, highly fossiliferous. Shale, calcareous, deeply weathered. Fossils: Ambocoelia umbonata (unc), Leptocoelina acutiplicata (c), Levenea sp. (c).	3	6		
14.	Covered interval. Shale float.	1			
13.	Limestone, with shaly interbeds. Limestone, thick bedded, fine grained, med. dk. gray, argillaceous, fossiliferous. Shale, med. bedded, highly calcareous, may be weathered highly argillaceous limestone. Fossils: Small brachiopods (unc) and trilobite fragments (unc).	2	7		
12.	Limestone, with shale interbeds. Limestone, med. to thick bedded, similar to Unit 13. Shale, in beds about 1" thick, calcareous, fossiliferous.	4	2		
11.	Limestone, in two thick beds separated by thin shale and limestone parting,				

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
fine grained, argillaceous, highly weathered with rounded fracture surfaces, fossiliferous. Fossils: *A. umbonata* (unc), *Levenea* sp. (c).	3	5		
10. Limestone and shale, interbedded. Limestone, med. bedded, fine grained, pale olive (10Y 6/2) weathered, argillaceous, fossiliferous. Shale, med. bedded, pale olive weathered, calcareous, fossiliferous. Fossils: *Phacops cristata* (unc).	1	4		
9. Limestone, fine grained, med. dk. gray, pale olive weathering, argillaceous, sparingly fossiliferous.		9		
Calcareous Shale Member			14	4+
8. Shale, with a few weathered limestone interbeds. Shale, pale olive weathered, splintery, strongly fractured. About 6" from top is a 1" bed of grayish yellow (5Y 8/4), highly fossiliferous clay, undoubtedly a bed of completely leached, argillaceous limestone. Fossils: *Styliolina fissurella* (a), *Phacops* sp. (unc).	2	9		
7. Limestone, in two thick beds with thin shale parting, fine grained, med. dk. gray, pale olive weathering, argillaceous, fossiliferous. Fossils: *Bollia ungula* (c).	1	5		
6. Shale, with thin argillaceous limestone interbeds. Shale, pale olive weathered, fossiliferous.	3			
5. Shale, pale olive weathered, calcareous, fossiliferous, with abundant rusty, horizontal burrows. Fossils: *A. umbonata* (c), *Leptocoelina acutiplicata* (unc).	3			

	Thickness Unit Ft.	In.	Total Ft.	In.
4. Covered interval. Shale float.	2			
3. Shale, with limestone interbeds, poorly exposed, weathered pale olive, with rounded surfaces.	1	4		
2. Concealed interval. Float of pale olive weathered shale.	2			
1. Shale, with limestone beds at top and base. Shale, med. gray (N5), pale olive weathering, calcareous. Limestone, in beds 4" thick, med. gray, olive weathering, argillaceous. Fossiliferous.	1	10		
Concealed interval of unknown thickness. Shale float.				

Ridgeley Sandstone (?)

Not exposed. Fragments of white "chert" scattered along road. Forms ridge on south side of which Needmore is exposed.

P43 OLD PORT: On south bank of Tuscarora Creek and along dirt road at top of bank, 0.4 mile east of Old Port and 0.5 mile south of Port Royal, Juniata Co. (5,500 feet south of lat. 40° 32' 30"N, 2,200 feet west of long. 77° 22' 30"W, at an elevation of between 420 and 450 feet, southeast portion of Mifflintown 7-1/2' Quadrangle.) The calcareous shale member and lower part of the Selinsgrove Limestone Member crop out on bank of creek, while the upper part of the Selinsgrove, the Needmore-Marcellus contact, and the Tioga Metabentonite occur along the dirt road and in the floor of a borrow pit south of the road. The lower Selinsgrove is involved in a minor anticlinal fold, and considerable slumping and rotation of beds have affected the same interval. Exposures lie on the north flank of the Limestone Ridge Snycline, just north of a major high-angle reverse fault (Conlin and Hoskins, 1962, pp. 32, 34). Attitude of bedding is variable, but averages N60° E/ 45° SE. Section by Inners.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Marcellus Formation				
Shale, fissile, dk. gray (N3) to black (N1), weathering rusty, non-calcareous.				
Needmore Formation			161?	
Selinsgrove Limestone Member			66	4?
73. Metabentonite and shale. Metabentonite, 3" thick, rusty weathered, silty, and micaceous, blocky. About 2" of dk. gray (N3), calcareous shale below. (Tioga.)		5		
72. Limestone, fine grained, med. dk. gray (N4), argillaceous, fossiliferous. Insoluble residue, 8.7%. Fossils: <u>Odontocephalus selenourus</u> (unc), small brachiopods (unc).		11		
71. Limestone and shale, interbedded. Limestone, med. to thick bedded, fine grained, med. dk. gray (N4) to dk. gray (N3), argillaceous, sparingly fossiliferous. Shale, dk. gray, calcareous, in thin partings. Insoluble residue (ls.), 8.0%. Fossils: <u>Amphigenia elongata</u> (r).	3			
70. Limestone and shale, interbedded. Limestone, thick bedded, fine grained, med. dk. gray, with numerous calcite and "rusty" veins. Shale, dk. gray, calcareous. Insoluble residue (ls.), 5.5%.	1	1		
69. Limestone, massive, fine grained, med. dk. gray, argillaceous, fossiliferous, with long segmented vertical burrows, 2 to 3mm. wide, 80mm. long. Fossils: Small brachiopods (c).		10		
68. Limestone and shale, interbedded. Limestone, thick bedded, fine grained, med. dk. gray, argillaceous, pyritic, fossiliferous. Shale in thin partings,				

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
dk. gray, calcareous. Fossils: Truncalosia truncata (unc), etc.	1	2		
67. Limestone, massive, fine grained, med. dk. gray, argillaceous, very fossiliferous. Joints covered by flowstone. Insoluble residue, 8.3%. Fossils: Ambocoelia umbonata (unc), T. truncata (unc), Longispina mucronatus (unc), Odontocephalus selenourus (c).		7		
66. Shale and limestone, interbedded. Shale, med. dk. gray, deeply weathered, calcareous, fossiliferous. Limestone, med. bedded, fine grained, med. gray (N5), argillaceous.	2	7		
65. Limestone, massive, fine grained, med. dk. gray, argillaceous, fossiliferous, with patches of sparry calcite and pyrite. Fossils: Small brachiopods (unc) and trilobite fragments (unc).		6		
64. Limestone and shale, interbedded. Limestone, med. bedded (in beds 1" to 3" thick), fine grained, med. gray, pyritic, fossiliferous. Shale, med. dk. gray, calcareous.	1	5		
63. Limestone, massive, fine grained, med. gray, argillaceous, fossiliferous. Fossils: Ambocoelia sp. (a, small individuals), Odontocephalus sp. (c).	2			

Units 73 to 63, inclusive, were measured along the dirt road at the top of the bluff overlooking Tuscarora Creek. Below Unit 63 is an extensively covered interval, which probably amounts to 35 feet stratigraphically. Units 62 to 1 are exposed on the hillside above the creek. The covered interval is considered to be a repetition of beds included in other units.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
62. Limestone and shale, interbedded. Limestone, massive, fine grained, dk. gray (N3), argillaceous, fetid, fossiliferous. Shale, dk. gray, calcareous. Fossils: *Odontocephalus* sp. (unc), small brachiopods (unc).	3			
61. Limestone and shale, interbedded. Similar to Unit 62. Insoluble residue, 4.0%. Fossils: Unidentified chonetid brachiopods (unc), etc.	2	6		
60. Concealed.	2			
59. Limestone, massive, fine grained, med. dk. gray, weathering lt. gray (N7), sparingly fossiliferous.	1			
58. Concealed.	2			
57. Limestone and shale, interbedded. Limestone, med. bedded (in beds 3" to 4" thick), fine grained, med. dk. gray, argillaceous, sparingly fossiliferous. Shale, in thin partings, med. dk. gray, calcareous. Insoluble residue (ls.), 23.4%.	1	10		
56. Shale, dk. gray, calcareous, fossiliferous.		6		
55. Limestone, massive, fine grained, med. gray, argillaceous. In two thick beds separated by 2" of dk. gray shale. Sparingly fossiliferous. Fossils: *O. selenurus* (r).	1	8		
54. Limestone and shale, interbedded. Limestone, med. to thick bedded (in beds 2" to 6" thick), fine grained, med. gray (N5), argillaceous, pyritic, fossiliferous. Shale, med. dk. gray, calcareous. (Bedding obscured by fracture cleavage.) Insoluble residue (ls.), 13.0%. Fossils: *Odontocephalus aegeria* (c), small brachiopods (c).	3			

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
53. Shale, dk. gray, poorly exposed.	1	2		
52. Limestone, fine grained, med. dk. gray (N4), argillaceous, very fossiliferous. Insoluble residue, 8.1%. Fossils: *Ambocoelia umbonata* (c, small individuals).		5		
51. Shale, dk. gray, poorly exposed.		11		
50. Limestone, similar to Unit 52. Fossils: Small brachiopods (c).		4		
49. Limestone and shale, interbedded. Limestone, med. bedded (in beds about 3" thick), fine grained, med. dk. gray (N4), argillaceous, fossiliferous. Shale, med. dk. gray, calcareous. Poorly exposed. Insoluble residue (ls.), 14.3%. Fossils: Small brachiopods (a).	1			
48. Limestone, massive, fine grained, med. dk. gray, pyritic, argillaceous.		7		
47. Shale, dk. gray, calcareous.		2		
46. Limestone, similar to Unit 48. Fossils: Trilobite fragments (c).	1			
45. Shale, dk. gray, calcareous.		3		
44. Limestone, massive, fine grained, dk. gray (N3), argillaceous, highly cleaved, fossiliferous. Insoluble residue, 16.0%. Fossils: Unidentified brachiopods (unc).		10		
43. Shale, deeply weathered.		6		
42. Limestone, fine grained, med. dk. gray, argillaceous.		4		
41. Shale, dk. gray, calcareous, deeply weathered at top.	1	4		
40. Limestone, similar to Unit 42.		6		
39. Shale, dk. gray, deeply weathered.	1			
38. Limestone, fine grained, med. dk. gray, argillaceous.		3		
37. Shale, dk. gray, calcareous.		6		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
36. Limestone, similar to Unit 38.		2		
35. Shale, med. dk. gray, calcareous.		7		
34. Limestone, fine grained, med. dk. gray, weathering lt. gray (N7), argillaceous.		4		
33. Shale, med. dk. gray, highly cleaved.		6		
32. Limestone, fine grained, med. dk. gray, highly cleaved.		2		
31. Shale, med. dk. gray, highly cleaved.		8		
30. Limestone, fine grained, med. gray (N5), argillaceous, fossiliferous. Fossils: Trilobite fragments (unc).		3		
29. Shale, dk. gray, calcareous.		4		
28. Limestone, similar to Unit 30.		6		
27. Shale, dk. gray, calcareous.		5		
26. Limestone, fine to med. grained, med. dk. gray, argillaceous, fossiliferous. Fossils: Trilobite fragments (unc).		4		
25. Shale, dk. gray, strongly cleaved.		4		
24. Limestone, similar to Unit 26.		9		
23. Shale, dk. gray, deeply weathered.	1			
22. Limestone, dk. gray (N3), fetid, containing masses of coarse barite crystals (1/4" to 1/2" long) in fine grained groundmass. Barite crystals form pods which follow along cleavage.	1	2		
21. Shale, dk. gray, deeply weathered.	2			
20. Limestone, massive, fine grained, med. dk. gray, argillaceous, strongly cleaved.	1	6		
19. Shale float.	2			
18. Limestone, massive, fine grained, med. gray (N5), argillaceous, strongly cleaved, very fossiliferous. Fossils: Unidentified brachiopods (c).	2	6		
17. Limestone, fine grained, med. gray (N5), highly fossiliferous. (Rather clean, well crystallized limestone.)				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Fossils: *Atrypa reticularis* (unc), trilobite fragments (c).	1	9		
16. Limestone and shale, interbedded. Limestone, thick bedded (beds up to 6" thick), fine grained, med. gray (N5), argillaceous, fossiliferous. Shale, dk. gray, calcareous. Massive limestone at 3 feet above base contains coarse crystals of barite (?) in hollow cylinders about 1/2" in diameter. Insoluble residue (ls.), 40.9%. Fossils: Trilobite fragments (c), unidentified brachiopods (unc).	4			
15. Limestone and shale, interbedded. Limestone, thick bedded (in beds 6" to 8" thick), fine grained, med. dk. gray (N4), weathering lt. gray (N7), argillaceous, fossiliferous. Shale, med. dk. gray, calcareous. At top is 2" bed of med. gray (N5), highly fossiliferous limestone. Fossils: Trilobite fragments (a), unidentified brachiopods (c, in top bed).	2			
Calcareous Shale and Beaverdam Shale members, undivided			94	8
14. Shale, dk. gray (N3), fossiliferous, with horizontal, rusty stained burrows. Fossils: Trilobite fragments (c).		11		
13. Limestone, fine grained, med. dk. gray, argillaceous.		6		
12. Shale, dk. gray, calcareous, sparingly fossiliferous.		8		
11. Limestone, similar to Unit 13.		5		
10. Shale, dk. gray, weathering pale olive (10Y 6/2), calcareous, with rusty weathered burrows.	1			

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
9. Limestone, fine grained, med. dk. gray, argillaceous, fossiliferous. Insoluble residue, 31.1%. Fossils: Ambocoelia umbonata (unc), etc.		3		
8. Shale, dk. gray, deeply weathered, rusty stained.	1	2		
7. Limestone, fine grained, med. dk. gray, argillaceous, with numerous rusty weathered burrows. (Two thick beds separated by 2" bed.)		11		
6. Shale, dk. gray, with a few thin beds of med. dk. gray argillaceous limestone. Sparingly fossiliferous.	2	4		
5. Limestone, thick bedded (in two beds about 6" thick separated by thin shale parting), fine grained, med. dk. gray, argillaceous, fossiliferous. Fossils: A. umbonata (unc).	1			
4. Shale, pale olive (10Y 6/2), with thin argillaceous limestone beds, fossiliferous. Fossils: A. umbonata (c), trilobite fragments (c).	3			
3. Limestone, fine grained, med. dk. gray, argillaceous, fetid, numerous rusty burrows.		6		
2. Shale, dk. gray, weathers lt gray (N7) with rusty stains. Bed of dk. gray limestone, 3" thick, at base. Another limestone bed about two feet above base. Highly fossiliferous. Upper 2 feet of unit is papery black shale. Fossils: A. umbonata (c), Leptocoelina acutiplicata (unc), unidentified chonetid brachiopods (unc), etc.	9	6		
1. Concealed interval, mostly shale float with few outcrops. Contact with Ridgeley not exposed.				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Fossils: <u>L. acutiplicata</u> (unc, about 10 feet above base).	72			

Ridgeley Sandstone
Sandstone, massive, med. to coarse grained, med. lt. gray (N6), fossiliferous, with several feet of thick bedded, dk. gray (N3), cherty, highly fossiliferous limestone at the top.
Fossils: <u>Rensselaeria elongata</u> (unc), etc.

P44 OLD PORT: At bend of Tuscarora Creek, about 0.3 mile south-southwest of gaging station and 1.9 miles southwest of Old Port, Juniata Co. (4,000 feet north of lat. 40° 30'00"N, 1,500 feet west of long. 77° 25' 00"W, at an elevation of 425 feet, south-central portion of Mifflintown 7-1/2' Quadrangle.) The upper part of the Selinsgrove Limestone Member and lower part of the Marcellus Formation (Shamokin Member) are exposed on the southeast side of the creek. The lower portion of the Needmore Formation can be seen in the creek bed. A minor fault appears to repeat the upper few feet of the Selinsgrove. Attitude of bedding is N 72° E/76° S on the north side of the fault and N 64° E/60° S on the south side. Section by Inners, assisted by Smith.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Marcellus Formation				
Shamokin Member				
Shale, fissile, grayish black (N2), carbonaceous, with interbedded limestone, concretionary, grayish-black, silty, at base.				
20. Metabentonite, yellowish-brown weathered, micaceous, blocky at base but shaly toward top. Bed graded from coarser to finer toward top. (Tioga.)		8		
19. Shale, med. dk. gray (N4), calcareous, with thin limy interbeds.	2			

	Unit Ft.	Unit In.	Total Ft.	Total In.
Needmore Formation				
Selinsgrove Limestone Member			24+	
18. Limestone, med. bedded, dk. gray (N3), argillaceous, fossiliferous. Fossils: Small brachiopods (c).		3		
17. Shale, poorly exposed.		4		
16. Limestone, similar to Unit 18.		5		
15. Metabentonite, yellowish-brown weathered, micaceous, silty, exhibits a blocky fracture. (Tioga.)		2		
14. Clay, deeply weathered.		6		
13. Limestone and shale, interbedded. Limestone, thin to med. bedded (in beds 1" and 3" thick), fine grained, med. dk. gray, argillaceous, fossiliferous, containing myriads of small brachiopods. Shale, thin bedded (in beds 1" and 0.5" thick), dk. gray, calcareous.		5.5		
12. Limestone and shale interbedded. Limestone, thin to med. bedded (in beds 1" and 4" thick), fine grained, dk. gray, argillaceous. Shale, thin bedded (in beds 2" and 1" thick), dk. gray, calcareous, fossiliferous, containing some small brachiopods.		8		
11. Shale, dk. gray, calcareous.		1		
10. Metabentonite, yellowish-brown to reddish-brown weathered, micaceous; soft, fine and shaly at base (1") and top (3.5"), blocky and coarse in middle (2"). (Tioga.)		6.5		
9. Shale, dk. gray, calcareous, fossiliferous. Fossils: Small brachiopods (a).		2		
Fault (above Unit 8).				
8. Limestone, fine grained, dk. gray, argillaceous.		3		
7. Shale, dk. gray, calcareous.		2		

	Unit Ft.	Unit In.	Total Ft.	Total In.
6. Limestone, thick bedded, fine grained, med. dk. gray, stylolitic, sparsely fossiliferous. Fossils: Small brachiopods (c).		9		
5. Limestone and shale, interbedded. Limestone, med. bedded, fine grained, med. dk. gray, argillaceous. Shale, thin bedded, med. dk. gray, calcareous.	1	4		
4. Limestone and shale, interbedded. Limestone, thin to med. bedded, fine grained, med. dk. gray, argillaceous, highly fossiliferous. Shale, thin bedded, med. dk. gray, calcareous. Fossils: Small brachiopods (f).	1	2		
3. Limestone and shale, interbedded. Similar to Unit 4. Fossils: Small brachiopods (a).	2	3		
2. Limestone and shale, interbedded. Limestone, thin to med. bedded (in beds 1" to 6" thick), fine grained, med. dk. gray, stylolitic, argillaceous, sparingly fossiliferous. Shale, thin bedded (in beds 1" thick), med. dk. gray, calcareous; uppermost bed is micaceous. Fossils: Small brachiopods (c).	1	6		
1. Limestone and shale, interbedded. Limestone, med. to thick bedded, fine grained, med. dk. gray, argillaceous, sparingly fossiliferous. Shale, thin bedded, med. dk. gray, calcareous.	13			
Lower part of member and formation covered by water of Tuscarora Creek.				

P45 EAST WATERFORD: Along dirt road on north bank of Tuscarora Creek, 0.25 mile north of East Waterford, Juniata Co. (200 feet south of lat. 40° 22' 30"N, 5,000 feet east of long.

77^{o} 37' 30"W, at an elevation of about 620 feet, northwest portion of Blain 7-1/2' Quadrangle.) The Shriver Chert, Ridgeley Sandstone, Needmore Formation, and Marcellus Formation crop out in a series of exposures that extend from the creek bank on the east side of a paved road westward for about 2,000 feet along the dirt road that parallels Tuscarora Creek. Beds strike N 40^{o} E and dip 45^{o} NW off the northwest flank of the Tuscarora Mountain Anticline. Thicknesses of Shamokin, Turkey Ridge, and Mahanoy members of Marcellus Formation from Arndt and others (1959, p. 27). Section by Inners, assisted by Smith.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Marcellus Formation			235+	
Mahanoy Shale Member			50+	
Shale, black (N1), silty and sandy, weathers olive green. Gradational contact with underlying Turkey Ridge.	50+			
Turkey Ridge Sandstone Member			103	
Sandstone, massive, med. grained, dk. gray (N3), calcareous in part. Deformed and partially repeated.	103			
Shamokin Shale Member			82	
Shale, black, carbonaceous, fissile. Partially cut out by decollement fault at base.	82			
Contact between Shamokin Shale and underlying Selinsgrove Limestone occurs within 5 ft. covered interval. Float of silty, micaceous, rusty-weathering metabentonite present.				
Needmore Formation			153	7
Selinsgrove Limestone Member			47	8
75. Limestone, fine grained, dk. gray (N3), argillaceous.		1		
74. Shale, deeply weathered.		8		
73. Limestone, fine grained, dk. gray, rusty flecked. Contains quartz grains.		3		

	Unit Ft.	Unit In.	Total Ft.	Total In.
72. Shale and limestone, interbedded. Limestone, med. bedded (in beds about 1" thick), dk. gray. Shale, dk. gray, calcareous.		11		
71. Limestone, in two thick beds separated by 2" of deeply weathered shale. Limestone, fine grained, dk. gray. Contains rusty tubes.	1	2		
70. Shale, dk. gray, calcareous, with 1/2" to 1" limestone beds at base and top.		9		
69. Limestone, dense, fine grained, dk. gray (N3), argillaceous.		5		
68. Shale, dk. gray, calcareous.		9		
67. Limestone, in two thick beds separated by 1" of soft, deeply weathered shale. Limestone, fine grained, dk. gray, pyritic, fetid.	1			
66. Shale, soft, deeply weathered, calcareous.		2		
65. Limestone and shale, interbedded. Limestone, med. bedded (in four beds), fine grained, dk. gray.		11		
64. Shale, lt. gray (N7), weathered, calcareous, fossiliferous. Fossils: Trilobite fragments (unc).		4		
63. Limestone, massive, fine grained, dk. gray, argillaceous.		7		
62. Limestone, shaly, fine grained, dk. gray, bituminous, pyritic.		11		
61. Limestone, thick bedded to shaly, med. dk. gray (N4) to dk. gray. Upper part very fetid.	1	3		
60. Limestone, thick bedded, with 1" of gray, calcareous shale at top. Limestone, massive to shaly, dk. gray(N3).		11		
59. Shale, dk. gray, calcareous.		3		
58. Limestone, in two thick beds (3" top, 6" bottom), separated by 1" of gray, calcareous shale. Limestone, shaly, med. dk. gray to dk. gray.		10		

	Unit Ft.	Unit In.	Total Ft.	Total In.
57. Shale, very rusty weathering, dk. gray. Well exposed high on bluff. Rusty weathering zone in middle of gray, calcareous shale unit.		5		
56. Limestone, fine grained, med. dk. gray, argillaceous, fossiliferous.		3		
55. Shale, lt. gray weathered, calcareous, iron-rust stained.		7		
54. Limestone and shale, interbedded. Limestone, thin to med. bedded, fine grained, med. dk. gray, argillaceous.	1	6		
53. Limestone, fine grained, med. dk. gray, argillaceous, fossiliferous.		4		
52. Shale, pale olive (10Y 6/2) weathered, calcareous.		3		
51. Limestone, similar to Unit 53.		4		
50. Shale, similar to Unit 52, fossiliferous. Fossils: Unidentified brachiopods (unc), trilobite fragments (c).		3		
49. Limestone, fine grained, med. dk. gray, fetid. Black specks.		4		
48. Shale, calcareous, pale olive weathered, papery, fossiliferous. Fossils: <u>Ambocoelia umbonata</u> (unc).		4		
47. Limestone, fine grained, med. dk. gray, fossiliferous.		7		
46. Shale, dk. gray, calcareous, fissile, containing small concretions less than 1/2" in diameter. Upper beds less strongly laminated (less fissile (?)). Rusty tubes common.	2			
45. Shale, soft, pale olive weathered, strongly leached.		9		
44. Limestone, fine grained, med. dk. gray.		9		
43. Shale, pale olive weathered, papery.	1	1		
42. Shale, pale olive weathered, sparingly fossiliferous.	1			

	Unit Ft.	Unit In.	Total Ft.	Total In.
41. Shale, dk. gray, calcareous, carbonaceous, papery. Strongly sheared at top.		8		
40. Shale, similar to Unit 42.	1	2		
39. Limestone, fine grained, med. dk. gray, sparingly fossiliferous.		5		
38. Shale, pale olive weathered, strongly burrowed.	1	4		
37. Limestone, fine grained, med. dk. gray.		4		
36. Shale, pale olive weathered, fossiliferous. Fossils: Small brachiopods.		9		
35. Limestone, fine grained, med. dk. gray, fossiliferous. Fossils: Small brachiopods (c).		2		
34. Shale, pale olive weathered.		1		
33. Limestone, fine grained, med. dk. gray, strongly weathered.		9		
32. Limestone and shale, interbedded. Limestone, med. bedded (in beds 1" to 2" thick), fine grained, med. dk. gray, fossiliferous. Shale, calcareous, pale olive weathered, fossiliferous.	1			
31. Shale and limestone, interbedded. Shale, calcareous, med. dk. gray, pale olive weathering, fossiliferous. Limestone, fine grained, medium dk. gray, strongly weathered, fossiliferous. Rusty burrows common. Bedding very obscure. Fossils: Trilobite fragments (unc), small brachiopods (unc).	1	6		
30. Shale, calcareous, pale olive weathered.		9		
29. Limestone, fine grained, med. dk. gray. Rusty tubes common.		11		
28. Shale, similar to Unit 30.		2		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
27. Shale, pale olive weathered, calcareous, fossiliferous. Fossils: Trilobite fragments (unc).		2		
26. Shale, pale olive weathered, calcareous, burrow markings.		2		
25. Limestone, fine grained, med. dk. gray.		10		
24. Shale, pale olive weathered.		2		
23. Limestone and shale, interbedded. Limestone, fine grained, med. dk. gray. Shale, pale olive weathered, calcareous.	1			
22. Shale, pale olive weathered, calcareous.	1	10		
21. Limestone, fine grained, med. dk. gray, fossiliferous. Fossils: Trilobite fragments (unc).		10		
20. Shale, pale olive weathered, calcareous. Contains rusty tubes.		8		
19. Limestone, fine grained, med. dk. gray. Contains rusty tubes.		8		
18. Shale, pale olive weathered, fossiliferous. Contains rusty tubes. Fossils: Unidentified brachiopods (unc).		9		
17. Limestone, fine grained, med. dk. gray, fossiliferous. Contains rusty burrows. Strongly cleaved.		8		
16. Shale and limestone, interbedded. Strongly weathered, fossiliferous. Fossils: *Ambocoelia umbonata* (c), unidentified brachiopods (unc), trilobite fragments (c).		4		
15. Limestone, fine grained, med. dk. gray.		5		
14. Shale, with thin limestone interbeds, pale olive weathered, calcareous, fossiliferous. Fossils: *Ambocoelia umbonata* (c).	1	9		

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
13. Limestone, fine grained, med. dk. gray.		6		
Calcareous Shale and Beaverdam Shale Members, Undivided			105	11
12. Shale, pale olive weathered, calcareous, fossiliferous. Fossils: A. umbonata (unc), trilobite fragments (unc).	2	1		
11. Limestone, med. dk. gray (N4), strongly weathered.		9		
10. Shale, weathering olive gray (5Y 4/1), fossiliferous. Fossils: Small brachiopods (c).	2	7		
9. Limestone, fine grained, med. gray (N5), shaly.		6		
8. Shale, with thin limestone interbeds. Shale, olive gray weathered, calcareous, sparingly fossiliferous.	8	3		
7. Limestone, fine grained, med. dk. gray, fossiliferous.		6		
6. Shale, pale olive weathered, calcareous.		1		
5. Limestone, fine grained, med. dk. gray.		1		
4. Shale, pale olive weathered, calcareous.		3		
3. Limestone, fine grained, med. dk. gray.		2		
2. Shale, pale olive weathered, calcareous.		8		
1. Covered interval.	90			
Contact with underlying Ridgeley Sandstone is probably exposed on opposite side of macadam road. Sequence above last thick chert bed in Old Port is as follows (in descending order):				
Gray, tan weathering, fissile shale with 1/2" band of black (N1), fossiliferous limestone in middle.	1			
Black, cherty limestone.		1.5		
Soft, clayey shale.		1		

	Thickness			
	Unit		Total	
	Ft.	In.	Ft.	In.
Ridgeley Sandstone				
Sandstone, med. grained, calcareous, interbedded with thick bands of dk. gray (N3) chert. Highly fossiliferous. (Called arenaceous limestone of Shriver by Arndt and others, 1959, p. 26.)				

P46 NEW BLOOMFIELD: Along road from New Bloomfield to McKee, 0.6 mile north of intersection of that road with Pa. Rte. 34, about 1.0 mile northwest of New Bloomfield, Perry Co. (1,300 feet north of lat. 40° 25' 00"N, 150 feet east of long. 77° 12' 30"W, at an elevation of about 825 feet, west-central portion of Newport 7-1/2' Quadrangle.) Needmore Formation. Locality discussed by Dyson (1963, p. 16).

P47 NEW BLOOMFIELD: On north side of Tressler Pond, about 450 feet southwest of Eckerd Dam, about 0.4 mile south of center of New Bloomfield, Perry Co. (1,000 feet south of lat. 40° 25' 00"N, 6,000 feet west of long. 77° 10' 00"W, at an elevation of 650 feet, south-central portion of Newport 7-1/2' Quadrangle.) Needmore Formation (portions of calcareous shale and Selinsgrove Limestone members). Section described by Kindle (1912, pp. 29-30). Locality near section described by Swartz and Swain (1941, pp. 390-392).

P48 BIXLER: Extensive outcrops along country road that parallels Bixler Run on northeast side of stream, about 0.8 mile north of Bixler, Northeast Madison Township, Perry Co. (2,200 feet north of lat. 40° 22' 30"N, 4,500 feet east of long. 77° 25' 00"W, at an elevation of about 680 feet, southeast portion of Spruce Hill 7-1/2' Quadrangle.) Needmore Formation (Selinsgrove Limestone Member).

P49 ALINDA: On Pa. Rte. 74, 1.7 miles northeast of Landisburg and 1.4 miles north of Alinda, Perry Co. (3,500 feet south of lat. 40° 22' 30"N, 100 feet east of long. 77° 17' 30"W, at an elevation of 730 feet, northeast portion of Landisburg 7-1/2' Quadrangle.) A highly fossiliferous exposure of the upper part of the calcareous shale member occurs on the east side of the road at Klings Farm. Beds strike N 40°/45° E and dip 65° - 85° S. Section by Inners.

	Unit Ft.	Unit In.	Total Ft.	Total In.
Needmore Formation				
Calcareous Shale Member			37	1+
Higher beds concealed.				
8. Shale and limestone, interbedded. Shale, weathered lt. olive gray (5Y 6/1), calcareous, fossiliferous. Limestone, med. to thick bedded, fine grained, dk. gray (N3), argillaceous, fossiliferous. Fossils: Crinoid stems (c), unidentified brachiopods (c), trilobite fragments (unc). (Fossils in shale 5 feet above base.)	7			
7. Shale and limestone, interbedded. Shale, weathered lt. olive gray, calcareous, fossiliferous. Limestone, med. bedded, fine grained, dk. gray, argillaceous, fossiliferous. Fossils: Unidentified brachiopods (c).	9			
6. Limestone, massive, fine grained, dk. gray, weathering tan and lt. olive gray, argillaceous.	1	2		
5. Shale, weathered lt. olive gray, calcareous, fossiliferous. Fossils: <u>Phacops pipa</u> (unc).	2			
4. Limestone, massive, fine grained, med. dk. gray, argillaceous.		7		
3. Shale, similar to Unit 5.	2	8		
2. Shale and limestone, interbedded. Shale, weathered lt. olive gray, calcareous, fossiliferous. Limestone, fine grained, med. dk. gray, argillaceous. Fossils: <u>Ambocoelia umbonata</u> (c), etc.	4	8		
1. Shale and limestone, float.	10			
Lower part concealed.				

P50 ALINDA: On secondary road that leads north off Pa. Rte. 850 into Little Indian Hollow between Milligan Ridge and Spotts

Knob, 0.75 mile northeast of Alinda, Perry Co. (6,000 feet north of lat. 40° 20' 00"N, 6,000 feet west of long. 77° 15' 00"W, at an elevation of 670 feet, northeast portion of Landisburg 7-1/2' Quadrangle.) Ridgeley Sandstone, Needmore Formation. Section described by Kindle (1912, p. 30).

P51 FALLING SPRING: In bed of stream tributary to Sherman Creek, 0.6 mile southwest of Falling Spring, Spring Township, Perry Co. (5,200 feet north of lat. 40° 20' 00"N, 3,500 feet west of long. 77° 12' 30"W, at an elevation of about 460 feet, northwest portion of Shermans Dale 7-1/2' Quadrangle.) Although exposure at this locality is poor, both upper and lower contacts of the Needmore can be quite accurately deliniated. Attitude of bedding is N 50° E/45° SE. Fossils were collected in a shallow cut along a country road at the northeast end of Quaker Hill, 0.9 mile southwest of the measured section. (2,300 feet north of lat. 40° 20' 00"N, 4,500 feet east of long. 77° 15' 00"W, at an elevation of about 450 feet.) Previously described by Kindle (1912, pp. 28-29). Section by Inners.

	Thickness			
	Unit		Total	
	Ft.	In.	Ft.	In.
Marcellus Formation				
Shale, fissile, dk. gray (N3) to grayish black (N2), exposed to edge of Sherman Creek.	30+			
Concealed interval.	13			
Needmore Formation			66	7
Selinsgrove Limestone Member			35	10
5. Limestone, med. dk. gray (N4), lt. gray (N7) weathering, argillaceous, forms last ledge in brook.		6		
4. Concealed interval.	11	4		
3. Limestone, with shale interbeds. Limestone, thick bedded (in beds 6" to 12" thick), med. dk. gray, lt. gray weathering, argillaceous, form ledges in bed of brook. Shale interbeds less than 6" thick.	24			

	Thickness Unit Ft.	In.	Total Ft.	In.
Calcareous Shale and Beaverdam Shale (?) Members, Undivided			30	9
2. Shale, with a few thin beds of limestone. Shale, weathered lt. olive gray (5Y 6/1), calcareous. Fossils: <u>Atrypa reticularis</u> (c), etc.	11	9		
Ridgeley Sandstone				
Sandstone, massive, coarse grained, quartzose, fossiliferous.				

P52 NEWTON HAMILTON: In deep cut on Penn Central Railroad, about 1.0 mile northeast of Newton Hamilton, Mifflin County. (5,000 feet south of lat. 40° 25' 00"N, 4,500 feet east of long. 77° 50' 00"W, at an elevation of about 580 feet, south-central portion of Newton Hamilton 7-1/2' Quadrangle.) Splendid exposures of all three members of the Needmore Formation, as well as the contact with the Ridgeley Sandstone, are present at this locality, the type section of the Beaverdam Shale Member. An old abandoned railroad cut, in which exposure is also quite good, lies about 100 feet to the southeast. Attitude of bedding is about N 45° W/5° SW. Previously described by Willard (1939, p. 153), Swartz and Swain (1941, pp. 395-398), and Swain (1958, p. 2866). Section by Inners.

	Thickness Unit Ft.	In.	Total Ft.	In.
Marcellus Formation				
Shale, fissile, black (N1), rusty weathering, carbonaceous. Contact with underlying Selinsgrove Limestone not exposed.				
Needmore Formation			105	2
Selinsgrove Limestone Member			33	1
68. Limestone, massive, fine grained, dk. gray (N3), argillaceous.	1			
67. Limestone and shale, alternating in beds 2" to 3" thick. Limestone, dk. gray, extremely fossiliferous. Shale,				

		Thickness			
		Unit		Total	
		Ft.	In.	Ft.	In.
	dk. gray, calcareous. Insoluble residue (ls.), 7.0%. Fossils: Small brachiopods (va), <u>Platyceras</u> (<u>Platystoma</u>) <u>turbinatum</u> (a). (Coarsely crystalline.)	2	1		
66.	Shale, grayish black (N2), calcareous, fetid, very fossiliferous. Fossils: Small brachiopods (va).		3		
65.	Limestone, fine grained, med. dk. gray (N4), rusty stained.		7		
64.	Shale, dk. gray, calcareous, with splintery fracture.		2		
63.	Limestone, fine grained, med. dk. gray, argillaceous, very fossiliferous. Insoluble residue, 10.5%. Fossils: Small brachiopods (va), trilobite fragments (c).		11		
62.	Shale, dk. gray, calcareous, very fossiliferous. Fossils: Small brachiopods (va).	1	4		
61.	Limestone and shale, interbedded. Limestone, thick bedded (in six beds 7" to 10" thick), fine grained, med. dk. gray, pyritic, argillaceous, with numerous rusty "tubes." Shale, thin to med. bedded (in beds 1" to 4" thick), fissile, calcareous. Insoluble residue (ls.), 10.0%.	4	10		
60.	Shale, dk. gray, calcareous.		3		
59.	Limestone, in two thick beds, fine grained, med. gray, pyritic, argillaceous, fossiliferous. Insoluble residue, 10.9%. Fossils: Trilobite fragments (c).	1	4		
58.	Shale, dk. gray, calcareous, fossiliferous. Fossils: Small brachiopods (c).		4		
57.	Limestone, dk. gray (N3), soft, bituminous, extremely fossiliferous. Fossils: Small brachiopods (f).		7		

Unit	Description	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
56.	Shale, dk. gray, calcareous, extremely fossiliferous, with slickensides. Fossils: Small brachiopods (f).		4		
55.	Limestone, fine grained, med. gray (N5), pyritic, argillaceous. Insoluble residue, 9.2%.		7		
54.	Shale, dk. gray, calcareous, powdery weathering.		2		
53.	Limestone, fine grained, med. dk. gray (N4), argillaceous, fossiliferous. Fossils: Small brachiopods (a).		11		
52.	Shale, dk. gray, calcareous, pyritic, fossiliferous.		2		
51.	Limestone, similar to Unit 53. Insoluble residue, 22.3%. Fossils: Small brachiopods (a), Orbiculoidea media (unc).		6		
50.	Shale, dk. gray, calcareous, with rusty band 1/2" in middle, pyritic, fossiliferous. Fossils: Small brachiopods (c).		4		
49.	Limestone, fine grained, med. dk. gray, argillaceous, fossiliferous. Fossils: Small brachiopods (c).		3		
48.	Shale, dk. gray, rusty weathering.		1		
47.	Limestone, thick bedded (in four beds separated by shale partings), fine grained, med. dk. gray, argillaceous, fossiliferous. Insoluble residue, 22.2%. Fossils: Odontocephalus aegeria (a), O. selenourus (c), Phacops sp. (unc), Orbiculoidea media (unc), Michelinoceras subulatum (unc), unidentified chonetid brachiopod (unc), unidentified nuculoid bivalve (unc). (Fossils are especially common in lower two beds.)	2	1		
46.	Shale, fissile, grayish black (N2), calcareous, rusty stained.		6		
45.	Limestone, fine grained, med. dk.				

	Unit Ft.	Unit In.	Total Ft.	Total In.
gray, argillaceous, fossiliferous. Fossils: Small brachiopods (c).		11		
44. Shale, fissile, grayish black (N2), rusty stained, calcareous, sparingly fossiliferous. (Crystals of white, platy gypsum coat rock.) Fossils: Orbiculoidea media (unc).		11		
43. Limestone, fine grained, med. dk. gray, argillaceous, pyritic.		5		
42. Shale, med. dk. gray, calcareous.	1	3		
41. Limestone, fine grained, med. dk. gray, dense, argillaceous. Insoluble residue, 43.9%.		5		
40. Shale, med. dk. gray, calcareous, fossiliferous. Fossils: Leptocoelina acutiplicata (unc).	1	5		
39. Limestone, similar to Unit 41.		5		
38. Shale, med. dk. gray, calcareous, fossiliferous. Fossils: Small brachiopods (unc).		7		
37. Limestone, fine grained, med. gray (N5), argillaceous, fossiliferous. Fossils: L. acutiplicata (unc).		4		
36. Shale, med. dk. gray, rusty stained, calcareous.		5		
35. Limestone, similar to Unit 37. Insoluble residue, 29.9%. Fossils: L. acutiplicata (unc), small brachiopods (unc).		6		
34. Shale, med. dk. gray, calcareous.		4		
33. Limestone, grayish black (N2), argillaceous, bituminous, fossiliferous. Fossils: Small brachiopods (c).	1			
32. Shale, dk. gray, calcareous, fossiliferous. Fossils: Small brachiopods (a), etc.	1	1		
31. Limestone, fine grained, med. dk. gray, argillaceous, fossiliferous. Insoluble residue, 27.3%.				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Fossils: Trilobite fragments (c), unidentified gastropods (unc).	1			
30. Shale, med. dk. gray, calcareous, fossiliferous. Fossils: Small brachiopods (c), etc.		8		
29. Limestone, fine grained, med. gray (N5), argillaceous, fossiliferous. Fossils: Ambocoelia umbonata (unc), trilobite fragments (unc).		6		
28. Shale, similar to Unit 30. Fossils: Small brachiopods (c).		8		
27. Limestone, fine grained, dk. gray, argillaceous, sparingly fossiliferous. Fossils: Small brachiopods (unc), trilobite fragments (unc).		8		
Calcareous Shale Member			54	9
26. Shale, med. dk. gray (N4), calcareous, fossiliferous, especially in upper 1-1/2 foot. Fossils: Unidentified brachiopods (unc), etc.	3			
25. Limestone, massive, fine grained, med. dk. gray, very argillaceous, sparingly fossiliferous. Insoluble residue, 35.4%.	1	3		
24. Shale, med. dk. gray, calcareous, fossiliferous, splintery fracture. Fossils: Trilobite fragments (unc).	3	3		
23. Limestone, fine grained, dk. gray, argillaceous, sparingly fossiliferous. Fossils: Small brachiopods (c).		6		
22. Shale, med. dk. gray, calcareous, sparingly fossiliferous. Fossils: Anoplia nucleata (unc), etc.	1	10		
21. Limestone, fine grained, med. dk. gray, very argillaceous, fossiliferous. Insoluble residue, 36.3%. Fossils: Unidentified brachiopods (unc), trilobite fragments (unc).		5		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
20. Shale, med. dk. gray, calcareous, fossiliferous. Fossils: Levenea sp. (unc), etc.	5	2		
19. Limestone, similar to Unit 21. Insoluble residue, 33.0%.		9		
18. Shale, med. dk. gray, calcareous, highly fossiliferous. Fossils: Agoniatites (?) sp. (c), Phacops sp. (unc), unidentified chonetid brachiopods (unc), crinoid columns (unc), unidentified gastropods (unc), unidentified bivalves (unc). (Most fossils concentrated 1'8" above base.)	4			
17. Limestone, fine grained, grayish black (N2), argillaceous.		5		
16. Shale, dk. gray, rusty stained, calcareous, highly fossiliferous, with abundant horizontal burrows. Fossils: Unidentified chonetid brachiopods (unc), Platyceras (Platystoma) cochleatum (c), Nuculoidea sp. (unc), Michilinoceras subulatum (c), Proetus (?) sp., etc. (6' to 9'); Leptocoelina acutiplicata (c), unidentified chonetid brachiopods (a), P. (P.) cochleatum (c) (at base).	9			
15. Limestone, fine grained, dk. gray, argillaceous (shaly), fossiliferous. Fossils: L. acutiplicata (unc), Palaeozygopleura hamiltoniae (unc), Michilinoceras subulatum (unc), etc.		4		
14. Shale, med. dk. gray, calcareous, fossiliferous. Fossils: L. acutiplicata (c).	2	5		
13. Limestone, fine grained, med. gray, argillaceous, fossiliferous.		10		
12. Shale, med. dk. gray, calcareous, fossiliferous (in lower 3 feet), with two 2" discontinuous limestone beds				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
in upper 4 feet. Fossils: L. acutiplicata (c), Levenea sp. (c), Anoplia nucleata (unc), etc.	12	5		
11. Limestone, fine grained, med. gray (N5), argillaceous, fossiliferous. Fossils: L. acutiplicata (a), Orbiculoidea media (c), etc.		6		
10. Shale, med. dk. gray, calcareous, very fossiliferous at base. Fossils: L. acutiplicata (a), Eodevonaria sp. (unc).	1	1		
9. Limestone, similar to Unit 11. Fossils: L. acutiplicata (a), Palaeozygopleura hamiltonia (unc), Eodevonaria sp. (unc).		8		
8. Shale, med. dk. gray, calcareous, fossiliferous. Fossils: L. acutiplicata (c).	1	3		
7. Limestone, fine grained, med. dk. gray, argillaceous, sparingly fossiliferous. Fossils: L. acutiplicata (unc).		4		
6. Shale, med. dk. gray, calcareous, fossiliferous, with several 2" beds of limestone, very argillaceous, fossiliferous. Burrowed. Fossils: L. acutiplicata (a), Orbiculoidea media (c), P. hamiltoniae (unc), Bembexia sp. (unc), Odontocephalus sp. (r), unidentified chonetid brachiopods (unc), etc.		10		
5. Limestone, fine grained, med. dk. gray, argillaceous, pyritic, fossiliferous. (Discontinuous.) Fossils: L. acutiplicata (c), Platyceras (Platystoma) sp. (unc), etc.		2		
4. Shale, med. dk. gray, calcareous, sparingly fossiliferous. Fossils: L. acutiplicata (c).	1	4		

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
Beaverdam Shale Member			17	4
3. Shale and limestone. Shale, med. dk. gray, calcareous, in 6" bed separating two 2" beds of limestone, irregularly bedded, grayish black (N2), glauconitic, phosphatic (?).		10		
2. Shale, dk. gray, calcareous, with some layers of black, rusty weathering, phosphatic oolites. At 10 feet and 11-1/2 feet above base are zones of dk. gray, very dense, pyritic calcareous-phosphatic concretians.	16			
1. Sandstone, quartzose, fine grained, dk. gray, moderately sorted, hematitic, calcareous. Reworked sand at contact with Ridgeley.		6		
Ridgeley Sandstone			7+	
Sandstone, quartzose, massive, fine to med. grained, med. lt. gray (N6), weathers grayish brown (5YR 3/2), well sorted, calcareous, fossiliferous, with some small-scale festoon cross-bedding.	7+			

P53 NEWTON HAMILTON: In rock cut on Penn Central Railroad, 1.0 mile southwest of Newton Hamilton, Mifflin Co. (3,200 feet north of lat. 40° 22' 30"N, 4,500 feet west of long. 27° 50' 00"W, at an elevation of about 620 feet, southwest portion of Newton Hamilton 7-1/2' Quadrangle.) The Selinsgrove Limestone Member, Tioga Metabentonite, and Marcellus Formation crop out on both sides of tracks. Attitude of bedding is about N 65° E/9° NW. Previously described by Swain (1958, pp. 2865-2866). Section by Inners.

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
Marcellus Formation				
Shale, fissile, dk. gray (N3) to grayish black (N2), calcareous in part, with				

	Thickness			
	Unit		Total	
	Ft.	In.	Ft.	In.
several thick beds of limestone, grayish black, bituminous, at base.				
32. Metabentonite, dk. gray, rusty weathering, silty, with blocky fracture. (Tioga B.)		2		
31. Shale, fissile, dk. gray, rusty weathering, calcareous.	1	7		
30. Limestone, med. bedded (in two beds separated by dk. gray shale parting), laminated, dk. gray, bituminous, sparingly fossiliferous. Insoluble residue, 31.8%. Fossils: Small brachiopods (unc).		8		
29. Shale, dk. gray, rusty weathering, calcareous.		4		
28. Limestone, laminated, dk. gray, bituminous.		6		
27. Shale, fissile, dk. gray, calcareous, with thin coating of white (N9) gypsum on bedding planes.	1	2		
26. Limestone and shale, interbedded. Limestone, med. to thick bedded (in beds 3" to 6" thick), laminated, dk. gray, bituminous, with a few highly fossiliferous layers. Shale, also in beds 3" to 6" thick, dk. gray, calcareous, fissile. Fossils: Small brachiopods (unc to f).	2	6		
Needmore Formation				
Selinsgrove Limestone Member			26+	
25. Limestone, fine grained, med. dk. gray, dense, argillaceous, fossiliferous. Insoluble residue, 10.7%. Fossils: Small brachiopods (c).		6		
24. Shale, fissile, dk. gray, calcareous, bituminous.		6		
23. Limestone, fine grained, med. dk. gray, argillaceous, bituminous,				

		Thickness			
		Unit		Total	
		Ft.	In.	Ft.	In.
	sparingly fossiliferous. Insoluble residue, 15.3%. Fossils: Small brachiopods (unc).		4		
22.	Metabentonite and shale. Metabentonite, rusty weathering, silty and micaceous. Shale, dk. gray, calcareous. (Tioga A.)		9		
21.	Limestone, massive, similar to Unit 23. Insoluble residue, 17.7%. Fossils: Small brachiopods (c).		11		
20.	Limestone and shale, interbedded, with 1/2" band of micaceous, pyritic metabentonite (?) at top. Limestone, med. bedded, fine grained, dk. gray, bituminous, highly fossiliferous. Shale, dk. gray, calcareous. Insoluble residue (ls.), 2.9%. Fossils: Small brachiopods (c), Platyceras (Platystoma) turbinatum (c). (Fossils coarsely crystalline.)	2			
19.	Limestone and shale, interbedded. Limestone, med. to thick bedded, fine grained, dk. gray, argillaceous, fossiliferous. Shale, dk. gray, calcareous. Insoluble residue (ls.), 15.7% at base, 5.5% in middle of unit.	1	6		
18.	Shale, fissile, dk. gray, calcareous.		11		
17.	Limestone and shale, interbedded. Limestone, in four massive beds, fine grained, med. dk. gray, dense, argillaceous, sparingly fossiliferous. Shale, dk. gray, calcareous. Insoluble residue, 13.4%.	2	7		
16.	Shale, fissile, dk. gray, calcareous.		3		
15.	Limestone, massive (in two thick beds separated by 1" bed of dk. gray shale), fine grained, med. dk. gray, argillaceous, sparingly fossiliferous. Fossils: Orbiculoidea media (r).	1	3		
14.	Limestone and shale, interbedded.				

		Thickness			
		Unit		Total	
		Ft.	In.	Ft.	In.
	Limestone, med. bedded, fine grained, med. dk. gray, argillaceous, fossiliferous. Shale, dk. gray, calcareous, highly fossiliferous. Fossils: Small brachiopods (va), trilobite fragments (c).		9		
13.	Limestone, massive, fine grained, med. gray (N5), pyritic, argillaceous, fossiliferous. Insoluble residue, 8.2%. Fossils: Small brachiopods (c), trilobite fragments (c).		6		
12.	Limestone, massive, grading into dk. gray shale at top and bottom, dk. gray, argillaceous, fetid, highly fossiliferous. Insoluble residue, 8.6%. Fossils: Small brachiopods (va).	1	2		
11.	Limestone and shale, interbedded. Limestone, med. to thick bedded (in beds 2" to 6" thick), fine grained, med. dk. gray, argillaceous, sparingly fossiliferous. Shale, dk. gray, calcareous. Insoluble residue (ls.), 10.0%. Fossils: Small brachiopods (unc), Orbiculoidea media (r).	1	7		
10.	Shale, dk. gray, calcareous, with 1/2" pyritic, rusty weathering band in middle.		4		
9.	Limestone and shale, interbedded. Limestone, med. to thick bedded (in four beds, lower three 4" to 6" thick, upper 1" thick), fine grained, med. gray (N5), argillaceous, highly fossiliferous. Shale, in beds about 1" thick, dk. gray, calcareous. Insoluble residue (ls.), 11.5%. Fossils: Odontocephalus aegeria (a, especially in second ls. bed from base), small brachiopods (c), etc.	1	8		
8.	Shale, dk. gray, calcareous, with 4"				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
of grayish black, calcareous, fissile shale in middle. Rusty stains common.		8		
7. Limestone, fine grained, med. dk. gray, argillaceous, somewhat laminated (breaks parallel to bedding surfaces).		6		
6. Shale, fissile, black (N1), calcareous, at top, dk. gray, calcareous, at base.	2	6		
5. Limestone, fine grained, med. gray (N5), very argillaceous. Insoluble residue, 25.7%.		8		
4. Shale, fissile, dk. gray, calcareous, sparingly fossiliferous, with a few calcareous concretions. A 3" bed of limestone lies 1'6" above base. Fossils: *Leptocoelina acutiplicata* (c), etc.	2	7		
3. Limestone, fine grained, med. dk. gray, argillaceous, sparingly fossiliferous.		5		
2. Shale, dk. gray, rusty weathering, calcareous, sparingly fossiliferous.		6		
1. Limestone, fine grained, med. gray, highly argillaceous, fossiliferous. Insoluble residue, 37.0%. Fossils: *L. acutiplicata* (c), etc.		8		
Lower part of member not exposed.				

P54 NEWTON HAMILTON: In cut along road that leads east from U.S. Route 22-522 toward Newton Hamilton, 0.4 mile east of main highway and 1.5 miles west-northwest of Newton Hamilton, Mifflin Co. (5,700 feet south of lat. 40° 25' 00"N, 4,500 feet east of long. 77° 52' 30"W, at an elevation of 700 feet, southwest portion of Newton Hamilton 7-1/2' Quadrangle.) Needmore Formation section described by Swartz and Swain (1941, pp. 399-400).

P55 ALFARATA: On west side of gap cut by Meadow Creek through unnamed ridge, 0.2 mile south-southwest of Alfarata, Decater

Township, Mifflin Co. (2,550 feet south of lat. 40° 40' 00"N, long. 77° 27' 30"W, at an elevation of 660 feet, southwest portion of Alfarata 7-1/2' Quadrangle.) Needmore Formation (upper part of calcareous shale member and lower part of Selinsgrove Limestone Member).

P56 JACKSON CORNER: On Pa. Rte. 26, 0.2 mile southwest of Jackson Corner, Huntingdon Co. (4,000 feet north of lat. 40° 35' 00"N, 2,700 feet east of long. 77° 52' 30"W, at an elevation of 700 feet, northwest portion of Allensville 7-1/2' Quadrangle.) Selinsgrove Limestone Member of Needmore Formation crops out on northwest side of road. Previously described by Swartz and Swain (1941, p. 400). Section by Inners.

	Thickness Unit Ft.	In.	Total Ft.	In.
Needmore Formation				
Selinsgrove Limestone Member			16+	
Upper part concealed.				
29. Limestone and shale, interbedded. Limestone, med. to thick bedded, fine grained, med. dk. gray (N4) to dk. gray (N3). Shale, dk. gray, calcareous. No fossils observed. Poorly exposed at top of slope.	3			
28. Limestone, fine grained, med. dk. gray, argillaceous.		2		
27. Limestone, fine grained, med. dk. gray to dk. gray, pyritic, numerous veins of calcite with abundant pink crystals.		3		
26. Shale, med. dk. gray, calcareous, poorly exposed.		3		
25. Limestone, thin to med. bedded (in four beds), fine to med. grained, highly bituminous, dk. gray to grayish black (N2). Beds are coquinites of small brachiopods. Thin shale seams between beds.		6		
24. Limestone, fine grained, dk. gray to med. dk. gray, pyritic, sparingly fossiliferous.		4		

	Thickness			
	Unit		Total	
	Ft.	In.	Ft.	In.
23. Shale, med. dk. gray, calcareous, forms recess.		1		
22. Limestone, fine grained, med. dk. gray, pyritic, weathered pits on surface.		3		
21. Limestone and shale, interbedded. Limestone, med. bedded (in three beds, each 2" thick), dk. gray, argillaceous. Shale, med. dk. gray, calcareous.		9		
20. Limestone, fine grained, crystalline, med. gray (N5).		3		
19. Shale, med. dk. gray, calcareous.		5		
18. Limestone, similar to Unit 20.		3		
17. Shale, med. dk. gray, highly calcareous.		9		
16. Limestone, med. bedded (in two 3" beds separated by thin shale seam), med. gray, crystalline, fossiliferous. Fossils: Trilobite fragments (c).		6		
15. Shale, med. dk. gray, calcareous.		3		
14. Limestone, fine grained, med. dk. gray, argillaceous and somewhat shaly.		7		
13. Concealed. Probably consists of interbedded shale and limestone. Limestone bed may be 3" thick slab lying on slope—fine grained, crystalline, med. gray.	1			
12. Limestone, fine grained, med. dk. gray, argillaceous.		1		
11. Shale, dk. gray, calcareous.		1		
10. Limestone, thick bed, fine grained, crystalline, med. gray, sparingly fossiliferous. Fossils: Ambocoelia umbonata (large) (unc).		10		
9. Shale, thin bedded, laminated toward top, med. dk. gray, moderately to highly calcareous. Appears to grade up from limestone below.		6		

	Thickness Unit Ft.	In.	Total Ft.	In.
8. Limestone, thick bedded, fine grained, med. dk. gray, strongly cleaved, with numerous en echelon tension gashes filled with calcite.		8		
7. Shale, lt. olive gray (5Y 6/1) weathered, calcareous, poorly exposed.		2		
6. Limestone, fine grained, med. dk. gray, pyritic, weathers shaly, argillaceous.		6		
5. Shale, lt. olive gray weathered, abundant lebenspuren, calcareous.		10		
4. Limestone, fine grained, med. dk. gray, argillaceous, bituminous (fetid). Veined by calcite.		8		
3. Shale, olive gray (5Y 5/1) weathered, only slightly calcareous.	1	3		
2. Limestone, fine grained, med. dk. gray, argillaceous.		10		
1. Shale, lt. olive gray weathered, calcareous.	2			

Lower part of Selinsgrove Limestone Member and remainder of Needmore Formation concealed.

Ridgeley Sandstone

Sandstone, quartzose, massive, med. grained. Exposed along access road behind cottage.

P57 MARTIN GAP: On north side of Martin Road in Martin Gap, 1.9 miles south-southwest of Jackson Corner, Huntingdon Co. (4,000 feet south of lat. 40° 35' 00"N, 4,500 feet west of long. 77° 50' 00"W, at an elevation of about 780 feet, west-central portion of Allensville 7-1/2' Quadrangle.) The Needmore Formation is poorly exposed here, but a fairly good thickness estimate can be obtained. Beds strike N 25° E and dip 55° W off west flank of the Kishacoquillas Anticline. Previously described by Swartz and Swain (1941, p. 401). Section by Inners, assisted by M. Inners.

	Thickness Unit Ft. In.	Thickness Total Ft. In.
Marcellus Formation		
Shale, fissile to laminated, dk. gray (N3) to grayish black (N2), rusty weathering, slightly calcareous.		
Needmore Formation		125±
Selinsgrove Limestone Member		35±
5. Concealed interval, sparse float of fine grained, argillaceous limestone. No fossils observed. (Probably includes some Marcellus.)	25	
4. Shale, with limestone interbeds. Shale, lt. olive gray (5Y 6/1) and tan weathered, strongly fractured, slightly calcareous. More calcareous layers are probably limestone beds. Sparingly fossiliferous.	9	
3. Limestone, thick bedded (in two beds separated by thin shale seam), med. dk. gray (N4), argillaceous, intensely cleaved.	1	
Calcareous Shale and Beaverdam Shale members, undivided		90±
2. Shale, laminated, med. dk. gray, calcareous, fossiliferous.	10	
1. Concealed interval. (May include some Ridgeley.)	80	
Ridgeley Sandstone		
Sandstone, quartzose, massive, fine to med. grained, saccharoidal, highly fossiliferous. Strongly leached.		

P58 ORBISONIA: On east side of U.S. Rte. 522, about 0.25 mile north-northwest of Orbisonia, Huntingdon Co. (Lat. 40° 15' 00"N, 6,000 feet east of long. 77° 15' 00"W, at an elevation of 680 feet, north-central part of Orbisonia 15' and south-central portion of Mt. Union 15' Quadrangles.) The upper part of the calcareous shale member and lower part of the Selinsgrove

Limestone Member crop out in a shallow road cut along the highway. The upper part of the Selinsgrove Limestone Member, as well as the Tioga Metabentonite, is exposed a few hundred yards farther north at the PennDOT storage shed. Attitude of bedding averages about N 15° E/45° W. Section by Inners.

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
Marcellus Formation				
Shale, fissile, black (N2), non-calcareous. Chips weather with white edges.				
Needmore Formation			54	11+
Selinsgrove Limestone Member			33	5
18. Limestone and shale, interbedded. Limestone, med. bedded, fine grained, dk. gray (N3), argillaceous. Shale, dk. gray, calcareous.	1			
17. Metabentonite, tan and rusty weathered, micaceous, splintery. (Tioga.)		4		
16. Shale, dk. gray to black (N1), calcareous, fetid, crowded with small brachiopods.		6		
15. Limestone, massive, dk. gray, fetid.		8		
14. Metabentonite, tan and rusty weathered, micaceous. (Tioga.)		2		
13. Limestone and shale, interbedded. Limestone, med. to thick bedded, med. dk. gray (N4), argillaceous, pyritic. Shale, med. dk. gray, lt. olive gray (5Y 6/1) weathering, calcareous.	3	6		
12. Metabentonite, tan weathered, poorly exposed. (Tioga.)		6		
11. Limestone and shale, interbedded. Limestone, med. to thick bedded, med. dk. gray, argillaceous, pyritic, with abundant hemititic tubes (burrows?) near base. Dk. gray, bituminous coquinite of small brachiopods at top. Shale, dk. gray, lt. olive gray weathering, calcareous. (Exposed near PennDOT shed.)	20			

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Concealed interval of undetermined thickness.				
10. Limestone and shale, interbedded. Limestone, med. to thick bedded, highly cleaved. Shale, lt. olive gray and splintery weathered. Fossiliferous. Fossils: *Leptocoelina acutiplicata* (unc), etc.	4			
9. Limestone, fine grained, lt. olive gray weathered, argillaceous, fossiliferous. Fossils: *L. acutiplicata* (unc), etc.		8		
8. Limestone and shale, interbedded. Limestone, thick bedded (in beds 6" to 8" thick), lt. olive gray weathered, argillaceous, fossiliferous. Shale interbeds poorly defined. Fossils: *L. acutiplicata* (c), *Ambocoelia umbonata* (c), unidentified ramose bryozoan (unc), trilobite fragments (c).	2	1		
Calcareous Shale Member			21	6
7. Shale, lt. olive gray weathered, calcareous, highly fractured, fossiliferous. Abundant horizontal burrows. Fossils: *A. umbonata* (c), *L. acutiplicata* (c).	3	6		
6. Limestone, massive, med. dk. gray, highly argillaceous, intensely cleaved, fossiliferous. Fossils: Small brachiopods (unc).	1	4		
5. Shale, similar to Unit 7, splintery. Fossils: *Phacops cristata* (unc), etc.	6			
4. Limestone, similar to Unit 6. Fossils: *L. acutiplicata* (c), *Phacops pipa* (unc), *Odontocephalus aegeria* (unc), etc.		11		

	Unit Ft.	Unit In.	Total Ft.	Total In.
3. Shale, med. gray, calcareous, splintery fractured, fossiliferous.	3			
2. Limestone, med. dk. gray, argillaceous, intensely cleaved, sparsely fossiliferous. Fossils: *Leptaena* (?) sp.		9		
1. Shale, med. gray, weathering lt. olive gray, intensely cleaved, fossiliferous. Fossils: *Phacops* sp. (unc), unidentified bivalves (a, near base).	6			
Lower part concealed.				

P59 FRANKSTOWN: On north side of U.S. Rte. 22, 0.1 mile east of Frankstown and 2.0 miles northeast of Hollidaysburg, Blair Co. (10,000 feet north of lat. 40° 25' 00"N, 5,200 feet west of long. 78° 20' 00"W, at an elevation of about 930 feet, north-central portion of Hollidaysburg 15' Quadrangle.) Ridgeley Sandstone, Needmore Formation (lower part, including bed of ferrugenous chert, "Huntersville," at base). Section described by Swartz and Swain (1941, pp. 402-404).

P60 CURTIN GAP: On north side of westbound lane of Interstate Rte. 80 in Curtin Gap, 1.3 miles south of Curtin Village, Centre Co. (1,500 feet south of lat. 40° 57' 30" N, 1,000 feet east of long. 77° 45' 00"W, at an elevation of 750 feet, west-central portion of Mingoville 7-1/2' Quadrangle.) The Needmore Formation is very thin here and can be differentiated from the Marcellus only by the occurrence of several limestone beds with characteristic Onesquethaw fauna. Both upper and lower contacts are exposed. A bed of the Tioga Metabentonite is present in the lower Marcellus. Exposure is on northwest limb of Nittany (Bald Eagle) Anticlinorium. Attitude of beds about N 65° E/ 65° NW. Section by Inners.

	Unit Ft.	Unit In.	Total Ft.	Total In.
Marcellus Formation				
17. Shale, laminated to fissile, dk. gray				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
(N3) to grayish black (N2), non-calcareous.				
16. Metabentonite, yellowish-brown weathered, micaceous, blocky at top, soft at base. Rather abrupt contact with underlying black shale. (Tioga.)		7		
15. Shale, grayish black, soft.		7		
14. Metabentonite, yellowish-brown weathered, micaceous, blocky.		0.5		
13. Shale, fissile, grayish-black, rusty weathering.	4			
12. Shale, brownish weathered, soft. (Metabentonitic (?))		6		
11. Shale, fissile, dk. gray (N3), calcareous	5	6		
Needmore Formation			32	7
Calcareous Shale Member			32	7
10. Limestone, thick bedded, fine grained, med. gray (N5), argillaceous, fossiliferous, with vertical burrows.	1	8		
9. Shale, laminated and fissile, dk. gray (N3), slightly calcareous	2	6		
8. Limestone, similar to Unit 10.		9		
7. Shale, fissile, grayish black (N2), slightly calcareous, bituminous, fossiliferous. Fossils: Unidentified chonetid brachiopods (c), *Coelospira camilla* (unc), *Ambocoelia umbonata* (c), *Styliclina fissurella* (a).	11	5		
6. Limestone, thick bedded, med. gray, argillaceous, sparingly fossiliferous.		7		
5. Shale, med. dk. gray (N4), calcareous, sparingly fossiliferous, with abundant horizontal burrows.	8			
4. Limestone, similar to Unit 6.		8		
3. Shale, med. gray, calcareous, fossiliferous, with horizontal burrows.				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Fossils: Leptocoelina acutiplicata (unc), Orbiculoidea media (unc), etc.	2			
2. Claystone, maroon weathered, calcareous.	1			
1. Shale, lt. gray (N7) weathered, calcareous, but generally leached, badly fractured. Abrupt contact with Ridgeley.	4			
Ridgeley Sandstone				
Sandstone, quartzose, thick bedded to massive, lt. gray (N7), weathering tan, highly fossiliferous. (Fossils are mostly brachiopod molds filled with rusty clay residue.)				

P61 TYRONE: On dirt road to town dump between Grazierville and Charlottsville, 0.15 mile southwest of railroad overpass on U.S. Rte. 220 and 1.5 miles southwest of Tyrone, Blair Co. (7,000 feet south of lat. 40° 40' 00"N, 5,600 feet west of long. 78° 15' 00"W, at an elevation of about 970 feet, southeast portion of Tipton 7-1/2' Quadrangle.) Upper part of Needmore Formation, Needmore-Marcellus contact, and Tioga Metabentonite are well exposed. The limestones of the Selinsgrove Limestone Member consist almost entirely of myriads of juvenile brachiopods. Exposures occur in the strike valley carved by Little Juniata River between the Allegheny Front to the northwest and Brush Mountain to the southeast. Attitude of bedding is about N 50° E/ 81° SE (overturned). Previously described by Swartz and Swain (1941, pp. 404-405). Section by Inners.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Marcellus Formation				
Shale, fissile, dk. gray (N3), weathering rusty, mostly non-calcareous. Numerous large (2 ft. to 3 ft. in diameter), ellipsoidal limestone concretions occur in the borrow pit to the south.				

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
34. Metabentonite, deeply weathered, micaceous. (Tioga B.)		2		
33. Shale, fissile, dk. gray, non-calcareous.	2			
32. Limestone, dk. gray, highly argillaceous, bituminous, fossiliferous. Fossils: Small brachiopods (unc).		2		
31. Shale, laminated, dk. gray, calcareous, fossiliferous. Fossils: <u>Styliolina fissurella</u> (a).	1	7		
30. Limestone, fine grained, dk. gray, highly argillaceous and bituminous, fossiliferous. Fossils: Small brachiopods (c).		4		
29. Shale and metabentonite. Shale, laminated, dk. gray, calcareous, with thin, dk. gray laminated limestone bed in middle. Metabentonite, 2" thick, occurs 2" below top of unit, rusty weathered, micaceous. (Tioga A.)	1			
28. Limestone, fine grained, dk. gray, argillaceous, bituminous.		4		
27. Shale, fissile and laminated, dk. gray, calcareous, fossiliferous. Fossils: Small brachiopods (c), <u>Styliolina fissurella</u> (c).	2			
Needmore Formation			48	9+
Selinsgrove Limestone Member			13	9
26. Limestone, thin to thick bedded, med. dk. gray, argillaceous and bituminous, highly fossiliferous. Insoluble residue, 10.9%. Fossils: Small brachiopods (f, avg. size 1mm. or less).	1	5		
25. Shale and limestone, interbedded. Shale, dk. gray, calcareous, bituminous, highly fossiliferous. Limestone, laminated, dk. gray, argillaceous,				

	Unit Ft.	Unit In.	Total Ft.	Total In.
bituminous, highly fossiliferous. Fossils: Small brachiopods (f).	2	6		
24. Limestone, laminated, med. dk. gray, argillaceous, bituminous, highly fossiliferous. Insoluble residue, 7.0%. Fossils: Small brachiopods, perhaps Meristella (f, avg. size 2-3mm.).		7		
23. Shale, dk. gray, calcareous, bituminous, fetid, highly fossiliferous. Fossils: Small brachiopods (f).	1			
22. Limestone, med. dk. gray, argillaceous, bituminous, fetid, highly fossiliferous. Fossils: Small brachiopods, perhaps Meristella (f, avg. size 1-2mm.).		4		
21. Shale, dk. gray, calcareous, bituminous, highly fossiliferous, with very irregular bedding surfaces. Fossils: Small brachiopods (f).		6		
20. Limestone, fine grained, dk. gray, argillaceous, sparingly fossiliferous. Insoluble residue, 27.7%. Fossils: Small brachiopods (unc).		8		
19. Limestone and shale, interbedded. Limestone, med. to thick bedded, dk. gray, argillaceous, bituminous, highly fossiliferous. Insoluble residue (ls.), 18.2%. Fossils: Small brachiopods (c to f, avg. size 2-3mm.), trilobite fragments (unc), Styliolina fissurella (c).	6			
18. Limestone, dk. gray, argillaceous, bituminous, highly fossiliferous. Insoluble residue, 12.1%. Fossils: Small brachiopods (f).		9		
Calcareous Shale Member			35	
17. Shale, dk. gray, calcareous, bituminous, fossiliferous. Fossils: Styliolina fissurella (f).	2	2		

	Thickness			
	Unit		Total	
	Ft.	In.	Ft.	In.
16. Limestone, dk. gray, argillaceous, bituminous, intensely cleaved.		8		
15. Shale, dk. gray, weathering pale olive (10Y6/2), calcareous.	4	2		
14. Limestone, fine grained, dk. gray, argillaceous, bituminous, fossiliferous. Insoluble residue, 14.4%. Fossils: *Palaeozygopleura hamiltoniae* (unc), etc.		6		
13. Shale, dk. gray, weathering pale olive, calcareous. Bed of argillaceous limestone, 4" thick, lies 2 feet above base.	2	9		
12. Limestone and shale, interbedded. Limestone, in two beds, med. bedded, fine grained, dk. gray, weathering with rusty stains, argillaceous, bituminous, fossiliferous. Shale, 3" thick, dk. gray, calcareous. Tube-like *lebenspuren* parallel to bedding are common. Fossils: *P. hamiltoniae* (unc).		10		
11. Shale, dk. gray, weathering pale olive, calcareous.	2			
10. Limestone, fine grained, dk. gray, weathering pale olive, argillaceous, bituminous, fossiliferous. Insoluble residue, 10.4%. Fossils: *Orbiculoidea media* (unc), small brachiopods (c).		5		
9. Shale, dk. gray, weathering pale olive, calcareous, with thin bed of limestone 1-1/2 feet above base.	6			
8. Limestone, thick bedded, fine grained, dk. gray, argillaceous, fossiliferous, with thin shale partings between beds. Fossils: *L. acutiplicata* (unc), *Atrypa reticularis* (unc).	2	4		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
7. Shale, dk. gray, calcareous, sparingly fossiliferous, with a thin band of limestone 1-1/2 feet above base. Tube-like <u>lebenspuren</u> (1 to 2mm. in diameter) parallel to bedding are common. Fossils: Trilobite fragments (unc).	5	3		
6. Limestone, fine grained, dk. gray, weathering pale olive, argillaceous.		6		
5. Shale, weathered pale olive, calcareous.	3			
4. Limestone, fine grained, med. dk. gray (N4), argillaceous, fossiliferous, with tube-like, rusty weathering <u>lebenspuren</u> parallel to bedding. Fossils: <u>Phacops</u> sp. (unc).		4		
3. Shale, fissile, weathered pale olive, fossiliferous. Fossils: Trilobite fragments (unc), unidentified chonetids (unc).	3	9		
2. Limestone, fine grained, med. dk. gray, argillaceous, fossiliferous. Fossils: <u>Agoniatites</u> (?) sp. (c).		4		
1. Covered interval, shale and limestone float.				

P62 EICHELBERGERTOWN: On old farm road on north side of a small stream that cuts through a Ridgeley Sandstone ridge, about 1.0 mile north of Eichelbergertown, Hopewell Township, Bedford Co. (3,200 feet south of lat. 40° 10' 00"N, 10,200 feet east of long. 78° 20' 00"W, at an elevation of 1,040 feet, east-central portion of Everett 15' Quadrangle.) Although the Needmore Formation is rather poorly exposed here, a good estimation of the total thickness can be obtained. Attitude of bedding is about N 12° E/61° SE. Previously described by Knowles (1966, p. 90). Section by Inners, assisted by Smith.

	Thickness Unit Ft.	In.	Total Ft.	In.
Marcellus Formation				
Shale, dk. gray (N3), non-calcareous, weathering into paper-thin chips with white and tan edges.				
Needmore Formation			82	8
Selinsgrove Limestone Member			23	8
10. Covered interval. Sparse float of limestone, fine grained, med. dk. gray (N4), argillaceous. Fossils: *Ambocoelia umbonata* (unc).	23			
9. Limestone, fine grained, med. dk. gray (N4), argillaceous, fossiliferous. Fossils: *A. umbonata* (unc).		8		
Calcareous Shale Member			33	8
8. Shale, fissile to splintery, weathered pale olive (10Y 6/2), argillaceous, calcareous in part. More fissile layers are non-calcareous.	13	6		
7. Limestone, fine grained, dk. gray (N3), argillaceous, sparingly fossiliferous. Contains numerous tube-like *lebenspuren* about 2mm. in diameter (horizontal). Fossils: *A. umbonata* (r).		6		
6. Shale, weathered pale olive, calcareous, fossiliferous. Fossils: Small crinoid stems (c).	1			
5. Shale, fissile, med. dk. gray (N4), weathering pale olive and lt. tan, non-calcareous.	17			
4. Limestone, fine grained, med. dk. gray, argillaceous, containing rusty-weathered, tube-like *lebenspuren*. Pyrite cubes in calcite vein fillings.		3		
3. Shale, weathered pale olive, calcareous, fossiliferous, with irregular star-shaped markings. Fossils: *A. umbonata* (c).	1	6		

	Unit Ft.	Unit In.	Total Ft.	Total In.
2. Limestone, similar to Unit 4.		3		
Beaverdam Shale Member			25	4
1. Shale, fissile, dk. gray (N3), weathering yellowish gray (5Y 7/2) to pale olive (10Y 6/2), non-calcareous, sparingly fossiliferous. Fossils: Leptocoelina acutiplicata (r).	25	4		
Ridgeley Sandstone				
Sandstone, quartzose, massive, med. to coarse grained, lt. gray (N7), containing numerous brachiopod molds. (Upper 11 feet covered, but sandy nature of float, with very few shale chips, indicates interval should be included with Ridgeley. A few pieces of iron-stained, oolitic Beaverdam shale are present.)				

P63 WARFORDSBURG: On northeast side of Interstate Rte. 70, 0.75 mile north of interchange with U.S. Rte. 522 and 1.1 miles northwest of Warfordsburg, Bethel Township, Fulton Co. (6,000 feet north of lat. 39° 45' 00"N, 2,200 feet east of long. 78° 12' 30"W, at an elevation of 540 feet, south-central portion of Needmore 7-1/2' Quadrangle.) The Ridgeley Sandstone, Needmore Formation, and Marcellus Formation crop out in road cut in gap of White Oak Run through Tonoloway Ridge. Interval between Needmore and Marcellus is poorly exposed and may be structurally disturbed. Attitude of bedding is N 20° E/70° W. Section by Inners.

	Unit Ft.	Unit In.	Total Ft.	Total In.
Marcellus Formation				
Shale, fissile, grayish black (N2), weathering rusty, non-calcareous.				
16. Metabentonite, deeply weathered, rusty, micaceous. (Tioga.)		6		

	Thickness			
	Unit		Total	
	Ft.	In.	Ft.	In.
Needmore Formation				
Calcitic Shale and Limestone Subfacies			40+	
15. Disturbed interval. Limestone, massive, grayish black (N2), bituminous, fetid, highly fossiliferous, containing myriads of small (juvenile?) brachiopods, with a few beds of limestone, fine grained, dk. gray (N3), argillaceous. Poorly exposed. Measured stratigraphic thickness of 60 feet is probably too great.				
14. Shale, med. dk. gray (N4) at top, weathered greenish gray (5Y 6/1) in lower part, calcareous, with numerous horizontal lebenspuren in dk. shale at top. Fossils: Leptocoelina acutiplicata (unc).	2	9		
13. Limestone and shale, interbedded. Limestone, med. bedded, fine grained, med. dk. gray, argillaceous, fossiliferous. Shale, weathered greenish gray, calcareous, fossiliferous. Fossils: Unidentified brachiopods (c), trilobite fragments (c), crinoid stems (c).	1	5		
12. Shale, weathered greenish gray, calcareous, fossiliferous, with some shaly limestone beds at top. Fossils: Unidentified small rugose corals (c), Atrypa reticularis (unc), Ambocoelia umbonata (c), Phacops sp. (c), Odontocephalus aegeria (unc), large crinoid stems (r).	6	2		
11. Limestone, massive, fine grained, med. gray (N5), weathering lt. gray (N7) and greenish gray, argillaceous, fossiliferous.				

		Thickness			
		Unit		Total	
		Ft.	In.	Ft.	In.
	Fossils: Unidentified brachiopods (c), <u>Phacops</u> sp. (c), <u>Phacops pipa</u> (c).	1	9		
10.	Shale, weathered greenish gray, calcareous, highly fossiliferous at top. Fossils: "<u>Heterophrentis</u>" sp. A (c), unidentified brachiopods (c), <u>Orbiculoidea media</u> (unc), <u>Phacops pipa</u> (c), small crinoid stems (c).	6	5		
9.	Limestone, med. bedded, fine grained, med. dk. gray, weathering greenish gray, argillaceous, fossiliferous, with thin shale partings. Fossils: Unidentified rugose corals (r), <u>Ambocoelia umbonata</u> (c), unidentified brachiopods (c), trilobite fragments (c), <u>Styliolina fissurella</u> (c).	1			
8.	Shale, weathered greenish gray and rusty, calcareous, highly fractured, fossiliferous. Fossils: <u>A. umbonata</u> (c), unidentified brachiopods (c), trilobite fragments (c), crinoid stems (a, in thin band 3 feet above base).	6	8		
7.	Shale and limestone, interbedded. Shale, weathered greenish gray, calcareous, sparingly fossiliferous. Limestone, med. bedded, fine grained, med. dk. gray, weathering greenish gray, argillaceous, highly fossiliferous. Fossils (mostly in ls.): <u>A. umbonata</u> (c), unidentified brachiopods (c), <u>Phacops</u> sp. (c), crinoid stems (c), etc.	2	7		
6.	Shale, weathered greenish gray and rusty, calcareous, fossiliferous. Fossils: <u>A. umbonata</u> (c), unidentified brachiopods (c), <u>Phacops</u> sp. (c), crinoid stems (c).	9	5		

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
5. Limestone and shale, interbedded. Limestone, med. bedded, fine grained, med. dk. gray, weathering greenish gray, argillaceous, fossiliferous. Shale, weathered greenish gray, calcareous, fossiliferous. Fossils: A. umbonata (c), Atrypa reticularis (unc), unidentified brachiopods (c), Phacops sp. (unc), crinoid stems (a).	1	9		
Calcitic Shale Subfacies			34	11
4. Shale, weathered greenish gray, calcareous, highly fossiliferous, with beds of limestone at 15' 8" above base (leached) and 10' above base (dk. gray, fossiliferous). Fossils: Anoplia nucleata (r), A. umbonata (a), Coelospira camilla (r), unidentified brachiopods (c), unidentified gastropods (c), Agoniatites (?) sp. (c, at 12' 1" above base), Phacops sp. (c), crinoid stems (a).	19	11		
3. Shale, weathered greenish gray, calcareous, with limestone bed at 5'11" above base (weathered to yellowish clay).	15			
Beaverdam Shale Subfacies			12	2
2. Shale, dk. gray (N3) to black (N1), rusty weathering, oolitic, with a few thick bands of black phosphatic oolites.	10	6		
1. Shale, sandy and oolitic, rusty weathered. (Sand reworked from underlying Ridgeley.)	1	8		
Ridgeley Sandstone				
Sandstone, quartzose, med. to coarse grained, lt. gray (N7) to white (N9), highly fossiliferous.				

P64 WARREN POINT: On east side of Pa. Rte. 456, just south of bridge across Licking Creek, near Stone Bridge Church (Md.), 1.5 miles southwest of Yeakle Mill, Warren Township, Franklin Co. (5,500 feet north of lat. 39° 42' 30"N, 5,100 feet west of long. 78° 02' 30"W, at an elevation of about 450 feet, north-central portion of Cherry Run, W. Va., 7-1/2' Quadrangle.) The Ridgeley Sandstone and Needmore Formation crop out on the right bridge abutment and along the road to the south. Exposures extend across the Mason-Dixon Line into Maryland. The Ridgeley-Needmore disconformity is well shown at this locality. Attitude of bedding is about N 35° E/ 35° SE. Previously described by Rowe (1900), Stose and Swartz (1912, pp. 9-10), Prosser, Kindle, and Swartz (1913, p. 83), and Swartz and Swain (1941, pp. 406-407). Section by Inners, assisted by M. Inners.

	Thickness			
	Unit		Total	
	Ft.	In.	Ft.	In.
Marcellus Formation				
Shale, fissile, dk. gray (N3), weathered to thin chips with white edges.				
6. Concealed interval. (Mostly Marcellus.)	41			
Needmore Formation			119	10
Calcitic Shale and Limestone Subfacies			53	
5. Shale and limestone, med. dk. gray, lt. olive gray (5Y 6/1) weathering, fossiliferous. Calcareous throughout, but no good beds of limestone observed. Fossils: *Levenea* sp. (unc), *Bollia ungula* (c), in upper part; *Ambocoelia umbonata* (c), unidentified brachiopods (c), *Odontocephalus* sp. (unc), *Bollia ungula* (c), in middle; *Levenea lenticularis* (c), *Favulella favulosa* (c), small rugose corals (unc), etc., in lower part.	53			
Calcitic Shale Subfacies			57	10
4. Shale, concealed, mostly lt. olive gray weathered float.	13	6		

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
3. Shale, med. dk. gray (N4), weathering lt. olive gray, non-calcareous, sparingly fossiliferous, with splintery fracture. Fossils: A. umbonata (unc), F. favulosa (unc).	13	10		
2. Shale, concealed, mostly lt. olive gray weathered float.	28	6		
Beaverdam Shale Subfacies			11	
1. Shale, soft, lt. olive gray weathered (with prominent orange and rusty layers), non-calcareous. Phosphatic nodules (as large as 3" in diameter) at base. Disconformable contact with Ridgeley.	11			
Ridgeley Sandstone				
Sandstone, quartzose, massive, med. gray (N5), weathering lt. tannish gray, highly calcareous, highly fossiliferous with fossils concentrated into bands along with small (3 to 4mm.) quartz pebbles. At very top is 5" bed of coarse, deeply weathered, rusty, fossiliferous sandstone with scattered round quartz pebbles about 12mm. (1/2") in diameter.				

P65 HYNDMAN: Cut on east side of Pa. Rte. 96, 1.7 miles southwest of Hyndman, Bedford Co. (1,500 feet north of lat. 39° 47' 30"N, 2,500 feet east of long. 78° 45' 00"W, at an elevation of 1,120 feet, west-central portion of Hyndman 7-1/2' Quadrangle.) Needmore Formation (calcitic shale and limestone subfacies).

P66 Walter Hess No. 1 well (Transcontinental Production Co.), Shohola Township, Pike Co. (Lytle, Bergsten, Cate, and others, 1961, p. 116; Fletcher and Woodrow, 1970, pl. 2.)

P67 C. Price No. 1 well (Transcontinental Production Co.), Damascus Township, Wayne Co. (Lytle, Bergsten, Cate, and others, 1961, p. 130.)

P68 L. Richards No. 1 well (Transcontinental Production Co.), Ransom Township, Lackawanna Co. (Lytle, Bergsten, Cate, and others, 1961, p. 113; Kehn, Glick, and Culbertson, 1966, pp. 64-78, pl. 2.)

P69 Graver Estate No. 1 well (Phillips Petroleum Co.), Towamensing Township, Carbon Co. (Lytle and others, 1965, p. 40.)

P70 Nellie J. Harrison No. 1 well (John T. Galey et al.), Huntington Township, Luzerne Co. (Fettke, 1956, p. 97.)

P71 John Sheehan No. 1 well (John H. Rebold), Mehoopany Township, Wyoming Co. (Fettke, 1956, p. 113.)

P72 Kelly-Hendrickson No. 1-A well (Gas Well Supply Co.), Choconut Township, Susquehanna Co. (Lytle, Bergsten, Cate, and others, 1961, p. 126.)

P73 E. J. Moran No. 1 well (Kewanee Oil Co.), Friensville Borough, Susquehanna Co. (Lytle, Bergsten, Cate, and others, 1961, p. 126.)

P74 C. Blemle No. 1 well (Pure Oil Co.), Wilmot Township, Bradford Co. (Lytle and others, 1963, p. 32; Rickard, 1969, pl. 13.)

P75 G. H. Hettick No. 1 well (Penn-York Natural Gas Corp.), Towanda Township, Bradford Co. (Fettke, 1933, pp. 648-653; 1950, p. 24; 1961, pp. 355-363.)

P76 Headlee No. 1 well (Obie Shaw), West Burlington Township, Bradford Co. (Lytle and others, 1964, p. 36.)

P77 H. B. French No. 1 well (Leo Leiderbach et al.), Granville Township, Bradford Co. (Fettke, 1956, p. 24.)

P78 Anna Carver No. 1 well (Parsons Brothers), Ridgebury Township, Bradford Co. (Lytle, Bergsten, Cate, and others, 1961, p. 55; Rickard, 1969, pl. 13.)

P79 S. G. Braisted No. 1 well (Mosherville Oil and Gas), Wells Township, Bradford Co. (Fettke, 1950, p. 24.)

P80 B. Bruschart No. 1 well (Blue Rocks Drilling Co.), Forks Township, Sullivan Co. (Fettke, 1956, p. 110.)

P81 A. W. Bennett No. 1 well (The California Co.), Davidson Township, Sullivan Co. (Fettke, 1956, p. 110; Rickard, 1969, pl. 13.)

P82 Knarr No. 1 well (Farmers Gas and Oil Co.), Locust Township, Columbia Co. (Fettke, 1961, p. 84; Wood, Trexler, and Kehn, 1969, p. 19.)

P83 G. C. Krick No. 1 well (Angas Corp.), Ralpho Township, Northumberland Co. (Fettke, 1956, p. 100; Wood, Trexler, and Kehn, 1969, p. 19.)

P84 Fox No. 1 well (Angas Corp.), Shamokin Township, Northumberland Co. (Fettke, 1956, p. 100; Wood, Trexler, and Kehn, 1969, p. 19.)

P85 Albert No. 1 well (Middle Creek Prospecting Co.), Adams Township, Snyder Co. (Wagner, 1958; Lytle, Bergsten, Cate, and others, 1961, p. 123.)

P86 A. E. Ging No. 1 well (Delta Drilling Co.), Cascade Township, Lycoming Co. (Fettke, 1956, p. 98.)

P87 W. Codney No. 1 well (Godfrey C. Cabot, Inc.), Cogan House Township, Lycoming Co. (Fettke, 1956, p. 98.)

P88 W. P. Day No. 1 well (Felmont Oil Corp.), Pine Township, Lycoming Co. (Lytle and others, 1962, p. 51.)

P89 Pa. Game Lands Tract 75-A No. 1 well (Felmont Oil Corp.), Brown Township, Lycoming Co. (Lytle and others, 1962, p. 51.)

P90 Pa. Tract 101 No. 1 well (N.Y. State Natural Gas Corp.), Brown Township, Lycoming Co. (Lytle and others, 1963, p. 39.)

P91 Weiboldt No. 1 well (Cayuga Gas), Elk Township, Tioga Co. (Fettke, 1950, p. 99.)

P92 W. J. Butters No. 1 well (Morris Run Coal Co.), Union Township, Tioga Co. (Fettke, 1950, p. 100.)

P93 C. Bolt No. 1 well (W. E. Snee et al.), Covington Township, Tioga Co. (Fettke, 1950, p. 98.)

P94 L. E. Shoemaker No. 1 well (Lycoming Natural Gas Corp.), Lawrence Township, Tioga Co. (Fettke, 1933, pp. 641-648; 1950, p. 89; 1961, pp. 343-353.)

P95 Ida Wheeler No. 1 well (Lycoming Natural Gas Corp.), Delmar Township, Tioga Co. (Fettke, 1933, pp. 637-641; 1950, p. 99; 1961, pp. 335-353.)

P96 L. Dickerson No. 1 well (N.Y. State Natural Gas Corp.), Gaines Township, Tioga Co. (Fettke, 1950, p. 99.)

P97 L. J. Roberts No. 1 well (N.Y. State Natural Gas Corp.), Clymer Township, Tioga Co. (Fettke, 1950, p. 83.)

P98 A. T. Pride No. 1 well (Penn-United Gas), Chatham Township, Tioga Co. (Fettke, 1950, p. 88.)

P99 J. G. Bertch No. 1 well (Hope Engineering Co.), Brookfield Township, Tioga Co. (Fettke, 1933, p. 637; 1950, p. 83.)

P100 W. B. Bennett No. 1 well (Lycoming Natural Gas Corp.), Ulysses Township, Potter Co. (Fettke, 1950, p. 69.)

P101 Heymann No. 1 well (Bug Drilling Co.), Pike Township, Potter Co. (Fettke, 1956, p. 104.)

P102 F. Estes No. 1 well (Bayless Natural Gas), Genesee Township, Potter Co. (Fettke, 1950, p. 65.)

P103 A. E. Matteson No. 1 well (Potter Development Co.), Hebran Township, Potter Co. (Fettke, 1933, pp. 631-636; 1950, p. 59; 1961, pp. 311-319.)

P104 E. J. Davis No. 1 well (New Penn Development Co.), Sharon Township, Potter Co. (Fettke, 1950, p. 53.)

P105 Crawford Estate No. 1 well (Potter Development Co.), Keating Township, Potter Co. (Fettke, 1950, p. 76; Rickard, 1969, pl. 14.)

P106 L. Franke No. 1 well (Bayless Natural Gas), East Fork Township, Potter Co. (Fettke, 1950, p. 77.)

P107 State of Pa. No. 2 well (Godfrey L. Cabot, Inc.), Wharton Township, Potter Co. (Fettke, 1949, pp. 22-27; 1950, p. 79; 1961, pp. 321-334.)

P108 C. R. Peters Unit No. 1 well (Godfrey L. Cabot, Inc.), Wharton Township, Potter Co. (Fettke, 1949, p. 37; 1950, p. 78.)

P109 Central Pa. Lumber Co. No. 4 well (Godfrey L. Cabot, Inc.), Wharton Township, Potter Co. (Fettke, 1949, p. 36; 1950, p. 78.)

P110 Emporium Lumber Co. No. 1 well (East Penn Development Co.), East Fork Township, Potter Co. (Fettke, 1949, pp. 35-36; 1950, p. 77.)

P111 Pa. State Lands, Warrant 4689, No. 1 well (Allegany Gas Co. et al.), Abbott Township, Potter Co. (Fettke, 1949, pp. 37-38; 1950, p. 77.)

P112 Pa. Dept. Forests and Waters N972 well (Consolidated Gas Supply Corp.), Stewardson Township, Potter Co. (Rickard, 1969, pl. 14.)

P113 C. C. Swartz No. 1 well (New York State Natural Gas Corp.), Leidy Township, Clinton Co. (Fettke, 1956, p. 47.)

P114 J. C. Foley No. 1 well (Godfrey C. Cabot, Inc.), Leidy Township, Clinton Co. (Fettke, 1956, p. 40.)

P115 State of Pa. Tract 23 No. 5 well (Post Publishing Co.), Leidy Township, Clinton Co. (Lytle, Bergsten, Cate, and others, 1961, p. 83.)

P116 State of Pa. Tract 13 No. 1 well (N.Y. State Natural Gas Corp.), Gallagher Township, Clinton Co. (Fettke, 1956, p. 59.)

P117 J. Springer No. 1 well (Murphy Oil and Gas Development Co.), Gallagher Township, Clinton Co. (Fettke, 1956, p. 60.)

P118 Mohawk Rod and Gun Club No. 1 well (Murphy Oil and Gas Development Co.), Gallagher Township, Clinton Co. (Fettke, 1956, p. 60.)

P119 State of Pa. Tract 102 No. 1 well (Phillips Petroleum Co.), Beech Creek Township, Clinton Co. (Lytle and others, 1964, p. 36.)

P120 State of Pa. Tract E No. 1 well (Manufacturers Light and Heat Co.), Beech Creek Township, Clinton Co. (Fettke, 1956, p. 60.)

P121 Homewood Hunting Club No. 1 well (Mid-Atlantic Oil and Gas Co.), East Keating Township, Clinton Co. (Fettke, 1956, p. 51.)

P122 State of Pa. Tract E No. 2 (Manufacturers Light and Heat Co.), Burnside Township, Centre Co. (Fettke, 1956, p. 37.)

P123 M. O'Brien No. 1 well (Lexa Oil and Gas Co.), Burnside Township, Centre Co. (Fettke, 1956, p. 37.)

P124 Pa. Game Lands No. 1 well (Clearfield Development Co.), Union Township, Centre Co. (Fettke, 1956, p. 37.)

P125 Lehigh Valley Coal No. 1 well (N.Y. State Natural Gas Corp.), Union Township, Centre Co. (Lytle and others, 1965, p. 40.)

P126 O. P. McCord No. 1 well (R. W. Dye et al.), Rush Township, Centre Co. (Fettke, 1956, p. 37.)

P127 Erhard No. 1 well (Bald Eagle Drilling Co.), Taylor Township, Centre Co. (Fettke, 1956, p. 37.)

P128 P. Swistock No. 1 well (N.Y. State Natural Gas Corp.), Bigler Township, Clearfield Co. (Lytle and others, 1964, p. 36.)

P129 Lilly Leamer No. 1 well (N.Y. State Natural Gas Corp.), Burnside Township, Clearfield Co. (Lytle and others, 1966, p. 54.)

P130 J. M. Chase No. 1 well (Consolidated Gas Supply Corp.), Knox Township, Clearfield Co. (Lytle and others, 1966, p. 55.)

P131 M. Avery No. 1 well (Manufacturers Light and Heat Co.), Boggs Township, Clearfield Co. (Lytle and others, 1963, p. 34.)

P132 Pa. Game Lands Tract 78 No. 1 well (Parsons Brothers), Graham Township, Clearfield Co. (Lytle, Bergsten, Cate, and others, 1961, p. 81.)

P133 A. Irwin No. 13 well (F. C. Deemer), Bell Township, Clearfield Co. (Fettke, 1956, p. 39; Lytle, Bergsten, Cate, and others, 1961, pl. 7.)

P134 M. L. Kirk No. 1 well (T. W. Phillips Gas and Oil Co.), Brady Township, Clearfield Co. (Lytle, Bergsten, Cate, and others, 1961, p. 60, pl. 7.)

P135 State of Pa. Tract C No. 2 well (Manufacturers Light and Heat Co.), Pine Township, Clearfield Co. (Fettke, 1956, p. 38; Lytle, Bergsten, Cate and others, 1961, pl. 7.)

P136 State of Pa. Tract 80 No. 1 well (N.Y. State Natural Gas Corp.), Huston Township, Clearfield Co. (Lytle, Bergsten, Cate, and others, 1961, p. 78.)

P137 Clearfield Trust Co. No. 1 well (N.Y. State Natural Gas Corp., Delta Drilling Co.), Girard Township, Clearfield Co. (Lytle and others, 1962, p. 46; Glover, 1970, pp. 112-115.)

P138 M. T. Steel No. 1 well (N.Y. State Natural Gas Corp.), Covington Township, Clearfield Co. (Fettke, 1956, p. 39.)

P139 State of Pa. Tract D No. 2 well (Keta Gas and Oil Co.), Gibson Township, Cameron Co. (Fettke, 1956, p. 36.)

P140 F. D. Floyd No. 1 well (Moffat et al.), Grove Township, Cameron Co. (Fettke, 1956, p. 36.)

P141 Vause and Jones No. 2 well (Harry Wines et al.), Gibson Township, Cameron Co. (Fettke, 1956, p. 26.)

P142 P. H. Johnson No. 1 well (Woodrock Oil and Gas Co.), Grove Township, Cameron Co. (Fettke, 1956, p. 27.)

P143 A. Pardee Estate No. 1 well (Godfrey L. Cabot, Inc.), Gibson Township, Cameron Co. (Fettke, 1956, p. 26; 1961, pp. 295-309.)

P144 Emporium Water Co. No. 1 well (Felmont Oil Corp.), Lumber Township, Cameron Co. (Lytle and others, 1966, p. 54.)

P145 First National Bank of Emporium No. 1 well (Tioga Natural Gas), Shippen Township, Cameron Co. (Fettke, 1950, p. 26.)

P146 Hercules Powder Co. No. 1 well (The Sylvania Corp.), Shippen Township, Cameron Co. (Fettke, 1956, p. 26.)

P147 F. Coleman No. 1 well (Lee E. Minter), Shippen Township, Cameron Co. (Lytle and others, 1962, p. 45.)

P148 A. Pardee Estate No. 7 well (N.Y. State Natural Gas Corp., Godfrey L. Cabot, Inc.), Shippen Township, Cameron Co. (Lytle and others, 1962, p. 46.)

P149 State of Pa. Tract 100 No. 1 well (N.Y. State Natural Gas Corp.), Shippen Township, Cameron Co. (Lytle and others, 1963, p. 34.)

P150 G. Summers No. 1 well (J. C. Walker), Benezette Township, Elk Co. (Lytle, Bergsten, Cate, and others, 1961, p. 89.)

P151 Dents Run Coal Co. No. 2 well (N.Y. State Natural Gas Corp.), Benezette Township, Elk Co. (Lytle, Bergsten, Cate, and others, 1961, p. 89.)

P152 Dents Run Coal Co. No. 1 well (George McKinney et al.), Benezette Township, Elk Co. (Fettke, 1956, p. 77.)

P153 State of Pa. Tract 26 No. 6 (Manufacturers Light and Heat Co.), Benezette Township, Elk Co. (Fettke, 1956, p. 81.)

P154 State of Pa. Tract 32 No. 1 well (N.Y. State Natural Gas Corp.), Benezette Township, Elk Co. (Fettke, 1956, p. 88.)

P155 A. J. Palumbo No. 6 well (N.Y. State Natural Gas Corp.), Fox Township, Elk Co. (Lytle, Bergsten, Cate, and others, 1961, p. 90.)

P156 Danforth No. 41 well (Humphrey Brick and Tile), Spring Creek Township, Elk Co. (Fettke, 1950, p. 32.)

P157 Pa. State Game Lands, Warrant 3653, No. 1 well (Pennsylvania Gas Co.), Highland Township, Elk Co. (Fettke, 1950, p. 32; 1961, pp. 467-490.)

P158 Warrant 3788, No. 3737 well (United Natural Gas Co.), Highland Township, Elk Co. (Fettke, 1933, pp. 611-620; 1950, p. 32; 1961, pp. 277-294.)

P159 Benjamin Haywood No. 1 well (Atlantic Seaboard Natural Gas), Hamlin Township, McKean Co. (Fettke, 1950, p. 50; 1961, pp. 229-238.)

P160 M. Zerbe No. 1165 well (Potter Development Co.), Liberty Township, McKean Co. (Fettke, 1950, p. 50; 1961, pp. 239-250.)

P161 C. Nunn et al. No. 2 well (Allegany Gas), Liberty Township, McKean Co. (Fettke, 1950, p. 50; Rickard, 1969, pls. 12, 14.)

P162 Al Nolan No. 1 well (Jack Shuman et al.), Ceres Township, McKean Co. (Lytle, Bergsten, Cate, and others, 1961, p. 115.)

P163 G. Taylor No. 1 well (New Penn Development Corp.), Ceres Township, McKean Co. (Fettke, 1950, p. 50.)

P164 L. D. Wilson No. 18 well (South Penn Oil Co.), Lafayette Township, McKean Co. (Fettke, 1950, p. 49; 1961, pp. 205-228; Rickard, 1969, pl. 12.)

P165 Central Pa. Lumber Co. No. 1 well (Penn-Bradford Oil Co.), Hamilton Township, McKean Co. (Fettke, 1950, p. 49; 1961, pp. 199-204.)

P166 Warrant 3416, No. 4 well (South Penn Oil Co.), Lafayette Township, McKean Co. (Fettke, 1950, p. 49; 1961, pp. 185-198.)

P167 L. E. Mallory and Son No. 1 well (Hiawatha Oil and Gas Co.), Corydon Township, McKean Co. (Fettke, 1950, p. 49; 1961, pp. 177-183.)

P168 Kinzua Valley Chemical Co. No. 1 well (Appalachian Development Corp.), Corydon Township, McKean Co. (Fettke, 1950, p. 49; 1961, pp. 169-176.)

P169 Delo No. 1 well (Bradford Deep Well Co.), Foster Township, McKean Co. (Fettke, 1933, pp. 620-621; 1950, p. 49.)

P170 E. A. Williams No. 1 well (Hiawatha Oil and Gas Co.), Foster Township, McKean Co. (Fettke, 1950, p. 49; 1961, pp. 159-168.)

P171 L. E. Mallory and Son No. 1 well (Appalachian Development Corp.), Corydon Township, McKean Co. (Fettke, 1950, p. 49; 1961, pp. 149-157.)

P172 E. A. Williams No. 1 well (Appalachian Development Corp.), Corydon Township, Warren Co. (Fettke, 1950, p. 103; 1961, pp. 139-147.)

P173 C. Erickson No. 1 well (C. E. Updegraff et al.), Elk Township, Warren Co. (Fettke, 1950, p. 102; 1961, pp. 81-94.)

P174 Lessor and Louner, Lot 42, No. 1 well (Potter Development Co.), Kinzua Township, Warren Co. (Fettke, 1950, p. 102; 1961, pp. 95-108.)

P175 Lessor and Louner, Lot 60, No. 1 well (H. C. Drilling Co.), Kinzua Township, Warren Co. (Fettke, 1950, p. 102; 1961, pp. 109-119.)

P176 M. W. Jamison No. 1 well (Sylvania Corp.), Kinzua Township, Warren Co. (Fettke, 1950, p. 103; 1961, pp. 121-137.)

P177 Dunham Oil Co. No. 1 well (Kane Industrial Gas), Watson Township, Warren Co. (Fettke, 1950, p. 102.)

P178 Mrs. Carl Keester No. 1 well (Pennsylvania Gas Co.), Brokenstraw Township, Warren Co. (Lytle, Bergsten, Cate, and others, 1961, p. 129.)

P179 Shaw No. 1 well (Biery and Johnson), Limestone Township, Warren Co. (Lytle, Bergsten, Cate, and others, 1961, p. 129; Rickard, 1969, pl. 12.)

P180 Orrin Smith No. 1 well (Mid-East Oil Co.), Eldred Township, Warren Co. (Fettke, 1956, p. 113.)

P181 Spetz No. 1 well (Potter Development Co.), Pittsfield Township, Warren Co. (Fettke, 1950, p. 102; 1961, pp. 65-80.)

P182 Edith Adams No. 1 well (Pennsylvania Gas Co.), Wayne Township, Erie Co. (Fettke, 1956, p. 93.)

P183 Esterline No. 1 well (Vandenburg), North East Township, Erie Co. (Lytle and others, 1962, p. 50.)

P184 Erie Deep Well (Presque Isle Gas), Mill Creek Township, Erie Co. (Fettke, 1950, p. 33.)

P185 P. M. Osborn No. 1 well (Stevens and Skrobat), Summit Township, Erie Co. (Fettke, 1956, p. 91.)

P186 C. Blount No. 1 well (Wittmer Co., Mellon and Pollock), McKean Township, Erie Co. (Fettke, 1950, p. 37.)

P187 Vanco No. 2 well (Flanigan et al.), Washington Township, Erie Co. (Lytle and others, 1963, p. 37.)

P188 W. C. Kibber No. 1 well (Dougherty Bros.), Girard Township, Erie Co. (Fettke, 1950, p. 37.)

P189 Frances Miles No. 3 well (New Penn Development Corp.), Springfield Township, Erie Co. (Fettke, 1950, p. 33; 1961, pp. 27-35.)

P190 N. Blickensderfer No. 22 well (Ohio Oil Co.), Springfield Township, Erie Co. (Fettke, 1950, p. 37; 1961, pp. 17-25.)

P191 Jay Childs No. 1 well (Ohio Oil Co.), Springfield Township, Erie Co. (Fettke, 1941, pp. 2-6; 1950, p. 36; 1961, pp. 3-16.)

P192 Jack Benedict No. 1 well (Netherland Gas and Fuel Co.), Springfield Township, Erie Co. (Fettke, 1950, p. 37.)

P193 Boothby No. 1 well (Layman Corp.), Springfield Township, Erie Co. (Lytle and others, 1967, p. 38; Kelley and McGlade, 1969, p. 34, pl. 2.)

P194 C. Huston No. 1 well (Paul Britton et al.), Conneaut Township, Erie Co. (Lytle, Bergsten, Cate, and others, 1961, p. 101.)

P195 Goodwill-Curley No. 1 well (V. R. Stephens et al.), Summit Township, Erie Co. (Wagner, 1958; Lytle, Bergsten, Cate, and others, 1961, p. 95.)

P196 T. Gosick No. 1 well (Atlas Drilling Co., Sun Oil Co.), Cussewago Township, Crawford Co. (Lytle and others, 1962, p. 47.)

P197 A. Cozad No. 1 well (Appalachian Development Corp.), Beaver Township, Crawford Co. (Fettke, 1950, p. 28.)

P198 F. D. Carter No. 1 well (J. S. McCluskey), Conneaut Township, Crawford Co. (Lytle and others, 1962, p. 47.)

P199 Ed Mullen No. 1 well (Benedum-Trees Oil Co.), S. Shenango Township, Crawford Co. (Lytle, Bergsten, Cate, and others, 1961, p. 86.)

P200 Ellen Calvin No. 2 well (Sylvania Corp.), East Fallowfield Township, Crawford Co. (Fettke, 1950, p. 30.)

P201 Huidekoper No. 1 well (I. W. Whitney), Sadsbury Township, Crawford Co. (Fettke, 1950, p. 30.)

P202 G. Kastle No. 1 well (Transamerican Petroleum Co.), Hayfield Township, Crawford Co. (Lytle and others, 1963, p. 36.)

P203 J. Chapin No. 1 well (Potter Development Corp.), Rockdale Township, Crawford Co. (Fettke, 1950, p. 29.)

P204 R. Halfast No. 1 well (Simpson et al.), Sparta Township, Crawford Co. (Lytle, Bergsten, Cate, and others, 1961, p. 85.)

P205 Halfast No. 1 well (Albaugh et al.), Rome Township, Crawford Co. (Lytle and others, 1962, p. 48.)

P206 E. Collins No. 1 well (W. C. Wasson et al.), Howe Township, Forest Co. (Fettke, 1950, p. 45; 1961, pp. 263-275.)

P207 Cook No. 134 well (Collins and Richard), Kingsley Township, Forest Co. (Fettke, 1950, p. 45.)

P208 R. M. Burnham Estate No. 1 well (Fairman Drilling Co.), Limestone Township, Clarion Co. (Lytle and others, 1967, p. 35.)

P209 J. A. Mays No. 2 well (Fairman Drilling Co.), Monroe Township, Clarion Co. (Lytle and others, 1965, p. 40.)

P210 H. Amsler No. 1 well (Fairman Drilling Co.), Piney Township, Clarion Co. (Lytle and others, 1966, p. 54.)

P211 Stellman No. 1 well (Carl E. B. McKenry et al.), Rockland Township, Venango Co. (Fettke, 1950, p. 101.)

P212 Clyde Van Camp No. 1 well (Hathaway Bros.), Jackson Township, Venango Co. (Fettke, 1950, p. 101.)

P213 J. V. Johnson No. 1 well (United Natural Gas Co.), Sandy Lake Township, Mercer Co. (Lytle and others, 1967, p. 49.)

P214 E. B. Minnis No. 1 well (United Natural Gas Co.), Worth Township, Mercer Co. (Fettke, 1950, p. 52.)

P215 J. Paul Miller No. 1 well (Mercer Oil and Gas Co.), Lake Township, Mercer Co. (Fettke, 1950, p. 51.)

P216 R. W. Temple No. 1 well (Peoples Natural Gas Co., Snee and Eberly), Lake Township, Mercer Co. (Lytle and others, 1966, p. 64; Wagner, 1969, pl. 1.)

P217 V. Partridge No. 1 well (Mercury Oil and Gas Co.), Perry Township, Mercer Co. (Lytle, Bergsten, Cate, and others, 1961, p. 115.)

P218 H. Probst No. 1 well (Clyde Fisher), Sugar Grove Township, Mercer Co. (Fettke, 1950, p. 51.)

P219 Jamestown Manuf. and Mach. Co. No. 1 well (Jamestown Manuf. and Mach. Co.), Jamestown Borough, Mercer Co. (Lytle, Bergsten, Cate, and others, 1961, p. 115.)

P220 Dale Kyser No. 1 well (Glenn Smith et al.), W. Salem Township, Mercer Co. (Fettke, 1956, p. 99.)

P221 Emma McKnight No. 1 well (Melken Oil Co.), Pymatuning Township, Mercer Co. (Wagner, 1958; Lytle, Bergsten, Cate, and others, 1961, p. 115; Rickard, 1969, pl. 12.)

P222 A. S. McCullough No. 1 well (Carnegie Natural Gas Co.), Jefferson Township, Mercer Co. (Fettke, 1941, pp. 6-10; 1950, p. 51.)

P223 C. Cromarti No. 1 well (Sharon Steel Corp.), Hickory Township, Mercer Co. (Fettke, 1956, p. 99.)

P224 S. H. Collins No. 12 well (E. A. Bream), Springfield Township, Mercer Co. (Fettke, 1950, p. 52.)

P225 Hughes No. 1 well (Freehold Oil and Gas Co.), Mahoning Township, Lawrence Co. (Fettke, 1950, p. 48.)

P226 G. H. Hohmann No. 1 (Peoples Natural Gas Co.), Scott Township, Lawrence Co. (Lytle and others, 1965, p. 50.)

P227 J. Scott Munnell No. 1 well (James H. Duff et al.), Slippery Rock Township, Lawrence Co. (Fettke, 1941, pp. 11-12; 1950, p. 48.)

P228 W. E. Currie No. 1-4 well (Carnegie Natural Gas Co.), Shenango Township, Lawrence Co. (Fettke, 1950, p. 48.)

P229 Laura M. Miller and Harry F. Myers No. 1 well (T. W. Phillips Gas and Oil Co., J. T. Galey), Slippery Rock Township, Lawrence Co. (Fettke, 1950, p. 48.)

P230 F. Cole No. 1 well (Peoples Natural Gas Co.), South Beaver Township, Beaver Co. (Lytle and others, 1966, p. 54.)

P231 J. L. Tennis Heirs No. 1 well (James H. Duff, J. T. Galey), South Beaver Township, Beaver Co. (Fettke, 1941, pp. 13-18; 1950, p. 21.)

P232 W. Wilsman No. 1 well (Wittmer Oil and Gas et al.), Independence Township, Beaver Co. (Fettke, 1950, p. 22.)

P233 J. P. Koehler Estate No. 1 well (St. Joseph Lead Co.), Center Township, Beaver Co. (Fettke, 1950, p. 22.)

P234 S. Chalfant No. 1 well (National Supply Co.), Harmony Township, Beaver Co. (Fettke, 1950, p. 22.)

P235 Abbie Linnenbrink et al. No. 1 well (Columbian Fuel Corp.), Rochester Township, Beaver Co. (Fettke, 1941, pp. 18-23; 1950, p. 22.)

P236 Elmer Pflug No. 1 well (L. D. McMichael et al.), New Sewickley Township, Beaver Co. (Fettke, 1950, p. 21.)

P237 P. Fanker No. 1 well (American Gas Co.), Jackson Township, Butler Co. (Fettke, 1950, p. 25.)

P238 Griffin Bros. No. 1 well (T. W. Phillips Gas and Oil Co.), Franklin Township, Butler Co. (Lytle, Bergsten, Cate, and others, 1961, p. 55.)

P239 Lehigh Portland Cement Co. No. 1 well (James H. Duff, J. T. Galey), Muddy Creek Township, Butler Co. (Martens, 1939, pp. 48-52; Fettke, 1950, p. 25.)

P240 Jessie Hockenberry No. 1 well (Manufacturers Light and Heat Co.), Mercer Township, Butler Co. (Fettke, 1950, p. 25; 1961, pp. 37-64.)

P241 Mary Becker No. 1 well (Hill Oil and Gas Co.), Cherry Township, Butler Co. (Fettke, 1950, p. 25.)

P242 Fowler-Campbell No. 1 well (South Penn Oil Co.), Concord Township, Butler Co. (Fettke, 1941, pp. 28-33; 1950, p. 25.)

P243 J. S. Walker No. 1 well (J. C. Walker et al.), Bruin Borough, Butler Co. (Fettke, 1956, p. 25.)

P244 W. T. Beidenbach No. 1 well (T. W. Phillips Gas and Oil Co., J. T. Galey), W. Franklin Township, Armstrong Co. (Fettke, 1950, p. 20.)

P245 Mary A. McGinley No. 1 well (Pittsburgh Plate Glass Co.), S. Buffalo Township, Armstrong Co. (Fettke, 1956, p. 24.)

P246 W. B. Porter No. 2 well (N.Y. State Natural Gas Corp.), South Bend Township, Armstrong Co. (Lytle and others, 1964, p. 35.)

P247 Margaret Rupert No. 1 well (Columbian Carbon Co.), South Bend Township, Armstrong Co. (Lytle, Bergsten, Cate, and others, 1961, p. 54.)

P248 M. J. Hilty No. 1 well (Peoples Natural Gas Co.), Cowanshannock Township, Armstrong Co. (Lytle and others, 1968, p. 31.)

P249 A. W. Wilson No. 1 well (James Drilling Corp.), Cowanshannock Township, Armstrong Co. (Lytle and others, 1967, p. 35.)

P250 L. M. Martin No. 4 well (Peoples Natural Gas Co.), Wayne Township, Armstrong Co. (Fettke, 1950, p. 21.)

P251 Verstine and Kline No. 8 well (F. C. Deemer), Eldred Township, Jefferson Co. (Fettke, 1950, p. 47.)

P252 Burt Wells No. 2 well (N.Y. State Natural Gas Corp.), Winslow Township, Jefferson Co. (Lytle and others, 1962, p. 51.)

P253 E. A. Haddow No. 1 well (Consol. Gas Supply Corp.), McCalmont Township, Jefferson Co. (Lytle and others, 1968, p. 35; Heyman, 1969, pl. 2.)

P254 R. and P. Coal Co. (Elk Run Unit 2) No. 1 well (Consol. Gas Supply Corp.), Young Township, Jefferson Co. (Lytle and others, 1968, p. 35.)

P255 Lindsey Coal Co. (Gabrielson Unit) No. 1 well (Fairman Drilling Co.), Perry Township, Jefferson Co. (Lytle and others, 1968, p. 36.)

P256 D. Croasman No. 5 well (J. and J. Enterprises), Perry Township, Jefferson Co. (Lytle and others, 1968, p. 35.)

P257 W. H. Irwin Co. Tract No. 1 well (F. C. Deemer), Gaskill Township, Jefferson Co. (Fettke, 1941, pp. 33-39; 1950, p. 47.)

P258 Ray C. Conrad No. 1 well (Columbian Carbon Co.), Gaskill Township, Jefferson Co. (Lytle, Bergsten, Cate, and others, 1961, p. 112.)

P259 A. Miller No. 1 well (N.Y. State Natural Gas Corp.), N. Mahoning Township, Indiana Co. (Lytle and others, 1965, p. 50.)

P260 Herbert Gernandt No. 1 well (Fairman Drilling Co.), Grant Township, Indiana Co. (Fettke, 1956, p. 96; Lytle, Bergsten, Cate, and others, 1961, pl. 7.)

P261 Farmers and Miners Trust Co. No. 1 well (Columbian Carbon Co.), Banks Township, Indiana Co. (Fettke, 1956, p. 96.)

P262 Frank Horton No. 1 well (N.Y. State Natural Gas Corp.), Banks Township, Indiana Co. (Lytle and others, 1963, p. 39.)

P263 C. G. Lisowitz No. 1 well (C. E. Fralich and Assoc.), Pine Township, Indiana Co. (Fettke, 1956, p. 96.)

P264 J. H. Ralston No. 1D well (Delta Drilling Co., et al.), Cherry Hill Township, Indiana Co. (Lytle and others, 1962, p. 51.)

P265 C. D. Petticord No. 1 well (N.Y. State Natural Gas Corp.), Armstrong Township, Indiana Co. (Lytle, Bergsten, Cate, and others, 1961, p. 105.)

P266 H. B. Strong No. 1 well (Chestnut Ridge Oil and Gas Co.), Cherry Hill Township, Indiana Co. (Fettke, 1956, p. 96.)

P267 A. B. Crichton No. 1 well (Manufacturers Light and Heat Co.), Brush Valley Township, Indiana Co. (Lytle and others, 1964, p. 42.)

P268 I. R. Smith No. 1 well (Columbian Carbon Co.), Brush Valley Township, Indiana Co. (Lytle, Bergsten, Cate, and others, 1961, p. 108.)

P269 G. W. Griffith No. 1 well (Peoples Natural Gas Co.), Jackson Township, Cambria Co. (Lytle and others, 1968, p. 31.)

P270 G. L. Reade No. 1 well (Bethlehem Steel Co., Snee and Eberly), Jackson Township, Cambria Co. (Lytle and others, 1966, p. 54.)

P271 C. Miller No. 1 well (Peoples Natural Gas Co.), W. Taylor Township, Cambria Co. (Lytle and others, 1967, p. 35.)

P272 Clearfield Bituminous Coal Co. No. 1 well (Peoples Natural Gas Co.), Jackson Township, Cambria Co. (Lytle and others, 1964, p. 36.)

P273 J. and H. Leiden Heirs No. 1 well (Peoples Natural Gas Co.), Chest Township, Cambria Co. (Lytle and others, 1963, p. 32.)

P274 H. Berkheimer No. 1 well (Phillips Petroleum Co.), Greenfield Township, Blair Co. (Lytle and others, 1967, p. 35.)

P275 State of Pa. Tract 26-A No. 1 well (Phillips Petroleum Co.), Greenfield Township, Blair Co. (Lytle and others, 1962, p. 45.)

P276 State of Pa. Tract 26-B No. 1 well (Phillips Petroleum Co.), Union Township, Bedford Co. (Lytle and others, 1962, p. 45.)

P277 Herbert Akers No. 2 well (N.Y. State Natural Gas Corp.), Monroe Township, Bedford Co. (Lytle and others, 1962, p. 45.)

P278 Paul Snyder No. 1 well (N.Y. State Natural Gas Corp.), Monroe Township, Bedford Co. (Lytle and others, 1963, p. 32.)

P279 L. LaMaster No. 1 well (N.Y. State Natural Gas Corp.), Mann Township, Bedford Co. (Lytle and others, 1965, p. 39.)

P280 N. R. Mowry No. 1 well (Peoples Natural Gas Co., Shee and Eberly), Allegheny Township, Somerset Co. (Lytle and others, 1964, p. 44.)

P281 M. V. Newman No. 1 well (Peoples Natural Gas Co.), Greenville Township, Somerset Co. (Fettke, 1956, p. 109.)

P282 R. F. Grove No. 1 well (Peoples Natural Gas Co.), Shade Township, Somerset Co. (Fettke, 1950, p. 82.)

P283 D. J. Beachly No. 1 well (Shell Oil Co.), Somerset Township, Somerset Co. (Lytle and others, 1965, p. 51.)

P284 J. W. Swift No. 1 well (Shell Oil Co.), Brothers Valley Township, Somerset Co. (Lytle and others, 1966, p. 65.)

P285 T. E. Sipe No. 1 well (Peoples Natural Gas Co.), Milford Township, Somerset Co. (Lytle and others, 1968, p. 37.)

P286 E. and M. Rugg No. 1 well (Manufacturers Light and Heat Co.), Lower Turkey Foot Township, Somerset Co. (Lytle and others, 1962, p. 52.)

P287 State of Pa. Tract 98 No. 2 well (Phillips Petroleum Co.), Jefferson Township, Somerset Co. (Lytle and others, 1963, p. 41.)

P288 Lutheran Camp. Assoc. No. 1 well (Snee and Eberly, Peoples Natural Gas Co.), Jenner Township, Somerset Co. (Lytle and others, 1962, p. 52.)

P289 High Ridge Water Supply Co. No. 1 well (James Drilling Co.), St. Clair Township, Westmoreland Co. (Lytle and others, 1968, p. 37.)

P290 Indiana Savings and Trust Co. No. 1 well (Potter Development Co., W. E. Snee), Fairfield Township, Westmoreland Co. (Martens, 1939, pp. 80-81.)

P291 State of Pa. Tract 98 No. 1 well (Phillips Petroleum Co.), Cook Township, Westmoreland Co. (Lytle and others, 1962, p. 53.)

P292 James S. Blair No. 2 well (Peoples Natural Gas Co.), Donegal Township, Westmoreland Co. (Lytle, Bergsten, Cate, and others, 1961, p. 132.)

P293 M. I. Keck No. 2 well (Peoples Natural Gas Co.), Mt. Pleasant Township, Westmoreland Co. (Lytle, Bergsten, Cate, and others, 1961, p. 131.)

P294 J. R. Frola No. 1 well (Peoples Natural Gas Co.), Unity Township, Westmoreland Co. (Fettke, 1956, p. 114.)

P295 Booth and Flinn No. 1 well (Devonian Gas and Oil Co.), Derry Township, Westmoreland Co. (Lytle and others, 1964, p. 45.)

P296 Frank Litvik No. 1 well (Mid-East Oil and Gas Co.), Derry Township, Westmoreland Co. (Fettke, 1956, p. 114.)

P297 N. Lemmon No. 1 well (Peoples Natural Gas Co.), Unity Township, Westmoreland Co. (Lytle and others, 1965, p. 53.)

P298 L. G. Haines No. 1 well (Peoples Natural Gas Co.), Salem Township, Westmoreland Co. (Lytle and others, 1967, p. 49.)

P299 A. E. Bailey No. 1 well (Peoples Natural Gas Co., Snee and Eberly), S. Huntington Township, Westmoreland Co. (Lytle and others, 1962, p. 53.)

P300 Duquesne Gas Co. No. 1 well (Fox, Coen, and Sloan), Franklin Township, Westmoreland Co. (Lytle and others, 1966, p. 65.)

P301 F. M. Sloan No. 1 well (Fox and Sloan), Franklin Township, Westmoreland Co. (Lytle and others, 1964, p. 44.)

P302 G. J. Sloan No. 1 well (Peoples Natural Gas Co., Pittsburgh Plate Glass Co.), Washington Township, Westmoreland Co. (Lytle and others, 1966, p. 65.)

P303 Houston-Starr No. 1 well (Albert Starr), Monroeville Township, Allegheny Co. (Lytle and others, 1962, p. 45.)

P304 Fred Backhaus No. 1 well (South Penn Oil Co.), West Deer Township, Allegheny Co. (Fettke, 1950, p.20.)

P305 A. Allison No. 1 well (James Drilling Co.), Robinson Township, Washington Co. (Lytle and others, 1962, p. 53.)

P306 W. O. Anderson No. 1 well (S. W. Jack Drilling Co.), Hanover Township, Washington Co. (Lytle and others, 1968, p. 37.)

P307 J. E. McCullough No. 1 well (The Texas Co.), Cross Creek Township, Washington Co. (Fettke, 1950, p. 104.)

P308 A. T. McBurney No. 1 well (Norwood P. Johnston et al.), Mt. Pleasant Township, Washington Co. (Martens, 1939, pp. 54-64; Fettke, 1941, pp. 23-28; 1950, p. 104.)

P309 H. Sutherland and L. Kelly No. 1 well (Washington Oil Co.), Buffalo Township, Washington Co. (Fettke, 1956, p. 113.)

P310 S. Cooper No. 2 well (J. T. Galey), Amwell Township, Washington Co. (Lytle and others, 1962, p. 53.)

P311 A. Conner No. 1 well (J. T. Galey, Gulf Oil Co.), W. Bethlehem Township, Washington Co. (Lytle and others, 1962, p. 53.)

P312 F. K. Buttermore Heirs No. 1 well (Peoples Natural Gas Co.), Connellsville Township, Fayette Co. (Fettke, 1956, p. 95.)

P313 G. W. Detwiler No. 1 well (Peoples Natural Gas Co., Snee and Eberly), Springfield Township, Fayette Co. (Lytle and others, 1964, p. 41.)

P314 Adolph Dupree No. 1 well (Mid-Atlantic Oil and Gas Co.), Saltlick Township, Fayette Co. (Fettke, 1956, p. 95.)

P315 I. Morrison No. 1 well (Peoples Natural Gas Co., Snee and Eberly), Stewart Township, Fayette Co. (Lytle and others, 1962, p. 50.)

P316 Grimes No. 1 well (Sun Oil Co.), Wharton Township, Fayette Co. (Lytle and others, 1964, p. 41.)

P317 John R. Thompson No. 1 well (Greensboro Gas Co.), Wharton Township, Fayette Co. (Martens, 1939, pp. 71-74; Fettke, 1950, p. 40.)

P318 Leo F. Heyn ("Summit Hotel") No. 1 well (W. E. Snee, North Penn Gas Co.), South Union Township, Fayette Co. (Martens, 1939, pp. 64-69; Fettke, 1950, p. 40; Lytle and others, 1965, p. 50.)

P319 Leo F. Heyn ("Summit Hotel") No. 2 well (W. E. Snee, North Penn Gas Co.), South Union Township, Fayette Co. (Martens, 1939, pp. 70–71; Fettke, 1950, p. 40.)

P320 Paul Dunham No. 1 well (Houze Convex Glass Co.), Wharton Township, Fayette Co. (Martens, 1939, pp. 74–80; Fettke, 1950, p. 44.)

P321 G. W. Gordon No. 1 well (John Fox et al.), Franklin Township, Greene Co. (Lytle and others, 1962, p. 51.)

P322 S. G. Alley No. 3 well (Manufacturers Light and Heat Co.), Richhill Township, Greene Co. (Fettke, 1950, p. 46.)

Maryland

M1 TONOLOWAY RIDGE: Along dirt road 400 feet north of Western Maryland Railroad tracks in gap of Potomac River through Tonoloway Ridge, directly across from Great Cacapon (W.Va.), 0.8 mile southeast of Woodmont, Washington Co. (625 feet north of lat. 39° 37' 30"N, 125 feet west of long. 78° 17' 30"W, at an elevation of 490 feet, south-central portion of Bellegrove 7-1/2' Quadrangle.) Ridgeley Sandstone, Needmore Formation. Section described by Kindle (1912, p. 36).

M2 FLINTSTONE: On north side of U.S. Rte. 40, 0.5 mile east-southeast of Flintstone, Allegany Co. (3,750 feet south of lat. 39° 42' 30"N, 5,500 feet west of long. 78° 32' 30"W, at an elevation of 820 feet, central portion of Flintstone 7-1/2' Quadrangle.) The Needmore Formation is almost completely exposed along highway in gap through Warrior Ridge east of Flintstone. Beds strike N 15° E and dip 40° E into the Polish Mountain syncline. Section by Inners, assisted by M. Inners.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Marcellus Formation				
Shale, fissile, non-calcareous, black (N1), weathering into paper-thin chips with white bleached edges.				
Needmore Formation				
Calcitic Shale and Limestone Subfacies			67	7
18. Metabentonite, brown and rusty weathered, with kaolinized feldspar grains. (Tioga.)	1			
17. Mostly concealed. Ledge of dense, fine grained, dk. gray (N3), argillaceous limestone at base.	9	6		
16. Limestone, dense, fine grained, dk. gray, argillaceous.		4		
15. Concealed.	7	2		
14. Shale, med. dk. gray (N4), weathering lt. olive gray (5Y 6/1), with horizontal burrows.	5			
13. Limestone, nodular, fine grained, med. dk. gray, argillaceous, sparingly fossiliferous.		2		
12. Shale, similar to Unit 14.	3	6		
11. Limestone and shale, interbedded. Limestone, med. bedded (in three beds 3", 4", and 5" thick), fine grained, med. dk. gray, argillaceous, highly fossiliferous. Shale, med. dk. gray, calcareous, in beds 4" and 8" thick. Fossils: *Odontocephalus aegeria* (c).	2	2		
10. Limestone and shale, interbedded. Limestone, med. bedded (beds indistinct), lt. olive gray weathered, very argillaceous. Shale, med. dk. gray, calcareous, fossiliferous. Fossils: *Atrypa reticularis* (c), *Levenea lenticularis* (c).	11			
9. Shale, med. dk. gray, weathered lt. olive gray, calcareous, with a				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
few indistinct very argillaceous limestone beds. Fossils: *Ambocoelia umbonata* (c).	25			
8. Limestone and shale, interbedded. Limestone, med. bedded (in beds 4" thick), fine grained, med. dk. gray, very argillaceous, fossiliferous. Shale, med. dk. gray, calcareous, fossiliferous. Fossils: *A. umbonata* (c), *L. lenticularis* (c), *Styliolina fissurella* (unc), crinoid fragments.	2	9		
Calcitic Shale Subfacies			65	
7. Shale, med. dk. gray, sl. calcareous, fossiliferous, with a thin (1-1/2") bed of very argillaceous limestone at base. Fossils: *Praecardium* cf. *P. multiradiatum* (unc).	9			
6. Shale, fissile and thinly laminated, dk. gray to black, non-calcareous to sl. calcareous, fossiliferous, pyritic, with rusty, horizontal *lebenspuren*. Fossils: *Platyceras* (*Platystoma*) *cochleatum* (c), *Michelinoceras subulatum* (c).	15			
5. Shale, lt. olive gray weathered, calcareous, fossiliferous. Fossils: *Leptocoelina acutiplicata* (c).	6			
4. Shale, non-fissile, med. dk. gray, very calcareous, with a few thin beds of fine grained, very argillaceous limestone. Cut by thin calcite-pyrite veinlets both across and parallel to bedding. Fossils: *L. acutiplicata* (unc), *L. lenticularis* (unc).	5			
3. Shale, lt. olive gray weathered, calcareous, with closely spaced calcite-pyrite veinlets. Fossils: *Ambocoelia umbonata* (r).	17			

	Thickness Unit Ft.	In.	Total Ft.	In.
2. Shale, fissile, med. gray (N5), calcareous, fossiliferous. More highly calcareous beds are very soft and less fissile. Horizontally burrowed zones, 6" to 12" thick, at base, in middle, and at top. Fossils: L. acutiplicata (c), Orbiculoidea media (unc).	13			
Beaverdam Shale Subfacies			20	
1. Shale, fissile, dk. gray to black, non-calcareous to sl. calcareous, barren. Broken into many small platy fragments. Basal 12" weathered to sticky tan-brown clay. Disconformable contact with Ridgeley.	20			
Ridgeley Sandstone				
Sandstone, quartzose, massive, med. grained to conglomeratic, lt. gray (N7), fossiliferous. Upper 2'2" consists of fine grained, reddish-black, hemitite-cemented quartz sandstone, the middle part of which is soft and knobly weathering.				

M3 LAVALE: Along Cash Valley Road and in bed of unnamed tributary of Braddock Run, 0.25 mile west of LaVale, Allegany Co. (3,100 feet south of lat. 39° 40' 00"N, 5,200 feet east of long. 78° 50' 00"W, at an elevation of 800 feet, east-central portion of Frostburg 15' Quadrangle.) The Shriver Chert and Ridgeley Sandstone are well exposed in the abandoned quarry on the north side of Cash Valley Road. The Needmore Formation crops out further west along the road and in the stream bed. Attitude of bedding is about N 44° E/86° W. Section by Inners.

	Thickness Unit Ft.	In.	Thickness Total Ft.	In.
Needmore Formation				
Calcitic Shale and Limestone Subfacies and Calcitic Shale Subfacies, undivided			166?	
3. Limestone and shale, interbedded. Limestone, fine grained, med. dk. gray (N4), very argillaceous, pyritic, sparsely fossiliferous. Shale beds are not distinct. Rock deeply leached, weathers pale olive (10Y 6/2), with rusty stains. Strongly jointed, with many irregular fractures. Some weathered beds have rounded, exfoliated surfaces. (Exposed in stream bed.) Fossils: Very small brachiopods (unc).	16		141?	
2. Concealed interval.	125?			
Beaverdam Shale Subfacies			25	
1. Shale, fissile, dk. gray (N3) to black (N1), non-calcareous, weathering to small (1/4") chips. Only a few feet exposed, mostly float-crop. Contact with Ridgeley concealed. Fossils: Leptocoelina acutiplicata (r).	25			
Ridgeley Sandstone				
Sandstone, quartzose, massive, med. to coarse grained, highly fossiliferous. Mostly deeply decomposed to friable sand-rock. Fossils: Costispirifer arenosus (c), Rensselaeria elongata (unc), Platyceras (Platystoma) ventricosum (c).				

M4 CORRIGANVILLE: Along Western Maryland Railroad, about 1.0 mile south of Corriganville, Allegany Co. (5,000 feet north of lat. 39° 40' 00"N, 9,000 feet east of long. 39° 50' 00"W, at an elevation of 920 feet, northeast portion of Frostburg 15' Quadrangle.) The calcitic shale and Beaverdam shale subfacies of the Needmore Formation crop out intermittently in cuts along the railroad a few hundred feet east of Cash Valley Road. Section by Inners.

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
Needmore Formation				
Upper part concealed.				
Calcitic Shale Subfacies			39	9+
7. Shale, med. dk. gray (N4), weathered tan and pale olive (10Y 6/2), calcareous, broken into many small fragments.	5			
6. Limestone, with thin calcareous shale interbeds. Limestone, med. to thin bedded (in beds 1" to 2" thick), fine grained, med. dk. gray, highly argillaceous, fossiliferous. Fossils: <u>Phacops</u> sp. (unc), small brachiopods (unc).		6		
5. Shale, med. dk. gray, weathering tan and pale olive, calcareous, fossiliferous. Fossils: <u>Ambocoelia umbonata</u> (r).	8			
4. Limestone, with thin shale interbeds. Similar to Unit 6.	1	3		
3. Shale, similar to Unit 5.	3			
2. Mostly concealed (beneath railroad bed).	22			
Beaverdam Shale Subfacies			10+	
1. Shale, dk. gray (N3) to black (N1), rusty weathering, non-calcareous. Beds have been badly contorted by creep. (Exposed on bank east of tracks.)	10			
Ridgeley Sandstone				
Sandstone, quartzose, med. to coarse grained, highly fossiliferous. (Occurs as large float blocks on hillside above tracks.)				

M5 Katherine Shartzer (Humbertson) No. 1 well (New Penn Development Co. *et al.*), Accident Township, Garrett Co. (Martens, 1945, pp. 752-758.)

Virginia

V1 GAINESBORO: On southwest side of U.S. Rte. 522 near bridge across Back Creek, 0.5 mile northwest of Gainesboro, Frederick Co. (13,000 feet north of lat. 39° 15' 00"N, 4,000 feet west of long. 78° 15' 00"W, at an elevation of about 600 feet, southeast portion of Capon Bridge 15' Quadrangle.) The Ridgeley Sandstone and Needmore Formation are exposed in an inactive roadside borrow pit. The contact between the two formations can be observed here and also in an abandoned sand pit on the opposite (north) side of Back Creek. Attitude of bedding (Needmore) is N 10° E/40° E. Previously discussed by Woodward (1943, p. 290). Section by Inners, assisted by M. Inners.

	Thickness Unit Ft.	Thickness Unit In.	Thickness Total Ft.	Thickness Total In.
Marcellus Formation				
Shale, dk. gray (N3) to black (N1), rusty weathering, non-calcareous. Contact with Needmore not exposed.				
Needmore Formation			13	6+
Calcitic Shale and Limestone Subfacies				
Upper part concealed.				
17. Shale, med. dk. gray (N4), weathering tan, calcareous, with a few thin, discontinuous beds of fine grained, med. dk. gray, argillaceous limestone.	3			
16. Limestone, fine grained, med. dk. gray, argillaceous, sparingly fossiliferous. Fossils: Odontocephalus sp. (r).		3		
15. Shale, lt. olive gray (5Y 6/1) weathered, calcareous.	1			
14. Limestone, med. dk. gray, argillaceous, poorly exposed.		2		
13. Shale, similar to Unit 15.	1			
12. Shale, fissile, dk. gray, rusty weathering, non-calcareous.				

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
11. Limestone, fine grained, med. dk. gray, very argillaceous.		6		
10. Limestone, fine grained, med. gray (N5), crystalline, highly fossiliferous. Fossils: *Trachypora* (?) sp. (va).		4		
9. Shale and limestone, interbedded. Hard, limy layers alternate with soft, fissile, laminated, dk. gray, calcareous shale.	4	3		
Calcitic Shale Subfacies			103	10
8. Shale, soft, very thinly laminated, dk. gray, with harder, med. gray (N5) weathering, non-fissile, calcareous mudrock at base. Mudrock weathers to form recess toward upper part of exposure. Fossils: *Styliolina fissurella* (a, in dark, laminated shale).	1	4		
7. Shale, non-fissile, well bedded, dk. gray, calcareous, highly fossiliferous. Fossils: *Trachypora* (?) sp. (va), *Leptaena rhomboidalis* (r), *Levenea lenticularis* (unc), *Atrypa reticularis* (unc), large crinoid columns (va).	12			
6. Shale, non-fissile, med. dk. gray, calcareous, sparingly fossiliferous.	30			
5. Shale, dk. gray, sl. calcareous, fossiliferous, burrowed. Fossils: *Ambocoelia umbonata* (c), *Platyceras (Platystoma) cochleatum* (unc), *Palaeozygopleura hamiltoniae* (unc), *Odontocephalus* sp. (r), small rugose corals (unc), etc.	30			
4. Shale, dk. gray, splintery, sl. calcareous, fossiliferous. Fossils: *Levenea* sp. (unc), *Praecardium* sp. (r), *Phacops pipa* (unc), *Odontocephalus aegeria* (unc), etc.	30			

	Thickness Unit Ft.	Unit In.	Total Ft.	Total In.
3. Shale, med. lt. gray (N6) weathered, highly calcareous, intensely burrowed (horizontal).		6		
Beaverdam Shale Subfacies			13	
2. Shale, dk. gray (N3), med. olive gray (5Y 5/1) weathering, slpintery, calcareous at top. Phosphatic concretions and oolites common toward base.	12			
1. Siltstone, crowded with black, phosphatic oolites, rusty weathering, blocky fracture. Disconformable contact with Ridgeley.	1			
Ridgeley Sandstone			50+	
Sandstone, quartzose, coarse grained to pebbly, med. gray (N5), weathering med. lt. gray (N6), highly calcareous (with calcite cement and many calcite veins), highly fossiliferous (brachiopods). At top is a rusty weathered, pebbly conglomerate layer, 9" thick.				

West Virginia

W1 BERKELEY SPRINGS: In active quarry of Pennsylvania Glass Sand Co., east side of Warm Spring Ridge, along U.S. Rte. 522, 2.0 miles north-northeast of Berkeley Springs, Morgan Co. (3,750 feet south of lat. 39° 40' 00"N, 10,750 feet east of long. 78° 15' 00"W, at an elevation of about 700 feet, west-central portion of Hancock, Md., 15' Quadrangle.) Ridgeley Sandstone, Needmore Formation. Section described by Swartz and Swain (1941, p. 407).

W2 W. Va. Power and Transmission Co. (Kaemmerling Trustee) No. 1 well (Ohio Oil Co.), Dry Fork District, Tucker Co. (Martens, 1945, pp. 557-567.)

W3 H. C. Greer et al. No. 8526 well (Hope Natural Gas Co.), Morgan District, Monongalia Co. (Martens, 1945, pp. 448-455.)

W4 C. S. Gribble No. 8517 well (Hope Natural Gas Co.), Grant District, Harrison Co. (Martens, 1945, pp. 264-278.)

W5 Alfred Woofter No. 8555 well (Hope Natural Gas Co.), Freemans Creek District, Lewis Co. (Martens, 1945, pp. 380-385.)

W6 Lewis Maxwell No. 11-F (GW-43) well (Columbian Carbon Co.), West Union District, Doddridge Co. (Martens, 1939, pp. 103-109.)

W7 Hope Natural Gas Co. No. 9634 well, the Sandhill Deep Well (Hope Natural Gas Co.), Walker District, Wood Co. (Woodward, 1959, pp. 16-27; Shearrow, 1959, pp. 34-52.)

W8 Ella Hammat et al. No. 1 (GW-416) well (Columbian Carbon Co.), Grant District, Pleasants Co. (Martens, 1945, pp. 462-463.)

W9 W. W. Campbell No. 1 well (J. C. Benedum), Union District, Pleasants Co. (Martens, 1945, pp. 466-469.)

W10 Lenora Ramsey No. 1 well (John T. Galey), Clay District, Hancock Co. (Martens, 1945, pp. 249-250.)

W11 Rachel E. Talbott No. 1 well (John T. Galey), Grant District, Hancock Co. (Martens, 1939, pp. 42-46.)

Ohio

O1 G. W. Crile No. 1 well (East Ohio Gas Co.), Chardon Township, Geauga Co. (Fettke, 1961, pp. 623-633.)

O2 F. H. Oates No. 1 well (Ohio Oil Co.), Prarie Township, Holmes Co. (Martens, 1945, pp. 792-795.)

O3 W. Strudhoff No. 1 well (Natural Gas Co. of W. Va.), Madison Township, Columbiana Co. (Martens, 1939, pp. 46-47.)

O4 George D. Miller No. 1 well (Columbian Carbon Co.), German Township, Harrison Co. (Martens, 1945, pp. 789-792.)

O5 A. E. Mobley No. 1 (784) well (Natural Gas Co. of W. Va.), Smith Township, Belmont Co. (Martens, 1945, pp. 770-780.)

O6 Louise Kerr No. 1 well (South Penn Oil Co.), Center Township, Monroe Co. (Martens, 1945, pp. 803-807.)

O7 Rosanna Hill No. 1 well (Sinclair-Prarie Oil Co.), Lawrence Township, Washington Co. (Martens, 1945, pp. 825-826.)

Kentucky

K1 FALLS OF THE OHIO: At the Falls of the Ohio, near north shore of Ohio River, about 0.75 mile downstream (west) of George Rogers Clark Memorial Bridge, Louisville, Jefferson Co. (7,000 feet south of lat. 38° 17' 30"N, 5,000 feet west of long. 85° 45' 00"W, at an elevation of 400 feet, southeast portion of New Albany, Ind., 7-1/2' Quadrangle.) Jeffersonville Limestone, etc.

PLATE I: BASE MAP OF ONESQUETHAWAN OUTCROP AND SUBSURFACE LOCALITIES, PENNSYLVANIA AND ADJACENT STATES.

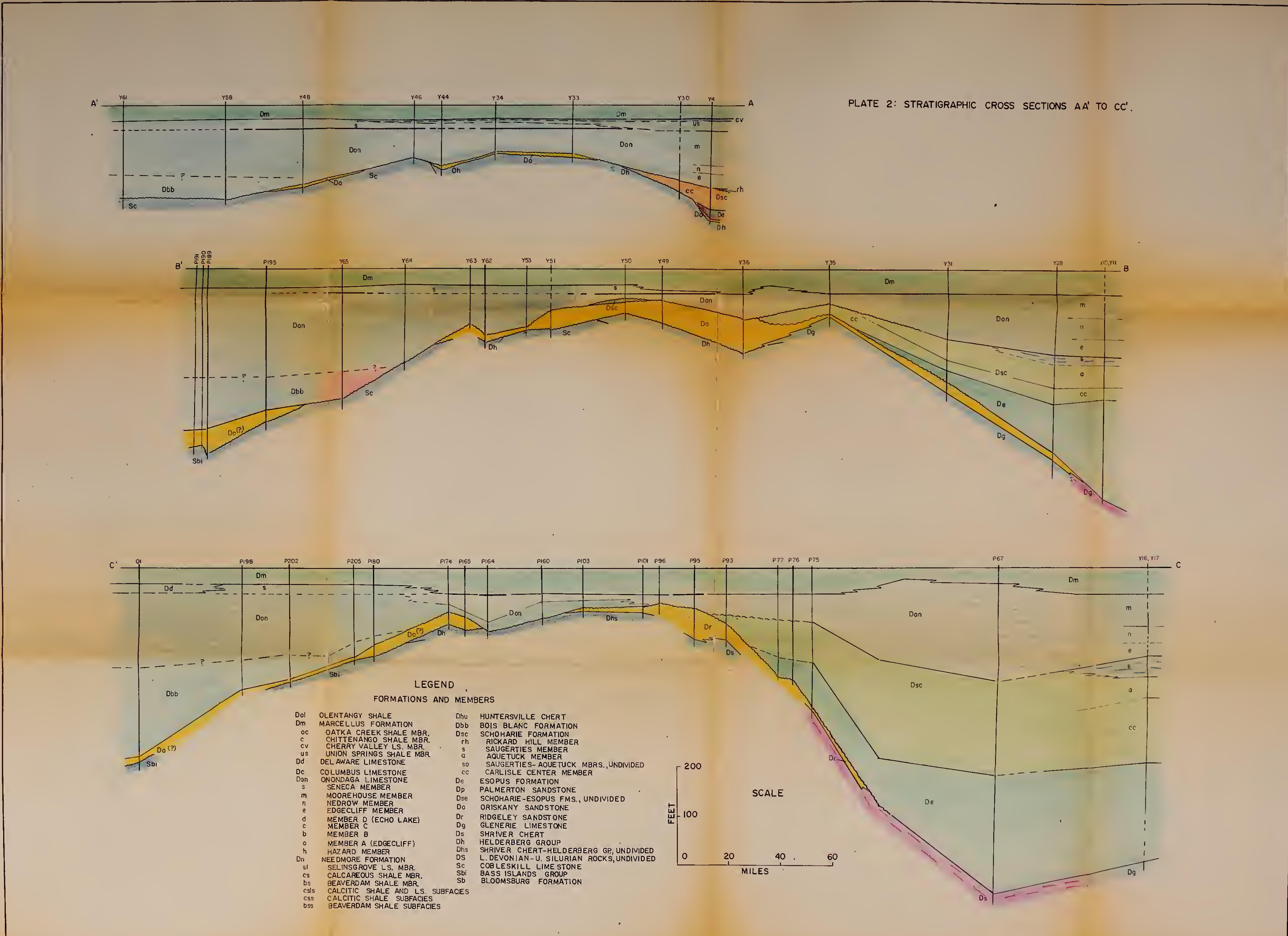


PLATE 2: STRATIGRAPHIC CROSS SECTIONS AA' TO CC'.

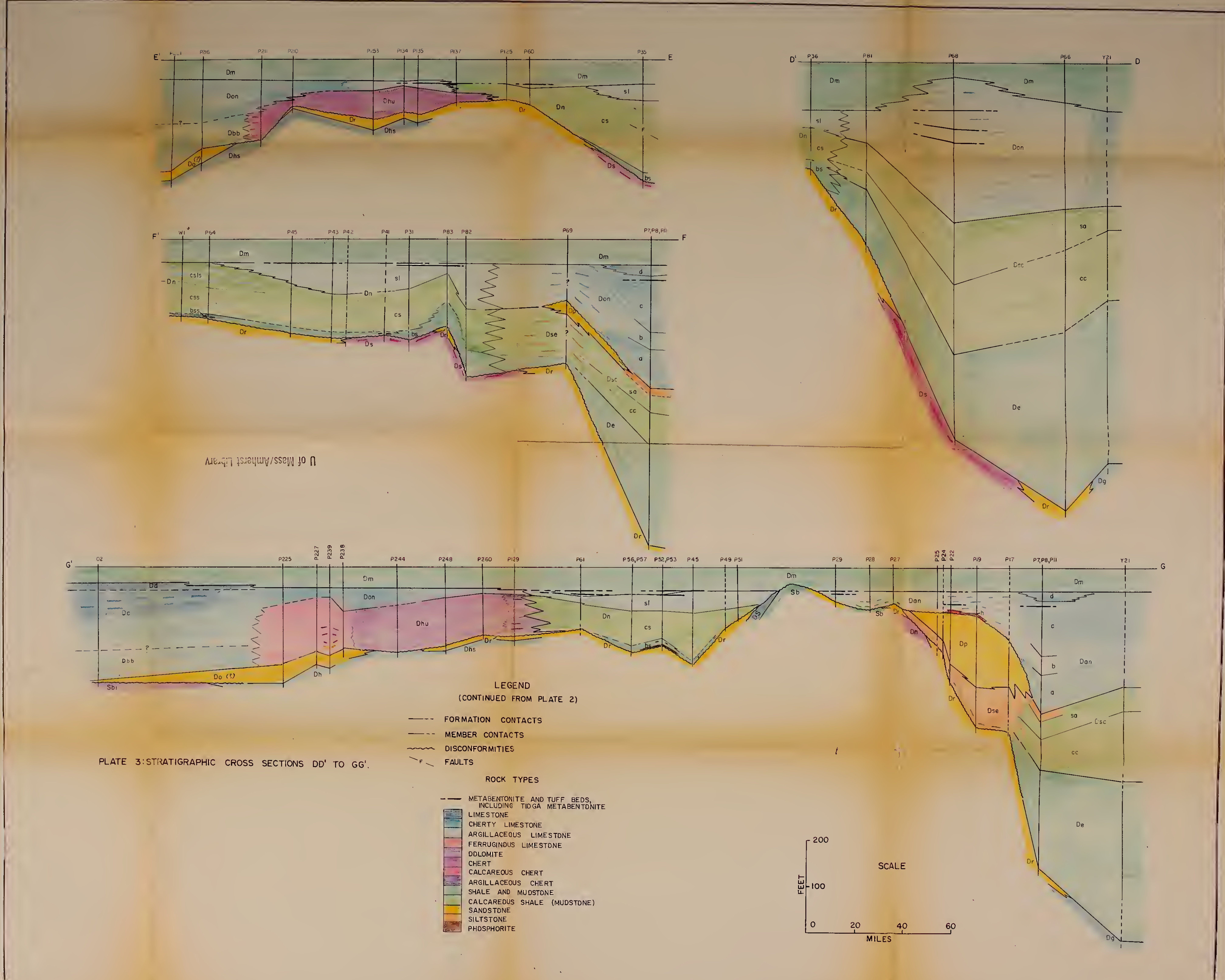


PLATE 3: STRATIGRAPHIC CROSS SECTIONS DD' TO GG'.

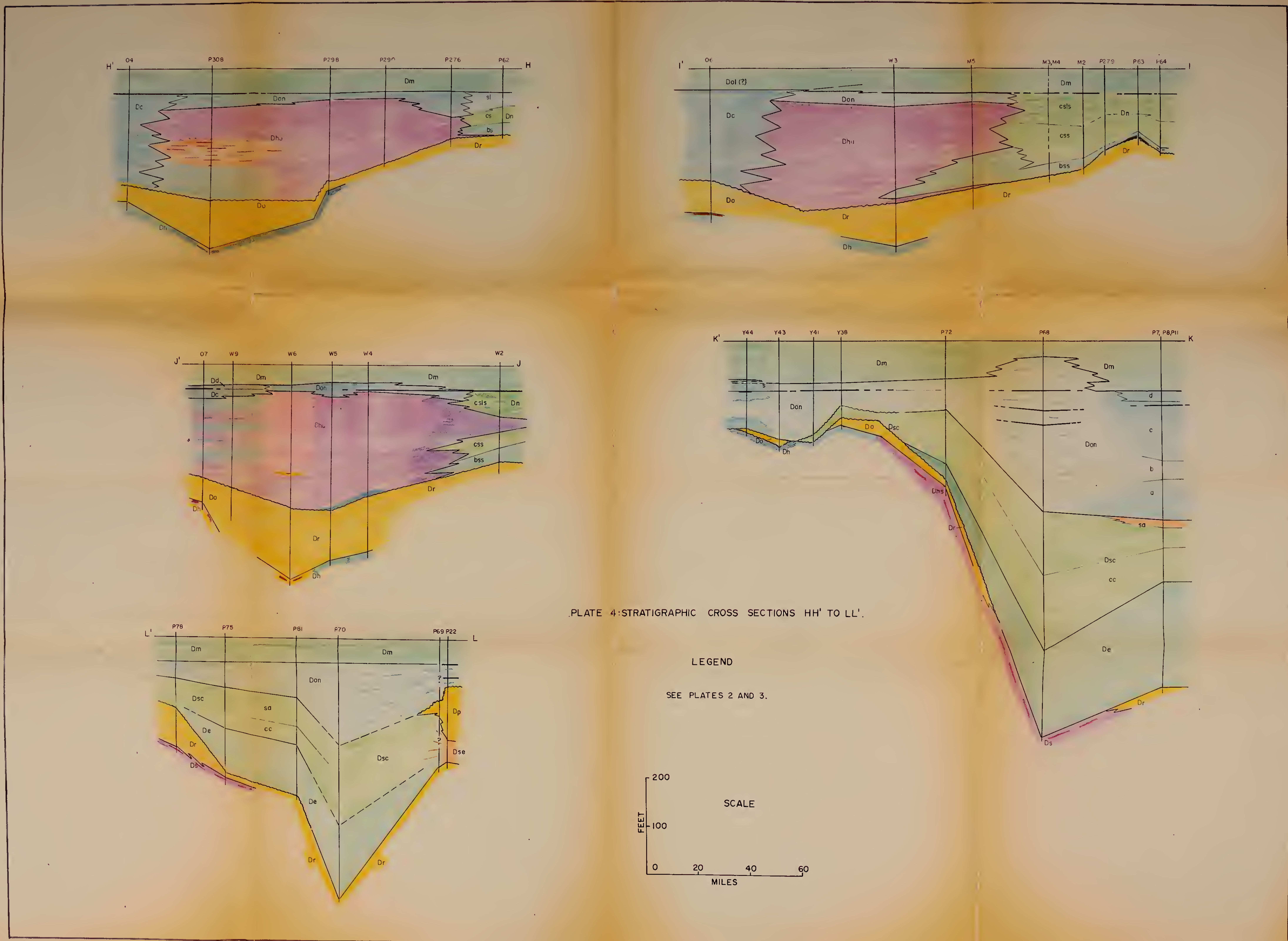


PLATE 4: STRATIGRAPHIC CROSS SECTIONS HH' TO LL'.

LEGEND

SEE PLATES 2 AND 3.

PLATE 5: STRATIGRAPHIC CROSS SECTIONS MM' TO RR'.

LEGEND

SEE PLATES 2 AND 3.