Mississippian Stratigraphy of Northwestern Pennsylvania

GEOLOGICAL SURVEY BULLETIN 1331-A

Prepared in cooperation with the Pennsylvania Topographic and Geologic Survey

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By GEORGE R. SCHINER and GRANT E. KIMMEL

CONTRIBUTIONS TO GENERAL GEOLOGY

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1972

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog-card No. 72-600086

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1.25 (paper cover)
Stock Number 2401-2169

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CONTRIBUTIONS TO GENERAL GEOLOGY

MISSISSIPPIAN STRATIGRAPHY OF NORTHWESTERN PENNSYLVANIA

By George R. Schiner and Grant E. Kimmel

ABSTRACT

The Mississippian sedimentary strata in northwestern Pennsylvania consist chiefly of alternating units of shale, siltstone, and sandstone having a total maximum thickness of about 460 feet. These rocks conformably overlie shales and siltstones of Devonian age and are unconformably overlain either by shales, sandstones, and conglomerates of Pennsylvanian age or by unconsolidated deposits of Pleistocene and Holocene age. In generally ascending order the section consists of the Cussewago Sandstone, Bedford Shale, an unnamed sandstone, Berea and Corry Sandstones (time equivalents), Shellhammer Hollow Formation (stratigraphic equivalent of the Berea and Corry), the Cuyahoga Group [Orangeville Shale (includes the Bartholomew Siltstone Member), Sharpsville Sandstone, and Meadville Shale], and the Shenango Formation (includes upper and lower members).

Complex facies changes, intertonguing, and the presence of time equivalents involving several deltas occur in the Mississippian section of northwestern Pennsylvania. The use of more than 50 geophysical logs substantially refined the definition of the subsurface Mississippian stratigraphy, particularly the limits of the Berea and Cussewago deltas and the Corry Sandstone in Mercer County.

A thickness map indicates that the maximum thickness of the Cussewago Sandstone ranges from about 80 to 100 feet in western Mercer and southwestern Crawford Counties—about 40–50 feet thicker than shown by previous workers in that area. The map shows that the thickest part of the Cussewago has a northern alinement in western Mercer and southwestern Crawford Counties.

Interpretations of gamma-ray logs have resulted in a closing of the distances between the eastern limits of the Berea Sandstone and western limits of the Corry Sandstone in Mercer County. The Corry as mapped by the authors lies above the Cussewago in places and extends westward from western Venango County into the east-central part of Mercer County. Previous workers have indicated that the Corry does not overlie the Cussewago, and they have mapped the Corry only as far west as the Mercer-Venango County line. The maximum thickness of the Corry is 31 feet in Mercer County. The Berea does not extend as far east in Mercer County as is indicated by previous workers. Thus, strata previously mapped as Berea in eastern Mercer County is probably the Corry Sandstone.

The Cuyahoga Group, where complete in Mercer County, ranges in thickness from about 200 feet in the eastern part of the county to about 240 feet

in the western part. The Cuyahoga thins as the Corry thickens. In much of Crawford County the full thickness of the Cuyahoga section is not present because the top has been removed by erosion. The three formations that comprise the Cuyahoga Group are difficult to separate, in both outcrop and gamma-ray logs. Gamma-ray logs, however, are the most reliable data available to determine the formation contacts. The Orangeville Shale thins eastward from the Pennsylvania-Ohio State line in Mercer and Crawford Counties as a result of intertonguing of the Orangeville and Sharpsville Sandstone at progressively lower stratigraphic positions. Thus, eastward, the top of the Orangeville occurs progressively lower in the Cuyahoga section. The Orangeville thins from about 60 feet in the western part of the Shenango 15-minute quadrangle to about 20 feet in the eastern part of the Stoneboro 15-minute quadrangle.

The Sharpsville Sandstone is about 80 feet thick at its type locality near Sharpsville, in the southwestern part of the Shenango quadrangle, which makes its thickness about 30 feet greater than that reported by White (1880). The formation is about 80 feet thick near the west edge of Mercer County and about 110 feet thick near the east edge. The Meadville Shale thins eastward from the Pennsylvania-Ohio State line in Mercer and southern Crawford Counties. The formation is about 90 feet thick in western Mercer and southwestern Crawford Counties and is 60–75 feet thick in eastern Mercer County and in the Meadville 15-minute quadrangle in Crawford County.

The Shenango Formation ranges in thickness from about 150 to 180 feet in the Shenango and Stoneboro quadrangles. Erosion has removed much of the upper part of the formation in western and northern Mercer County and in southern Crawford County. The base of the Shenango Formation is about 230 feet above the Berea in western Mercer County and about 200–230 feet above the Corry in eastern Mercer County.

The Berea Sandstone, Corry Sandstone, Bartholomew Siltstone Member of the Orangeville Shale, and Shenango Formation are generally good key stratigraphic markers, wherever they are present in northwestern Pennsylvania.

INTRODUCTION

Although the regional stratigraphy of the lower part of the Mississippian rock section in northwestern Pennsylvania has been described (Pepper and others, 1954), the scarcity of outcrops, lack of sufficient reliable subsurface data, and small amount of field mapping in the region have hampered a detailed description of the units that comprise the total Mississippian section. Complex facies changes, intertonguing, and the presence of time equivalents in a region where several deltas were deposited have added to the difficulties involved in the detailing of the Mississippian stratigraphy and have caused some confusion in stratigraphic interpretations—particularly in areas where these rocks do not crop out.

This report is the result of recent mapping in Mercer and southern Crawford Counties by the U.S. Geological Survey in cooperation with the Pennsylvania Geological Survey. The principal area of study is the Shenango and Stoneboro 15-minute quadrangles (pl. 1), but significant information was obtained in nearby 15-minute quadrangles. The purpose of the report is to describe and define the Mississippian strata, show primarily their subsurface extent and variations, and clarify ambiguities in stratigraphic correlations. The study partly supplements the report on the Lower Mississippian rock section by Pepper, Wallace, and Demarest (1954), which covers the Appalachian basin and includes western Pennsylvania.

GENERAL GEOLOGIC SETTING

Northwestern Pennsylvania is within the glaciated part of the Allegheny Plateau physiographic province. The topograhy consists of rolling hills, on which bedrock is poorly exposed, and broad, drift-filled valleys. A veneer of unconsolidated Pleistocene and Holocene deposits conceals much of the bedrock, especially at lower altitudes. Therefore, most contacts between rock units are not easily observed.

The area is underlain by rocks of Devonian, Mississippian, and Pennsylvanian age that crop out in northeastward-trending belts. The rocks of Mississippian age have a maximum thickness of about 460 feet and consist of alternating beds of sandstone, siltstone, and shale. These rocks conformably overlie shales and siltstones of Devonian age and are unconformably overlain by either shales, sandstones, and conglomerates of Pennsylvania age or unconsolidated deposits of Pleistocene and Holocene age. Three delta deposits having different source areas occupy the lower part of the Mississippian section.

The rocks of Mississippian age crop out in several counties in northwestern Pennsylvania. (See fig. 1.) They lie on the north flank of the northeastward-trending Appalachian basin and have a regional southerly dip of about 17 feet per mile. Thus, progressively older rocks of Mississippian age crop out northward in the area shown in figure 1. Minor reversals of the regional dip are common locally.

METHODS OF INVESTIGATION

The use of more than 50 geophysical logs in this study has permitted a greater degree of reliability in the subsurface correlation of stratigraphic units than has heretofore been possible by

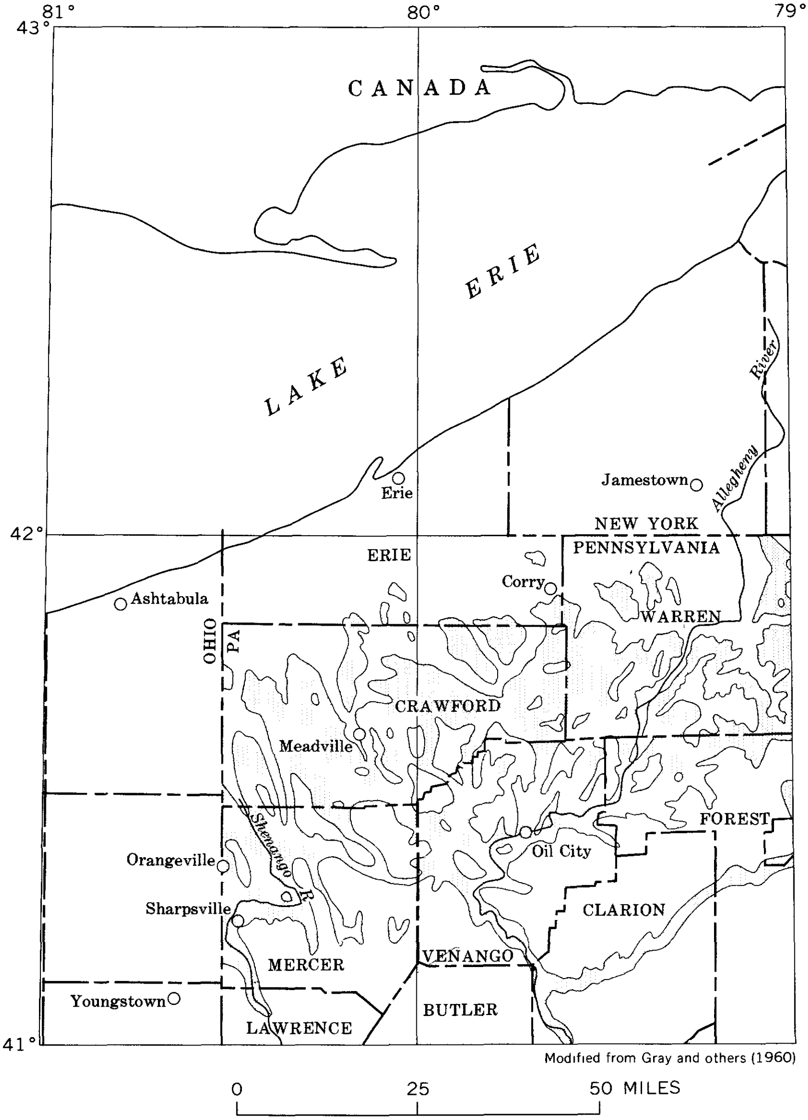

FIGURE 1.—Areas of outcrop of the Mississippian rocks in northwestern Pennsylvania.

previous workers' use of driller's logs and sample logs. Formations only a few feet thick were traced by gamma-ray logs into areas previously mapped as undiffereniated "shale and shells."

The fence diagram (pl. 4) showing the subsurface distribution of most Mississippian sandstones in the Shenango and Stoneboro quadrangles was compiled from gamma-ray logs. Correlations were possible because the sandstone units (collectively or individually) had characteristic gamma-ray traces. Correlations were somewhat generalized in places, because some beds were too thin to plot.

Most of the geophysical logs herein used were gamma-ray logs obtained by lowering the probe down the borehole at rates ranging from 6 to 16 feet per minute. In a few instances, logs compiled from a study of samples collected from wells drilled by the cable-tool method were compared with gamma-ray logs of the same well. The gamma-ray logs were generally much more definitive than the sample logs in showing lithologic changes. Several electric logs were used for interpretive studies.

Lithologic descriptions of the rock units were made from borehole samples and outcrop studies. Exposures of the upper part of the Mississippian rock section were studied chiefly in Mercer County, and exposures of the lower part of the Mississippian section were studied mostly in Crawford County. Outcrops are rare and generally reveal only a small part of the total Mississippian section, because relief is moderate and the area is covered with drift. Few outcrops expose more than 200 feet of vertical section, and all outcrops have covered intervals. Exposed sections were measured with an altimeter, hand level, and tape.

Rock colors were based on the Geological Society of America Rock-Color Chart for dry samples (Goddard and others, 1948), where possible. The unweathered Mississippian rocks are generally a shade of gray, but the color value of gray is dependent on the relative amounts of clay, silt, sand, and micaceous material contained in the rock. Shale containing little silt is dark gray, and shale containing much silt is medium dark gray or medium gray. Siltstone and very fine grained silty sandstone are medium light gray to light gray. Sandstone is light gray to very light gray depending upon the amount of silt and micaceous material in the rock. The silt and micaceous material tend to darken the very light gray coloration. Weathered shale, siltstone, and sandstone generally are olive to greenish gray in color. The color of siltstone and sandstone may be a shade of brown or yellowish orange when highly weathered. Sandstone may be colored light gray to white if the iron in the rock is leached out. Highly weathered shale may be brown or reddish colored. To avoid repetition in describing the

Mississippian rock section, the rock colors were omitted, except when a color was different from the general description as given above.

In outcrops, the sandstone and siltstone units of Mississippian age appear to be stratified. The rocks, however, commonly split into flags within the stratified units on weathering. Cross-stratification is rarely seen. For consistency in description, the terminology of McKee and Weir (1953) has been followed. The splitting property is described as shaly if in siltstone or shale, and platy if in sandstone.

NOMENCLATURE

The stratigraphic nomenclature for the Mississippian section was introduced by White (1880, 1881) for rocks in northwestern Pennsylvania and by Newberry (1870) for rocks in northeastern Ohio. Many stratigraphic correlations and nomenclatural changes and additions have been made subsequently by geologists in Ohio and Pennsylvania. Some of these correlations and the nomenclature are discussed below and shown in figure 2. A thorough review of the correlation and nomenclature used to describe the lower part of the Mississippian rock section is given by Pepper, de Witt, and Demarest (1954).

The name Cussewago was applied by White (1881, p. 94–96) to a sequence of rocks along Cussewago Creek valley (pl. 1), Crawford County, Pa., consisting of a sandstone overlain by a shale capped by a thin limestone. The section was divided by White into the Cussewago Sandstone, the Cussewago Shale, and the Cussewago Limestone. De Witt, (1946) found that the Cussewago Limestone was not a valid mappable unit and that White's Cussewago Shale was correlative with Newberry's (1870, p. 21) Bedford Shale in Ohio. The name "Cussewago" is now restricted to the sandstone unit. De Witt (1946) redefined the Cussewago Sandstone as the unit found below the Bedford Shale at White's (1881, p. 204) Bartholomew section (pl. 1). As defined by de Witt (1951), the Cussewago Sandstone is underlain by the Riceville Shale and overlain by the Bedford Shale or Shellhammer Hollow Formation. Demarest (1946) showed the Cussewago to be correlative with the Murrysville sand in the subsurface of southern and central Pennsylvania.

The Bedford Shale was named by Newberry (1870, p. 21) for a shale and siltstone section along Tinkers Creek near Bedford,

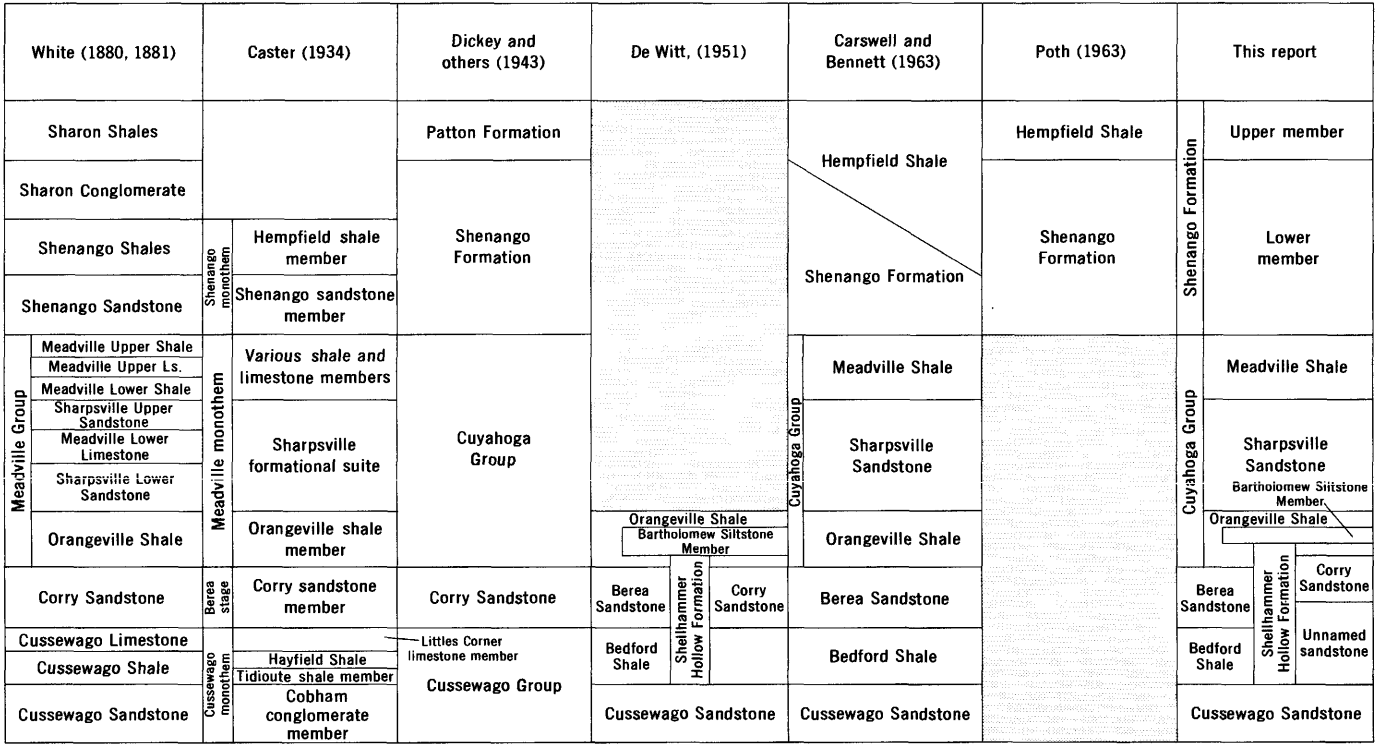

FIGURE 2.—Stratigraphic names applied to the Mississippian rocks in northwestern Pennsylvania.

Ohio. It was traced by outcrops from its type locality into Crawford County, Pa., by de Witt (1946).

The Corry Sandstone was named by White (1881, p. 92–94) for a sandstone or siltstone quarried at the Colegrove quarries (now abandoned and largely filled) south of Corry in Erie County, Pa. De Witt (1946) traced the Corry by outcrop from its type locality to the vicinity of Riceville, Crawford County, Pa. Sass (1960) made a thorough study of the fauna of the Corry Sandstone, divided the formation into three members, and suggested that the lower member is correlative with the upper part of the Bedford Shale of Ohio.

The Berea Sandstone was named for exposures of sandstone at Berea, Ohio, by Newberry (1870, p. 21–29). De Witt (1946) traced the Berea by outcrop from its type locality into Crawford County, Pa., and he showed that, although the Corry and Berea are time equivalents, they have different source areas; thus, the Corry is not an eastern facies of the Berea as suggested by some geologists (White, 1881, p. 93; Prosser, 1912, p. 396; Caster, 1934, p. 122, 163–165). De Witt (1951, p. 1362) found the Corry and Berea Sandstones and the Bedford Shale to be inseparable in the vicinity of Meadville, Crawford County, Pa., and named the undivided rocks in this area the Shellhammer Hollow Formation. The type locality for the Shellhammer Hollow Formation is the Shellhammer Hollow section (pl. 1). Regional relationships of the Cussewago, Bedford, Berea, and Corry are described in detail by de Witt (1951) and Pepper, de Witt, and Demarest (1954).

The Orangeville Shale was named by White (1880, p. 63) for an exposure of silty shale, mudstone, and some siltstone along Pymatuning Creek, at Orangeville, Pa. De Witt (1951, p. 1364) recognized the presence of a persistent and widespread siltstone bed near, or at the base of, the Orangeville Shale and named this unit the Bartholomew Siltstone Member of the Orangeville Shale. The type locality of the siltstone is the Bartholomew section of White (1881, p. 204). White named the Sharpsville Sandstone (1880, p. 62) for a sequence of alternating layers of sandstone and shale exposed along the Shenango River at Sharpsville, Pa. The Meadville Shale was first termed the Crawford Shales by White (1880, p. 61) who applied the name to the shale section lying between his Shenango Sandstone and Sharpsville Sandstone in Mercer and Crawford Counties. In his report on Crawford and Erie Counties (1881), White renamed his Orangeville Shale the Sharpsville

Sandstone and the Crawford Shales the Meadville Group; he subdivided the Meadville into the Orangeville Shale, Sharpsville Lower Sandstone, Meadville Lower Limestone, Sharpsville Upper Sandstone, Meadville Lower Shale, Meadville Upper Limestone, and Meadville Upper Shale (1881, p. 83–90). The Meadville Group of White is equivalent to the presently (1969) accepted Cuyahoga Group of Pennsylvania and Ohio (Cushing and others, 1931, p. 48–54; Poth, 1963, p. 12; Carswell and Bennett, 1963, p. 18), which consists of the Orangeville Shale, Sharpsville Sandstone, and Meadville Shale. Cushing, Leverett, and Van Horn (1931, p. 48–54) first applied the name Cuyahoga Group to the rock section previously known as the Cuyahoga Shale (Newberry, 1870, p. 21) and designated the three subdivisions as formations rather than members.

The Shenango Sandstone was named by White (1880, p. 60–61) for exposures of a massive sandstone, along the Shenango River valley, that overlie the Meadville Upper Shale of his 1881 report. From White's discussion of the rocks in both Mercer (1880) and Crawford (1881) Counties, it is clear that he believed that the formation was a single sandstone unit 3–35 feet thick. Later reports (Sherrill and Matteson, 1941; Dickey and others, 1943; Poth, 1963; Carswell and Bennett, 1963) used the name Shenango Formation to include White's Shenango Sandstone in a more complex and much thicker formational unit.

Kimmel and Schiner (1970) established a type section for the Shenango Formation at White's Moyer section (1880, p. 163) along the Shenango River valley (pl. 1). They divided the Shenango Formation into an upper predominantly shale member and a lower predominantly sandstone member. The Hempfield Shale (Caster, 1934, p. 147) previously used as the name for the upper member by Poth (1963), Carswell and Bennett (1963), and others was abandoned by Kimmel and Schiner (1970).

STRATIGRAPHY

CUSSEWAGO SANDSTONE

Where the Cussewago Sandstone is thicker than about 50 feet, sample logs and examinations of outcrops indicate it may be divided into two parts. The upper part is a micaceous well-indurated fine-grained to very fine grained mostly thin-bedded sandstone containing interbeds of siltstone and shale. The thin-bedded part of the Cussewago is generally covered with ripple marks. The lower part of the Cussewago is a poorly indurated mostly massive bedded fine- to coarse-grained orthoquartzite (in accordance with the terminology of Pettijohn, 1957, p. 291), which may contain quartz or chert pebbles or very coarse sand near the base. Generally, the larger sand grains are rounded to well rounded. In many places the pebbles are discoidal in shape. In places, the massive sandstone exhibits steep-angle crossbedding. In contrast to the younger Mississippian and Pennsylvanian sandstones, which are generally well indurated, the lower unit is porous. In outcrop the Cussewago is characteristically dark greenish yellow, which contrasts sharply with the light- to dark-gray overlying and underlying rocks.

Potable water of good quality may be present in the lower part of the Cussewago Sandstone, whereas gas, oil, or saline water may be present in the upper part of the sandstone in the same well in some areas of the Shenango quadrangle.

The distribution and thickness of the Cussewago was first detailed by Demarest (1946). He mapped the formation as a large lobate delta, spread over western Pennsylvania and northeastern Ohio, whose source area was to the southeast. The shape, extent, and thickness of the Cussewago determined by a combination of surface and subsurface data somewhat modifies Demarest's work and is shown on plate 2. Gamma-ray logs show that the Cussewago is more than 80 feet thick in areas where a 40-foot thickness is shown by Demarest. For comparison, Demarest's illustration of the form of the Cussewago delta is show on plate 2. The thickness data used to delineate the northern part of the delta were obtained from de Witt (written commun., 1966). The thickness lines shown on plate 2 indicate a due north axis for the delta in Mercer and Crawford Counties, slightly east of the center of the Shenango quadrangle. The maximum thickness of the delta is about 100 feet. A notable feature is the fact that the delta thins rapidly eastward. The east side appears to be correlative with the top part on the west side; therefore, the eastward thinning may occur mostly in the basal part of the formation. (See correlations on plate 4.)

In most places the contact between the Cussewago and the overlying Bedford Shale is gradational, but in other places the contact may be sharp. Where the Shellhammer Hollow Formation caps the Cussewago, the contact is sharp. In general the contact between the Cussewago and the underlying Riceville Shale is sharp.

The upper and lower Cussewago contacts observed at outcrops are clearly marked in the subsurface by the gamma-ray logs (pl. 3).

The lower part of the Cussewago is a conspicuous feature on gamma-ray logs and can be traced easily, but the upper part is much less distinctive. Several examples of gamma-ray correlations are shown on plate 3. The gamma-ray logs of wells 300, 3100, and 2654 illustrate the dual character of the Cussewago in the area of maximum thickness. Correlations of the Cussewago were made from the thickest parts of the formation, where the sand body is well defined, into areas where the sand is more poorly defined. These correlations are supported in places by sample-study logs and examinations of outcrops.

The approximate limits of the Cussewago are shown on plate 1. The limits in Mercer and Crawford Counties slightly modify Demarest's limits (1946). The extent and stratigraphic relations of the Cussewago in the subsurface in the Shenango and Stoneboro quadrangles are shown graphically in the fence diagram on plate 4.

BEDFORD SHALE

The Bedford Shale consists of thin beds of dark-gray silty shale, ripple-marked siltstone, and very fine grained standstone. The siltstone beds commonly contain ichnofossils on their upper surface.

From the Pennsylvania-Ohio State line the Bedford thins eastward in Mercer and Crawford Counties and grades laterally into the Shellhamer Hollow Formation. Its maximum thickness is about 30 feet in the Neshannock quadrangle, about 20 feet in the Shenango quadrangle, and about 40 feet in the Linesville quadrangle.

The contact between the Bedford and the underlying Cussewago is sharp in some places and gradational in others. The upper contact with the Berea is conformable. Its contacts with an unnamed sandstone that occurs locally in the subsurface appears sharp in most gamma-ray logs.

In Crawford County, where the Bedford is exposed, the formation was traced by outcrop to the eastern part of the Meadville quadrangle, where it grades into the Shellhammer Hollow Formation. South of Crawford County the Bedford is present only in the subsurface, and its extent is not fully known. For purposes of this report, the extent of the Bedford is arbitrarily chosen to coincide approximately with the limits of the Berea, as shown on plate 1.

UNNAMED SANDSTONE

The occurrence of a sandstone unit below the Berea and Corry Sandstones and above the Cussewago was recognized in the gamma-ray logs of several wells in the Shenango and Stoneboro 15-minute quadrangles (pl. 3). De Witt (written commun., 1970) suggests that the sandstone unit may be correlative to the Hungry Run Sandstone Member of the Orangeville Shale (de Witt, 1951). Although the correlation is reasonable, few substantive data are available and for purposes of this report the unit is herein designated "the unnamed sandstone." This unit does not crop out in Mercer County. Samples of the sandstone were obtained only from well 2777 where it consisted of about 15 feet of very fine grained hard light-gray sandstone, light-gray siltstone, and some dark-gray shale. Six miles to the southeast, in well 3222, prominent kicks in the gamma-ray log of the well (see pl. 3) indicate that the sandstone unit is 24 feet thick and contains some interbeds of shale.

The unit can be traced along the east flank of the Cussewago delta northward to well 3183, where it is 19 feet thick, and as far south as well 332, where it is also 19 feet thick. Eight miles east of well 3222 (in well 3213) it is 11 feet thick, but 9.5 miles east of well 3222 (in well 3201) it is not present. A sandstone is present at the probable horizon of the unnamed sandstone in a well east of well 3222, but the lack of subsurface information to the south and east of well 3213 does not permit correlations east of well 3213.

Gamma-ray logs indicate that the upper and lower contacts of the unnamed sandstone are sharp. The formation is separated from the overlying Corry by thin shale. The unnamed sandstone apparently wedges into the Bedford Shale and in places is either directly overlain by the Berea or is overlain and underlain by the Bedford. It is overlain by the Shellhammer Hollow in the area where the Berea and Corry grade into the Shellhammer Hollow Formation. A thin shale separates the unnamed standstone from the underlying Cussewago. Where the Cussewago is absent, the formation overlies the Riceville Shale (pl. 3). Where present, the unnamed sandstone has been identified by previous workers as the Berea, Corry, or Cussewago, because of its proximity to these units.

The unnamed sandstone was traced in the subsurface throughout most of the Stoneboro quadrangle and into the midcentral part of the Shenango quadrangle, where it wedges out. Examinations of outcrops and gamma-ray logs indicate it does not extend northward into The Meadville quadrangle. If the unnamed sandstone is correlative to the Hungry Run Member of the Orangeville Shale, its source is northwest of the Stoneboro quadrangle. The extent and stratigraphic relations of the unnamed sandstone in the subsurface in the Shenango and Stoneboro quadrangles are shown graphically in the fence diagram (pl. 4).

BEREA SANDSTONE

The Berea Sandstone of northwestern Pennsylvania is an eastern siltstone facies of the much thicker and coarser Berea Sandstone of northern Ohio (Pepper and others, 1954). Well logs and studies of borehole samples in Mercer County and outcrop studies in Crawford County indicate that the Berea consists mostly of thin lenticular beds of hard siltstone, some beds of shale, and scattered thin beds of very fine grained sandstone. The sandstones and siltstones are generally calcareous. In places the Berea may contain thin lenses of siliceous limestone. In well 17, Trumbull County, Ohio, a sample from near the bottom of the Berea consisted of medium-grained, and some larger, subrounded to well-rounded quartz sand. However, study of many samples from Pennsylvania show that where the Berea is sandy, the sand is fine to very fine grained.

In the area shown on plate 1 the Berea is a siltstone wedge that thins eastward from the Pennsylvania-Ohio State line. In Mercer County the Berea generally occurs in the subsurface. Its eastward thinning was traced by gamma-ray logs. These logs show that the Berea thins from a 20–30-foot thickness in western Mercer County to a 4–8-foot thickness in wells 3136, 2777, and 3221 in the central part of the county. A short distance east of the aforementioned wells, the Berea grades into the Shellhammer Hollow Formation. The eastward thinning of the Berea from western to central Crawford County was traced by outcrop and gamma-ray logs. The formation is 20–30 feet thick in western Crawford County, and gamma-ray logs show it is 2 and 12 feet thick, respectively, in wells 414 and 416. The lateral gradation of the Berea into the Shellhammer Hollow in Crawford County may be observed in outcrops near the line showing the eastern limit of the Berea on plate 1.

In Mercer and Crawford Counties the upper contact of the Berea is sharp, but conformable with, the overlying Orangeville

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Shale. Because the lithology of the Berea is distinctly different from that of the Orangeville, the Berea is readily identified in geophysical logs and in some driller's logs. The top, therefore, is a good control marker for locating other less prominent formations. The top of the Berea or its stratigraphic equivalent in the Corry Sandstone is used as a reference datum for the correlation of the sections shown on plate 3 and also in the fence diagram on plate 4.

The approximate limits of the Berea are shown on plate 1. The limits in Mercer and Crawford Counties modify those shown in Demarest's report (1946) for that area. In Mercer County the Berea does not extend as far east as is shown by Demarest. Beyond the north boundary of the Meadville quadrangle, the Berea extends into the southwestern part of the northern adjacent Cambridge Springs 15-minute quadrangle. The limits of the Berea shown in Venango and Butler Counties are from the Demarest report. Gamma-ray logs of well 6 and the J. Jolly 7 well in southern Venango County show that the Berea is not present in that area.

The extent and stratigraphic relations of the Berea in the subsurface in the Shenango and Stoneboro quadrangles are shown graphically in the fence diagram (pl. 4).

CORRY SANDSTONE

Exposures of the Corry Sandstone were observed by the authors only in the area of the confluence of Oil Creek and the Allegheny River (pl. 1). Here, the Corry consists of about 30 feet of flaggy to slabby light-gray very fine grained sandstone with interbedded shale. According to de Witt (1951), the Corry consists of about 20 feet of gray and white siltstone and some interbedded fine-grained sandstone near its type locality at the Colgrove quarry, 1 mile south of Corry, Pa. De Witt also reports that at many places in eastern Crawford County and northern Venango County, the Corry can be separated into three units—a lower unit of massively bedded siltstone and fine-grained sandstones; a medial unit of thinner bedded siltstones intercalated in silty mudrock and silty shale; and an upper unit of massive siltstones separated by some thin shaly partings. Fossils are reported common in the Corry at many places. Caster (1934) recorded more than 56 genera of invertebrates from the Corry, and Sass (1960) identified numerous species of 3 genera.

In the area shown on plate 1, the Corry occurs as a lobe thinning to the southwest. In Mercer County the Corry is present in the subsurface, and its thickness is reliably known only from gamma-ray logs. Gamma-ray logs indicate that in the Stoneboro quadrangle the Corry ranges in thickness from zero in some wells to a maximum of 31 feet in well 3218, in the east-central part of the quadrangle (pl. 1). The Corry is 2 feet thick in well 3600 in northwestern Venango County, about 10 feet thick in wells 3185 and 3186, and 2 feet thick in well 3222, Mercer County. A short distance west of the aforementioned wells, the Corry grades into the Shellhammer Hollow Formation. The Corry as mapped by the authors in the Stoneboro quadrangle is considerably thicker than the Corry mapped by Demarest (1946) in the same area.

Gamma-ray logs indicate that in Mercer County the contact between the Corry and the overlying Orangeville is sharp (pl. 3). In much of the Stoneboro quadrangle the Corry rests on generally thin beds of shale that separate it from an unnamed sandstone. Where the unnamed sandstone is absent, the formation lies on the Riceville Shale. De Witt (1951) reports that throughout much of the Corry outcrop (most of Venango County and eastern Crawford County) the contact of the Corry with the Riceville is generally sharp and conformable. The upper contact with the Orangeville, according to de Witt, is not sharply defined in much of the outcrop area. Where the Corry is thick, in the Stoneboro quadrangle, gamma-ray logs exhibit characteristic sharp-pronged low-intensity kicks that are easily indentified as the Corry (pl. 3). Like the Berea, the Corry is a good stratigraphic marker. It is used with the Berea as the reference datum on plate 3. The bottom beds of the Corry are stratigraphically a few feet above the top beds of the Berea where the formations are nearby, and the two sandstones probably do not meet or overlap (pl. 4).

The approximate limits of the Corry are shown on plate 1. The limits shown in Crawford, Venango, and Clarion Counties are slightly modified from Demarest's 1946 report. The Corry mapped by the authors in eastern Mercer County extends as much as 12 miles west of the western limit mapped by Demarest (1946) in that area and is shown to be present above the Cussewago. The stratum previously mapped as Berea in parts of eastern Mercer County is probably the Corry Sandstone. The extent and stratigraphic relations of the Corry in the subsurface in the Stoneboro quadrangle are shown graphically in the fence diagram (pl. 4).

De Witt (1946) and Demarest (1946) demonstrated that the

Corry has a lobate shape and northeasterly source area; they suggested that the formation is a delta deposit. The lobate shape and thickness of the Corry, as determined by gamma-ray logs in the Stoneboro quadrangle, support this suggestion.

SHELLHAMMER HOLLOW FORMATION

The Shellhammer Hollow Formation, where seen in outcrops in Crawford County, generally consists of a thin sequence of intercalated irregularly bedded siltstones, silty mudstones, and silty shale. The siltstones become progressively less conspicuous east and west of the limits of the Berea and Corry, and in the general area midway between the two formations, the Shellhammer Hollow is mostly silty shale. At the Shellhammer Hollow type section (pl. 1) the formation consists of about 5 feet of lenticularly bedded siltstone intercalated in silty shale. About 6 miles east the Shellhammer Hollow is made up of about 4 inches of silty shale.

The Shellhammer Hollow thins progressively as it extends farther from its Berea and Corry boundaries and is thinnest in the general area midway between the boundaries. In Crawford County the formation is 5.1 feet thick at the Shellhammer Hollow section, but it thins to 3.7 feet about 4 miles to the northeast and is only 4 inches thick about 6 miles east of the Shellhammer Hollow section (pl. 1). The thickness of the formation outside Crawford County is not known.

The contacts between the Shellhammer Hollow and the Berea and Corry Sandstones are gradational. The Shellhammer Hollow is everywhere capped by the Bartholomew Siltstone Member of the Orangeville Shale. In most places the formation overlies the Cussewago Sandstone, but where the Cussewago is absent, it overlies the Riceville Shale.

The Shellhammer Hollow Formation occupys the approximate area between the eastern limits of the Berea and the western limits of the Corry (pl. 1). In the area of plate 1 the formation can be traced in outcrop only in Crawford County. In the rest of the area it occurs in the subsurface. Only one gamma-ray log (well 6) shows the Shellhammer Hollow in the subsurface. The extent of the formation as mapped by the authors somewhat modifies its extent shown by Demarest as an area of shells in his 1946 report. In Mercer County the belt between the Berea-Corry limits, representing the Shellhammer Hollow, is much narrower than the shell belt of Demarest.

CUYAHOGA GROUP (ORANGEVILLE SHALE, SHARPSVILLE SANDSTONE, MEADVILLE SHALE)

The Cuyahoga Group in northwestern Pennsylvania is generally divided into three formations. In ascending order these formations are the Orangeville Shale, Sharpsville Sandstone, and Meadville Shale (Dickey and others, 1943; Pepper and others, 1954; Carswell and Bennett, 1963). Caster (1934, p. 129) suggested that the Cuyahoga Group be renamed the Meadville Monothem (Formation) and divided into eight units. More recently, Hall (1958) and Szmuc (1958) defined the Cuyahoga Group in Ohio as a formation. The threefold division of the Cuyahoga is retained in this report, although it is difficult to separate the individual formations in either outcrop or gamma-ray logs. A shale-sandstone-shale sequence generally exists, but exact lateral correlations are often uncertain even with the use of abundant geophysical logs (pl. 3). Lateral changes in lithology within the individual formations appear to be abrupt. For example, the Sharpsville Sandstone contains beds of sandstone that are stratigraphically equivalent to shale beds a few miles distant (pls. 3, 4).

In the area of this report the Cuyahoga Group might almost be considered a formation consisting of shale and silty shale containing widespread lenses of sandstone near the middle part.

The thickness of the Cuyahoga Group is fairly uniform throughout Mercer County. The thickness is 235 feet near the Pennsylvania-Ohio State line (well 3100), 245 feet near Greenville (well 2654), and 220 feet near Hadley (well 3183). Near Stoneboro and eastward, the Cuyahoga is 200 feet thick or less, because the Corry Sandstone occupies part of the lower Cuyahoga interval. For example, the Cuyahoga is 200 feet thick in well 3218, and the Corry Sandstone occupies about 30 feet of the Orangeville interval. In much of Crawford County the top part of the Cuyahoga has been removed by erosion. In the vicinity of Meadville (pl. 1), where high hills contain the entire Cuyahoga section, the group is about 200 feet thick.

In Mercer and Crawford Counties the Cuyahoga rests on either the Berea, Corry, or Shellhammer Hollow formation, and it is overlain by the Shenango Formation.

The Cuyahoga Group was traced in outcrop and in gamma-ray logs from the Pennsylvania-Ohio State line (pl. 1), across the Shenango and Stoneboro quadrangles, eastward at least to the western parts of the Titusville, Oil City, and Foxburg quadrangles and south into the Neshannock and Mercer quadrangles.

ORANGEVILLE SHALE

The Orangeville Shale is a soft medium- to dark-gray argillaceous to silty blocky to fissile shale that contains thin beds of light-gray very fine grained sandstone or siltstone. Sandstone and siltstone beds are most numerous near the top of the formation, where the Orangeville grades into the overlying Sharpsville Sandstone. A persistent and widespread thin siltstone, termed the Bartholomew Siltstone Member by de Witt (1951) is present at or near the base of the Orangeville. The shale commonly is fissile and silty. It contains concretions in some places and is commonly iron stained. Some beds are fossiliferous. The Orangeville erodes rapidly leaving poorly exposed outcrops.

The Orangeville thins eastward from the Pennsylvania-Ohio State line, in Mercer and Crawford Counties, as a result of intertonguing of the Orangeville Shale and the Sharpsville Sandstone at progressively lower stratigraphic positions to the east. Eastward, the top of the Orangeville occurs progressively lower in the Cuyahoga section. As mapped by the authors in outcrop and in the subsurface in the Shenango and Stoneboro quadrangles, the Orangeville is about 60 feet thick on the west side of the Shenango quadrangle and 20 feet thick on the east side of the Stoneboro quadrangle. Examination of outcrops show that the Orangeville is about 90 feet thick in the western part of the Linesville quadrangle. About 1 mile east of Meadville the gamma-ray log of well 416 indicates the Orangeville is 42 feet thick. Pepper (Pepper and others, 1954) reports that the Orangeville is 29 feet thick near Riceville (fig. 1), but a short distance east the formation cannot be separated from the Sharpsville Sandstone.

Outcrops in Mercer and western Crawford Counties show that the contact between the Orangeville and overlying Sharpsville is mostly gradational. Locally, the contact may be sharp. The contact between the Orangeville and the underlying Berea and Shellhammer Hollow is sharp. De Witt (1951) reports that the Orangeville-Corry contact is not sharply defined, especially in southeastern Crawford County and Venango County. Most gamma-ray logs in the Stoneboro quadrangle indicate a sharp contact between the Orangeville and the Corry.

The Orangeville was traced by the authors in outcrop and in the subsurface throughout Mercer County and western Crawford Counties. De Witt (1951) traced the formation in Crawford County to the vicinity of Riceville. According to de Witt, in southeastern Crawford County and western Venango County the Orangeville Shale and Sharpsville Sandstone merge.

In well 2774, shown on the southwest corner of the fence diagram on plate 4, and in geophysical logs of nearby wells, 5 feet of siltstone or sandstone is present 35 feet above the Berea. The unit is a conspicuous marker in the logs in that area. It is not present however, in wells 3100 and 3136, north and east of well 2774. A similar unit was identified in the gamma-ray logs of wells 3186 and 3187.

BARTHOLOMEW SILTSTONE MEMBER

The Bartholomew Siltstone Member in Crawford County is a gray or grayish-brown hard siltstone at or near the base of the Orangeville Shale. It averages less than a foot in thickness and is characterized by many curly dark-gray markings less than an inch long, which make it easy to identify. The unit is sparingly fossiliferous. The Bartholomew does not crop out in Mercer County, and it cannot be identified in gamma-ray logs because it is too thin to contrast with the overlying and underlying strata.

Near the Pennsylvania-Ohio State line in Crawford County, the member occurs 15 feet above the Berea. It is 8 feet above the Berea at the Bartholomew section, and less than 1 foot above the Berea in Cussewago Township, in north-central Crawford County. The Bartholomew directly overlies the Shellhammer Hollow Formation. De Witt (1951) reports that the Bartholomew is 1–3 feet above the Corry near Corry and Oil City.

Where the Berea is present, the Bartholomew rests on the basal beds of the Orangeville Shale. Pepper (Pepper and others, 1954) reports that the Bartholomew may directly overlie the Corry or be separated from it by a few inches to several feet of Orangeville Shale.

The Bartholomew Siltstone Member is a conspicuous stratigraphic marker in northwestern Pennsylvania. It was traced by the authors throughout western Crawford County and was traced by de Witt (1951) at least as far east as Warren County and at least as far south as Oil City.

SHARPSVILLE SANDSTONE

The Sharpsville Sandstone in Mercer and western Crawford Counties is composed of beds of sandstone that are as much as 40 feet thick and are separated at irregular intervals by beds of siltstone and shale. Locally, the Sharpsville may consist mostly of sandstone. In places the lower part of the formation may be composed almost completely of massive siltstone and sandstone (Pepper and others, 1954, p. 45). At the type locality of the Sharpsville (White, 1880, p. 62), along the Shenango River valley at Sharpsville, the formation consists of about 80 feet of sandstone containing thin beds of shale. At this locality the shale beds become thicker and the sandstone beds thinner near the base of the formation.

The sandstone of the Sharpsville is thin bedded, very hard, and uniformly silty and very fine grained. Generally, the sandstone is flaggy, but in some places it is slabby. Where thicker than about 0.3 foot, the sandstone characteristically fractures conchoidally. The shale is generally fissile and contains concretions.

The Sharpsville Sandstone thickens eastward from the Pennsylvania-Ohio State line as it take up more of the Orangeville Shale section. The formation is about 80 feet thick near the west edge of Mercer County and about 110 feet thick near the east edge. The Sharpsville Sandstone, as defined by White at the type locality at Sharpsville, is 52 feet thick. However, 10 feet below the base of White's Sharpsville, beds of silty sandstone thicken northward to a total thickness of 35 feet in well 300. The basal beds of this sandstone unit can be traced eastward by gamma-ray logs into positively identified Sharpsville strata. Consequently, the Sharpsville-Orangeville contact is moved downward, making the Sharpsville 80 feet thick at Sharpsville—about 30 feet thicker than White's figure for this locality. The full thickness of the Sharpsville is not present in northwestern Crawford County because the upper part has been removed by erosion. The thickness of the formation in well 300, in southwestern Crawford County, is about 95 feet (pl. 3). Examinations of outcrops and gamma-ray logs indicate that the Sharpsville ranges in thickness from about 80–100 feet in the vicinity of Meadville. East of Meadville the thickness of the Sharpsville is not known.

The Sharpsville Sandstone is overlain by the Meadville Shale and underlain by the Orangeville Shale. Outcrops examined in Mercer and Crawford Counties show that the contact between the Sharpsville and the Meadville is fairly well defined in some places and poorly defined in others. In many sample logs and some geophysical logs, the top of the Sharpsville is poorly defined. A very detailed sample log for well 2777 did not indicate the distinct change in lithology at the Meadville-Sharpsville boundary, which is shown on the gamma-ray log of the well (pl. 3). The top of the Sharpsville in western Mercer County becomes progressively less distinct eastward.

As mapped by the authors in outcrop and in the subsurface, the Sharpsville Sandstone extends throughout Mercer County and most of western Crawford County. Erosion has removed the Sharpsville from parts of northern Crawford County. The distribution of sandstone units in the Sharpsville in the Shenango and Stoneboro quadrangles is shown in the fence diagram on plate 4. To extend correlations of the Sharpsville in the fence diagram, it was sometimes necessary to pick arbitrarily a sandy bed as the top of the Sharpsville rather than a distinct sandstone, because in places sandstone beds are not present in the upper part of the formation. Therefore, a dashed line is used to show the upper boundary on the fence diagram.

Although the Sharpsville was traced at least to the vicinity of Riceville by Pepper (Pepper and others, 1954) and into Western Venango County by de Witt (1951), they reported that its boundaries at these localities could not be accurately determined. The gamma-ray log of the J. Jolly 7 well (Bergsten and Heeren, 1961) indicates that the Sharpsville is present in southern Venango County.

MEADVILLE SHALE

The Meadville Shale consists of thin interbeds of micaceous resistant siltstone and silty shale and some lenses of fine-grained to very fine grained sandstone as much as 10 feet thick. The shale is commonly fissile and contains brownish-gray sideritic concretions. Locally, the siltstones are ripple and current marked and contain worm borings and fucoids. Some beds of siltstone are full of worm borings. Invertebrate fossils, such as brachiopods, are more common in the Meadville than in any other Mississippian formation in the area. Silty or sandy limestone and limy siltstone and sandstone 0.5 to 2 feet thick are present locally. One such limestone in the southern part of the Meadville quadrangle, named the Meadville Upper Limestone by White (1881), is a good stratigraphic marker. This limestone also is present in the northern parts of the Shenango and Stoneboro quadrangles.

The Meadville thins eastward from the Pennsylvania-Ohio State line across Mercer and southern Crawford Counties. As mapped by the authors in outcrop and in the subsurface, the Meadville is about 90 feet thick in western Mercer County and southwestern Crawford County. The formation ranges in thickness from 60 to 75 feet in eastern Mercer County and in the Meadville quadrangle in Crawford County.

The contact between the Meadville Shale and the underlying Sharpsville is transitional. In outcrop, the contact is placed at the base of a persistent 2- to 6-foot-thick fissile shale bed that is overlain by a few feet of Sharpsville-type sandstone and generally is underlain by a relatively thick Sharpsville-type sandstone. In most gamma-ray logs, the contact is placed at the base of the lowermost high intensity zone (shale) above a series of distinct gamma-ray kicks that generally identify the underlying Sharpsville (pl. 3). Generally the contact between the Meadville Shale and the overlying Shenango Formation is fairly sharp in outcrop and in the subsurface. Excellent exposures showing the Meadville-Shenango contact may be seen along the Shenango River valley in the Shenango quadrangle and along French Creek valley in the southern part of the Meadville quadrangle.

The Meadville was traced by the authors in outcrop and in the subsurface throughout Mercer County into western Venango County and southwestern Crawford County. The formation has been removed by erosion in most of northwestern Crawford County.

SHENANGO FORMATION

The definition and use of the name Shenango Formation in this report follow that of Kimmel and Schiner (1970) who divided the formation into two members. The lower member consists primarily of a sequence of interbedded sandstone, shale, and siltstone of irregular thickness, and the upper member consists primarily of interbedded shale and siltstone. Two sections showing correlations of the Shenango Formation in Mercer County are given on plate 5. The Shenango ranges in thickness from about 150 to 180 feet in the Shenango and Stoneboro quadrangles. Erosion has removed much of the upper part of the formation in western and northern Mercer County and in southern Crawford County. A major unconformity at the top of the Shenango separates the Mississippian System from the overlying Pennsylvanian System.

The Shenango is a conspicuous stratigraphic marker in the Mississippian rock section of northwestern Pennsylvania because of its distinctive lithology and relatively wide areal extent. The base of the Shenango Formation is about 230 feet above the Berea in western Mercer County and about 200–230 feet above the Corry in eastern Mercer County. In eastern Mercer County the Shenango-Corry interval thins as the Corry thickens eastward.

LOWER MEMBER

The lower member of the Shenango Formation consists of a sequence of intertonguing sandstone, shale, and siltstone that indicate a change in the character of deposition of the Mississippian rock system. This change is reflected in the sands of the lower member, which are generally coarser, more crossbedded, thicker, and less shaly than the subjacent Sharpsville Sandstone.

Sandstones in the lower member are generally fine grained, but medium-grained and very fine grained sandstones are common. The sandstone is a protoquartzite (Pettijohn, 1957, p. 291) and consists principally of well-rounded to subrounded quartz grains that are generally cemented with secondary silica. Thus, the rock is generally well indurated. The minor components of the sandstone are biotite, muscovite, unidentified dark minerals, and lithic fragments. Rounded mudstone pebbles and plant fossils occur near the base of some sandstone beds. Ripple marks generally occur only in the fine-grained upper beds of the sandstones. Some beds of sandstone that appear massive exhibit planar laminated bedding on close examination. Low-angle crossbedding is generally also present in one or more of the sandstone beds that are included in the member. The sandstones characteristically split along planes of parting into irregular and lens-shaped layers most commonly flaggy, but in places, slabby to massive.

Beds of dark- to medium-gray shale and siltstone are interbedded with the sandstones. Bedding in the shale and siltstone is generally papery to laminated, but the siltstone is flaggy in places. Some beds of siltstone contain worm borings, tracks, trails, fucoids, brachiopods, and pelecypods.

The number, position, and thickness of the lower member sandstone beds differ from place to place. Individual beds of sandstone within the member may be correlated over short distances, but the character of the entire formation generally changes over distances of several miles. For example, in well 425 most of the sandstones are at the base of the member. In well 1006, 7.5 miles to the north, the top of the member contains most of the sandstones, and in well 1008, 1.6 miles northwest of well 1006, the entire member consists of thin beds of sandstone and shale (pl. 5). Outcrop and subsurface data suggest that the upper part of the lower member becomes increasingly more thin bedded when traced northward from southern Mercer County into southwestern Crawford County.

The thickness of the lower member increases eastward from the Pennsylvania-Ohio State line in Mercer County. As mapped by the authors, in outcrop and in the subsurface, the member thickens from 80 feet in the northwestern part of the Shenango quadrangle to 120 feet in the eastern part of the Stoneboro quadrangle; however, the increase in thickness is not uniform. Reports by Carswell and Bennett (1963) and Poth (1963) indicate that the lower member thickens eastward from about 60 feet in the southwestern part of the Neshannock quadrangle to about 110 feet in the eastern part of the Mercer quadrangle. Poth (1963) reports that the thickness ranges from 65 to 95 feet in the Franklin and Hilliards quadrangles and increases eastward to about 160 feet in the northern part of the Oil City quadrangle. The full thickness of the member is not present in Crawford County, because erosion has removed part of the section.

The basal sandstones of the lower member generally lie disconformably on the Meadville Shale. The basal sandstones of the lower member occupy channels and pockets in the underlying Meadville. These sandstones generally contain rounded shale pebbles probably derived from the Meadville. Locally, the Shenango-Meadville contact appears to be conformable. In outcrop the contact between the Shenango and the Meadville is generally marked, because the basal sandstone beds of the lower member form conspicuous ledges. In poorly exposed outcrops the Shenango-Meadville contact may be difficult to place, because the upper part of the Meadville often contains beds of sandstone similar in lithology to the basal Shenango. The lower member of the Shenango Formation conformably underlies the upper member.

In most gamma-ray logs the base of the lower member is clearly evident, but in some wells (as in poorly exposed outcrops) the base cannot be correctly identified unless gamma-ray log correlations to nearby wells can be made. For example, a sandstone about 5 feet thick is present about 12 feet below the horizon shown as the base of the lower member in wells 3190, 3195, and 2380. This unit merges with the Meadville Shale in the surrounding area and, thus, is more properly placed in the Meadville. (See pl. 5.)

The lower member of the Shenango was traced by the authors in outcrop and by geophysical logs throughout most of Mercer County, into southwestern Crawford County, into western Venango County, and in southern Venango County as far east as the J. Jolly 7 well in the northeastern part of the Foxburg quadrangle. Sherrill and Matteson (1939, 1941) and Dickey, Sherrill, and Matteson (1943) report that the Shenango Sandstone (lower member) is present in the Hilliards, Franklin, and Oil City quadrangles. In the Shenango quadrangle, erosion before the deposition of the Pennsylvanian System, has removed the top of the formation north and west of a line extending from the east edge of Hickory Township, northeast across Delaware, through the center of Otter Creek Township, to the center of Salem Township. The entire lower member is present in the southern part of the Stoneboro quadrangle. Glacial erosion has apparently removed part of the section in the northern part of the Stoneboro quadrangle and most of southern Crawford County.

UPPER MEMBER

The upper member consists of gray shale, intercalated thin beds of siltstone and very fine grained sandstone, thin silty limestones, and thin layers of siderite concretions. The shale is commonly silty, the sandstones flaggy and micaceous, and the siltstones well indurated. Worm borings, fucoids, and current-striation marks occur in some beds of siltstone. The lithology of the upper member is similar to the lithology of parts of the lower member; in outcrop, therefore, the upper member cannot be distinguished from the lower member unless distinct key beds in other parts of the section are exposed. Generally, the upper member is poorly exposed in outcrop.

The full thickness of the upper member in Mercer County is not known, because it is everywhere separated from the rocks of the overlying Pennsylvanian System by a regional unconformity. The maximum thickness of the member in Mercer County is 78 feet in the Shenango quadrangle, at the type section for the Shenango Formation along the Shenango River valley in south-central Delaware Township (Kimmel and Schiner, 1970) (pls. 1, 5). However, the thickness may be greater elsewhere, as the unit is poorly exposed. The member is reported to range in thickness from 15 to 60 feet in the Neshannock quadrangle (Carswell and Bennett, 1963, p. 21) and from 40 to 60 feet in the Mercer quadrangle (Poth, 1963, p. 15). In the Stoneboro quadrangle, the unit is 50–60 feet thick (pl. 5). Interpretation by the authors of the gamma-ray log of the J. Jolly 7 well (Bergsten and Heeren, 1961), in the northwestern part of the Foxburg quadrangle, indicates that the upper member is about 50–60 feet thick in that area.

Although a regional unconformity separates the upper member of the Shenango from the overlying Pottsville Group (Pennsylvanian), the contact may be difficult to place in outcrop and in the subsurface if the basal beds of the Pottsville are shale. In the gama-ray log of well 3196 (pl. 5), for example, the upper contact was necessarily placed at a break in the log consistent with the projected thickness of the unit in the area. Where the upper member is overlain by sandstone of the Pottsville, their contact is readily identified in both outcrop and gamma-ray logs. The contact with the underlying lower member ranges from gradational to sharp. In gamma-ray logs the contact is generally placed at the top of the topmost sandstone bed in the sandstone series that identifies the Shenango (pl. 5).

The upper member was traced in outcrop and in the subsurface throughout all but the northwest third of Mercer County, into southern Venango County, and east to the J. Jolly 7 well. Erosion has removed the unit in southern Crawford County.

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U. S. GOVERNMENT PRINTING OFFICE : 1972 O - 469-514