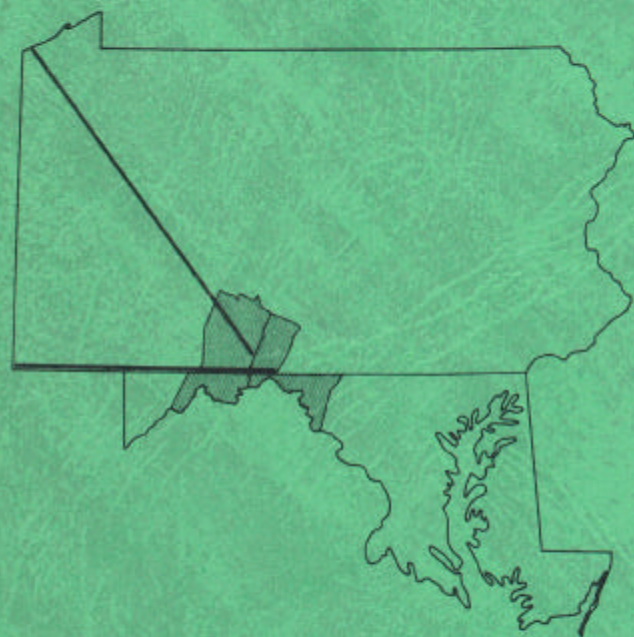


GUIDEBOOK



44th. Annual Field Conference  
Of Pennsylvania Geologists



*Devonian  
Shales  
of  
South-Central  
Pennsylvania  
and Maryland*

October 5 and 6, 1979  
Bedford, Pa.

Hosts : University of North Carolina  
East Tennessee State University  
Pennsylvania Geological Survey

Guidebook for the  
44th ANNUAL FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

DEVONIAN SHALES  
IN  
SOUTH-CENTRAL PENNSYLVANIA  
AND  
MARYLAND

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## INTRODUCTION

The 44th Field Conference of Pennsylvania Geologists brings together diverse efforts to understand the correlations and depositional environments of the Devonian shales. Field relationships will focus on south-central Pennsylvania, to show the present understanding of facies changes eastward toward the source of these marine detrital clastics. The marine prodelta manifestations of the Fulton Lobe and Perry Bay will be examined, along with an eastward disappearance of deeper water, euxinic shales. Certain basin-wide sea level changes have left an imprint on the sedimentary record. There is much interest at the present time in the gas potential of the Devonian shales of the Pennsylvania subsurface, and this guidebook offers a refined attempt to correlate the western subsurface with the Valley and Ridge outcrops of the Devonian shales. Along the field trip route there is opportunity to examine new work on the Breezewood fault, which is part of the Transylvania fault system which roughly follows the 40th Parallel, and may have influenced Paleozoic sedimentation. We will also examine a spectacular exposure of the polymictic diamictite which occurs locally in the Rockwell Formation, near the base of the Mississippian System.

Guidebooks offer an ideal opportunity to test informally stratigraphic ideas as they are developing. According to the Stratigraphic Code, a guidebook publication clearly does not constitute a valid place for stratigraphic nomenclature proposals to become formalized. Therefore, we feel free to present different, occasionally conflicting proposals for organizing stratigraphic nomenclature. The intent is to stimulate discussion and to clarify approaches to stratigraphic analysis. Strong feedback from field trip participants will be an important aid in developing a workable formal stratigraphic nomenclature as a basis for future work on depositional interpretation of the Devonian shales and their faunal assemblages, as well as their economic exploitation.

John M. Dennison  
Kenneth O. Hasson

1979 Field Trip Coordinators



DEVONIAN SHALE STRATIGRAPHY BETWEEN  
PERRY BAY AND THE FULTON LOBE  
SOUTH-CENTRAL PENNSYLVANIA AND MARYLAND

by

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INTRODUCTION

For the past 14 years we have been investigating the regional stratigraphic relationships of the Devonian shale complex in an area which has grown to encompass 15,000 square miles from south-central Pennsylvania to the Virginias. We have presented the on-going results of this work in a series of papers and oral presentations (Hasson, 1966, 1972; Hasson and Dennison, 1967, 1973, 1974, 1977, 1978; Hasson and Liebe, 1968; Hasson and Cocke, 1973; Dennison and Hasson, 1974, 1976, 1977a, 1977b). Our stratigraphic interpretations and cross sections were brought together in U. S. Department of Energy Open-file Report ESGP 110 (Hasson and Dennison, 1978).

It is our principal purpose in this field conference to demonstrate the outcrop stratigraphic relationships and nomenclatural changes among the Brallier Formation, Harrell and Burket Shales, Tully Limestone, and Mahantango Formation as one proceeds from an open-marine embayment (Perry Bay in the northeast part of the conference area) toward a marine deltaic lobe (Fulton Lobe in the south-east part of the conference area). A secondary purpose is to illustrate the facies and faunal changes within the Needmore Shale and to demonstrate the intertonguing relationship between the Needmore Shale and Huntersville Chert.

Establishment of a suitable nomenclature scheme for the Devonian shales involves deciphering the general east-west facies changes (Figure 1) which occur in the Hamilton and Portage Groups across the area of the Fulton Lobe. The Fulton Lobe was named for Fulton County and is the southernmost of three Devonian deltaic distributaries recognized by Willard (1934, 1939) in Pennsylvania. The Fulton Lobe is bounded on the north by Perry Bay (Willard, 1939), an embayment which was enlarged by the eastern shift of the Devonian shoreline at the time of the Taghanic eustatic sea level rise at the end of the Middle Devonian. This configuration resulted in the coarser, nearer-shore clastics being interbedded with the generally finer, dark, more organically rich offshore sediments. Because of the regional facies changes it is convenient to divide the area into three belts: an Eastern Belt of outcrops east of the Broadtop synclinorium, a Central Belt extending from the Allegheny Front to the outcrops along the west edge of the Broadtop synclinorium, and a Western Belt, which is subsurface under the Allegheny Plateau.

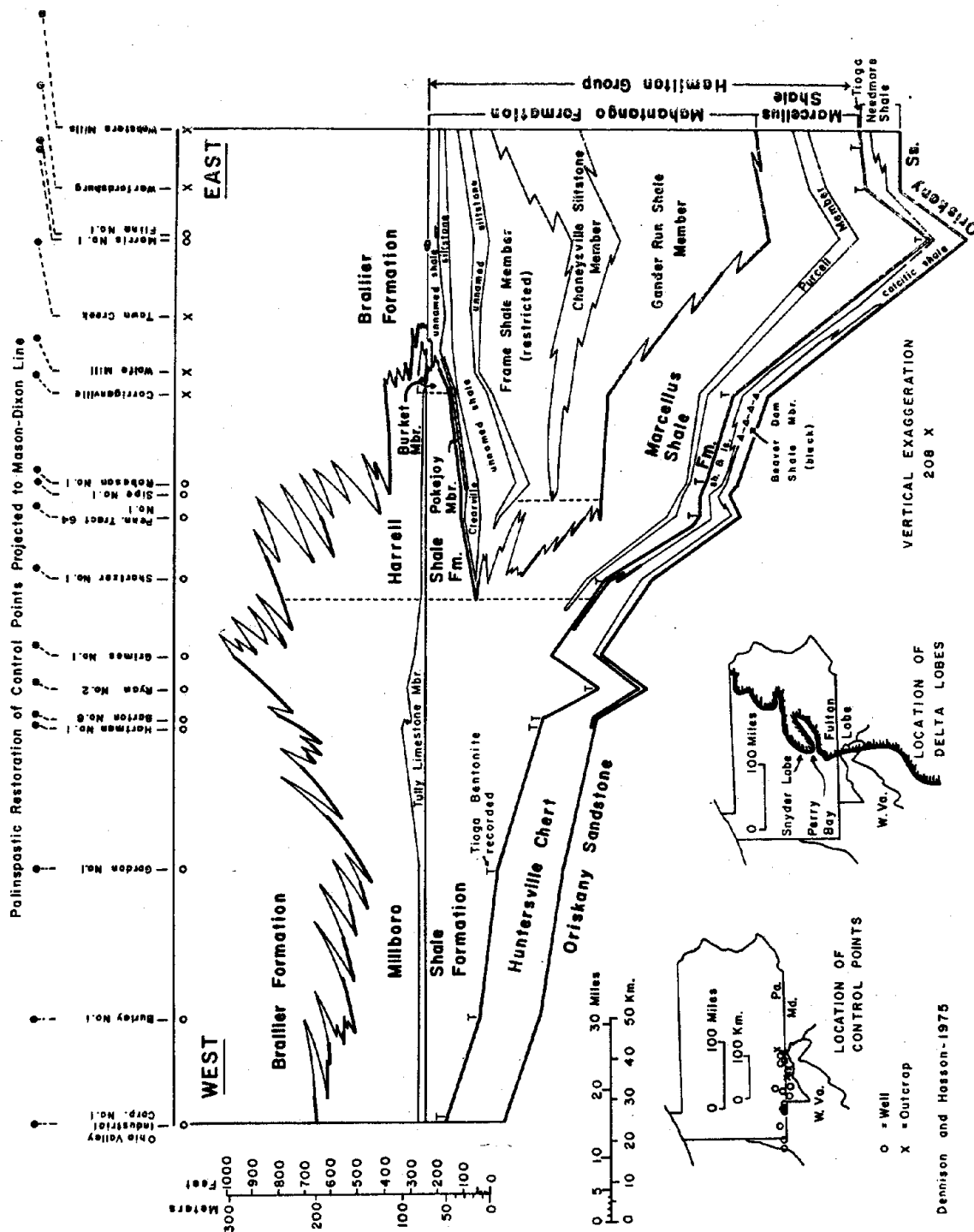


Figure 1. Stratigraphic cross section of Devonian shales along latitude 39° 43' N in a cross section of the Fulton Lobe at the Mason and Dixon Line. (After Dennison and Hasson, 1976, p. 280-281)

### Eastern Belt

The Eastern Belt includes the area of easternmost Huntingdon and Fulton Counties, Pennsylvania, and Washington County, Maryland. In the Eastern outcrop belt of Devonian shales, the dark Harrell and Burket Shales are absent, and the Brallier Formation rests directly on the Mahantango Formation. The units we recognize in the Eastern Belt are:

- Brallier Formation
- Mahantango Formation
  - Unnamed Shale
  - Clearville Siltstone (informal)
  - Unnamed Shale
  - Unnamed Siltstone
  - Frame Shale Member (restricted from original definition)
  - Chaneyville Siltstone Member
  - Gander Run Shale Member
- Marcellus Shale
  - Purcell Member (informal)
- Tioga Bentonite
- Needmore Shale
- Oriskany Sandstone

### Central Belt

The Central Belt includes those outcrop belts in Bedford County, Pennsylvania and Allegany County, Maryland. The stratigraphy of the Central Belt is more complex than that of the Eastern Belt. The Mahantango Formation changes facies to the northwest across structural strike, as well as in a northeast-southwest direction along strike. It is in this area that the coarser Mahantango clastics are replaced in part and from the base upward by fissile, black Marcellus-type shale. The facies changes are coupled with a eustatic sea level rise at the end of the Middle Devonian extending over the nearer-shore portions of the Fulton Lobe, so that the deeper water, finer grained, more organically rich shales are shifted eastward to form the Harrell Shale. Details of Devonian shale stratigraphy along the Allegheny Front have been provided by Dennison (1963), Hasson (1966, 1972), Dennison and Hasson (1976, 1977a), and Hasson and Dennison (1978). The Devonian shale stratigraphy along the Allegheny Front is shown schematically in Figure 2.

### Western Belt

The Western Belt includes the subsurface area west of the Allegheny Front. The downward sequence in the Western Belt is much more simple than that of the Central or Eastern Belts, because the Mahantango Formation has disappeared by facies change, and the Brallier to Tioga interval is occupied by black shale. However, the Needmore Shale changes facies westward into Huntersville Chert. The sequence we use in the Western Belt, which is entirely subsurface in Pennsylvania and Maryland, is as follows:

- Brallier Formation
- Millboro Shale
  - Tully Member
  - Purcell Member (informal)



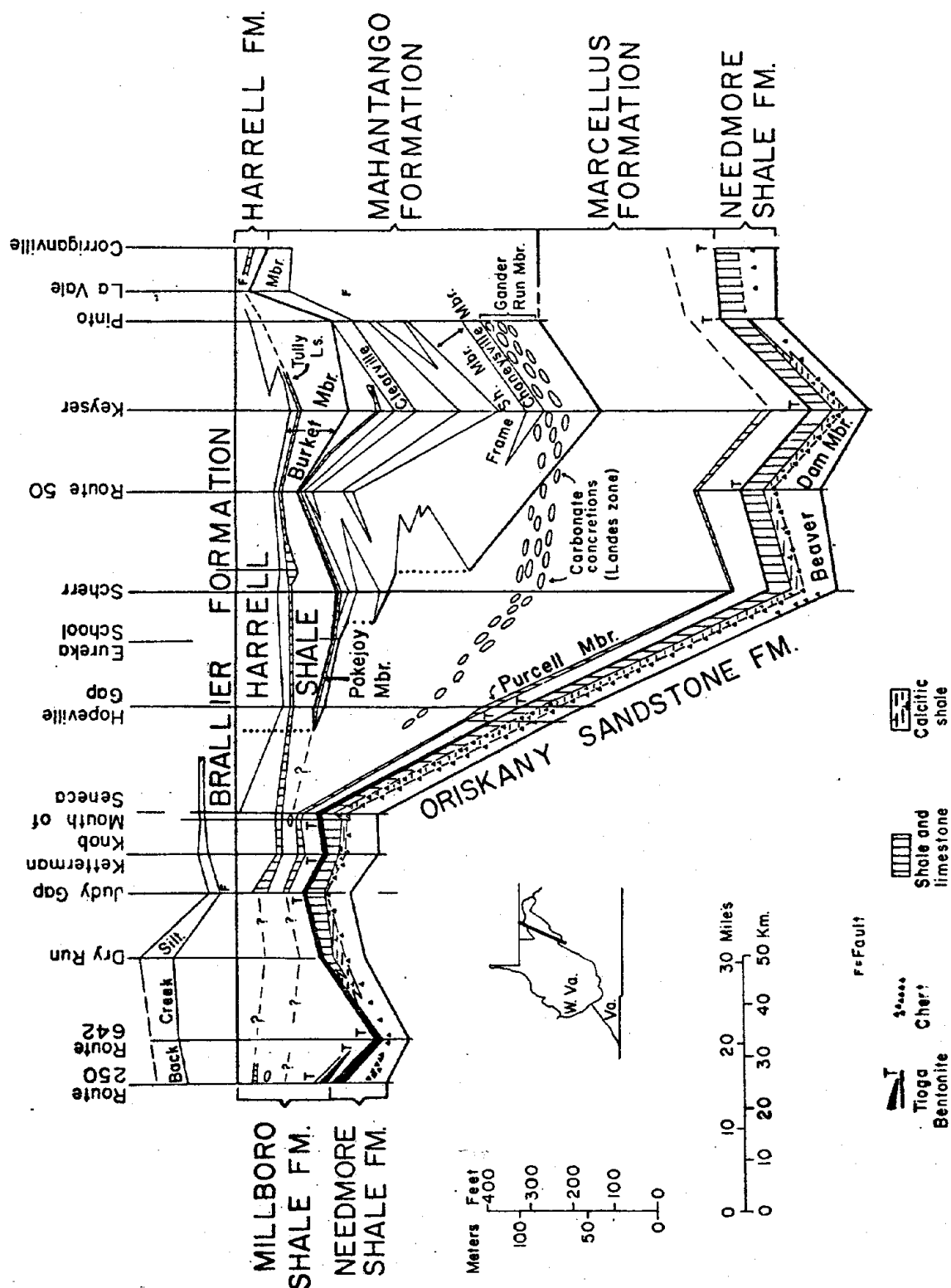


Figure 2. Stratigraphic cross section of Devonian shales along the Allegheny Front from Maryland to Highland County, Virginia (from Hasson and Dennison, 1977, p. 641).

Tioga Bentonite  
Needmore Shale  
Oriskany Sandstone

This is a lithostratigraphic classification based on well-cutting sample descriptions, reflecting chiefly color and grain size of the detrital clastic sediments. Outcrop stratigraphic nomenclature relies heavily on these same properties. Lithically the Millboro cannot be subdivided, except for the two limestone-bearing horizons. Geophysical logs, notably gamma ray logs, sometimes permit tracing of characteristic signatures from well to well; it is difficult to tie those geophysical signatures into outcrop stratigraphic nomenclature, because of facies changes eastward toward the outcrops and because there have been few geophysical measurements of outcropping strata to match with the well logs. Consequently the matching of geophysical stratigraphy with outcrop nomenclature has its own special stratigraphic nomenclature difficulties, not well-handled by the Stratigraphic Code.

#### STRATIGRAPHIC SUMMARY

In the following descriptions we will consider the units from youngest to oldest, that is, in the order of drill penetration. These descriptions are taken with modification from U. S. Department of Energy ESGP Open-file Report 110 (Hasson and Dennison, 1978).

#### Brallier Formation

The Brallier Formation was named by Butts (1918) for exposures near Brallier Station, a stop on the Huntingdon and Broadtop Mountain Railroad about 5 miles northeast of Everett, Bedford County, Pennsylvania. The Brallier consists of interbedded shale and siltstone. The shale is thickly laminated, medium-dark gray on fresh outcrops and weathers to characteristic olive to light-olive gray chips. The siltstones generally are in sharply bounded beds ranging from about 0.1 foot (0.03 m) to about one foot (0.3 m) thick. Although light to medium gray on fresh surfaces, the beds commonly are yellowish gray or rust color on the weathered surface, and are sometimes cross-laminated and may exhibit graded bedding. The thickness of the Brallier Formation turbidite strata is on the order of 1,800 to 2,000 feet. The lowest distinct, sharply bounded siltstone succeeded by interbedded olive-weathering shale and siltstone is considered the base of the Brallier.

In outcrops of the Eastern Belt, the Brallier rests directly on the Mahantango Formation. There, the lowest distinct siltstone directly overlying the silty, lumpy-weathering olive shales or the indistinctly bedded siltstones or fine sandstones of the Mahantango is taken as the contact between the two Formations. An additional helpful criterion is that the Mahantango always has an abundant fauna, but fossils are very scarce to absent in the Brallier strata. These contact relationships in the Eastern Belt are particularly well exposed at Burnt Cabins, Fort Littleton, and Harrisonville Road in Pennsylvania, and at Hancock (STOP 9) and Pectenville in Maryland.

The Brallier Formation everywhere overlies the Harrell Shale in the Central Belt within the field conference area in Pennsylvania and Maryland, but in the southern extension of the Central Belt into parts of West Virginia and Virginia, the Brallier overlies the Millboro Shale. Throughout the Central Belt the

Brallier maintains its monotonous lithic characteristics of olive-weathering shale interbedded with sharply bounded, blocky-weathering siltstones. Dennison (1963) reports a thickness of 2,000 feet at Corriganville, Maryland, and 1,300 feet at Scherr, Grant County, West Virginia. As before, we use the lowest distinct siltstone as the base of the Brallier. However, in the Central Belt the contact with the underlying Harrell Shale is gradational.

In the Western Belt (and in the southwest part of the central belt in parts of West Virginia and Virginia) the Brallier Formation directly overlies the Millboro Shale in both subsurface and certain outcrops. As in the other belts, the Brallier consists of shale and siltstone, and we have used the lowest recognizable siltstone in well sample descriptions as the base of the Brallier. Of course, the characteristic sharply-bounded nature of Brallier siltstones is not detectable in well cuttings, and there are no cores through the Brallier in the area of our investigation.

#### Harrell Shale

The Harrell Shale was named by Butts (1918) for exposures at Horrell Station in Blair County, Pennsylvania, on the Petersburg Branch of the Pennsylvania Railroad. The name was apparently transcribed with a spelling error; the location of the now-demolished station is given as Horrell on the Hollidaysburg-Huntingdon folio (Butts, 1945), and the stationmaster at Hollidaysburg assured Hasson in 1965 that the name had always been Horrell. However, the spelling Harrell is a well-established geologic name, and that spelling should be retained; it is now official usage of the Maryland Geological Survey for part of the Jennings Formation (a formation name now abandoned) and by the West Virginia Geological and Economic Survey for rocks previously termed Genesee.

The Harrell Shale crops out in the fold belts east of the Allegheny Front, averaging about 150 feet (46 m) in thickness in the central part of the outcrop area, but thins and grades eastward into coarser clastics of the upper part of the Mahantango Formation and the basal Brallier Formation. In the subsurface west of the Allegheny Front and to the southwest along strike, the Harrell passes laterally into the thicker and generally darker mass of the Millboro Shale and is not separable as a distinct formation.

The Harrell Shale consists of very dark gray, thinly laminated, platy- to sheety-weathering shale underlain in certain areas by the grayish black shale of the Burket Member. The Harrell is everywhere overlain by the olive shales and siltstones of the Brallier Formation and is underlain in certain areas by the Tully Limestone, or in others (especially where the Tully is absent) by the Middle Devonian Mahantango Formation.

Within the general field conference area there are three distinct divisions within the Harrell: a basal Burket Member, a middle very dark gray shale portion, and an upper zone transitional with the Brallier.

The contact between the Harrell and Brallier is gradational, forming a zone averaging 25 feet (8 m) thick in the outcrop area (Hasson, 1972). The lowest distinct siltstone is considered the Brallier-Harrell contact. Below this siltstone the Harrell resembles the shale within the Brallier, but lacks the interbedded siltstones. In this transition zone the Harrell is thickly to



thinly laminated, somewhat silty, and weathers to olive or light olive gray plates and chips. Silt content in this zone increases upward, and the shales become more thickly laminated, flaggy plates.

Below the transitional zone and above the Burket Member, the main mass of Harrell Shale is very dark gray, thinly to thickly laminated shale which weathers to yellowish gray plates and sheets. The formation changes facies and thins eastward, and the Harrell is not a mappable unit in the Eastern Belt of outcrops in Fulton and Washington Counties.

Figure 3 is an isopachous map of the Harrell Shale within the field conference area, with all formal and informal members combined.

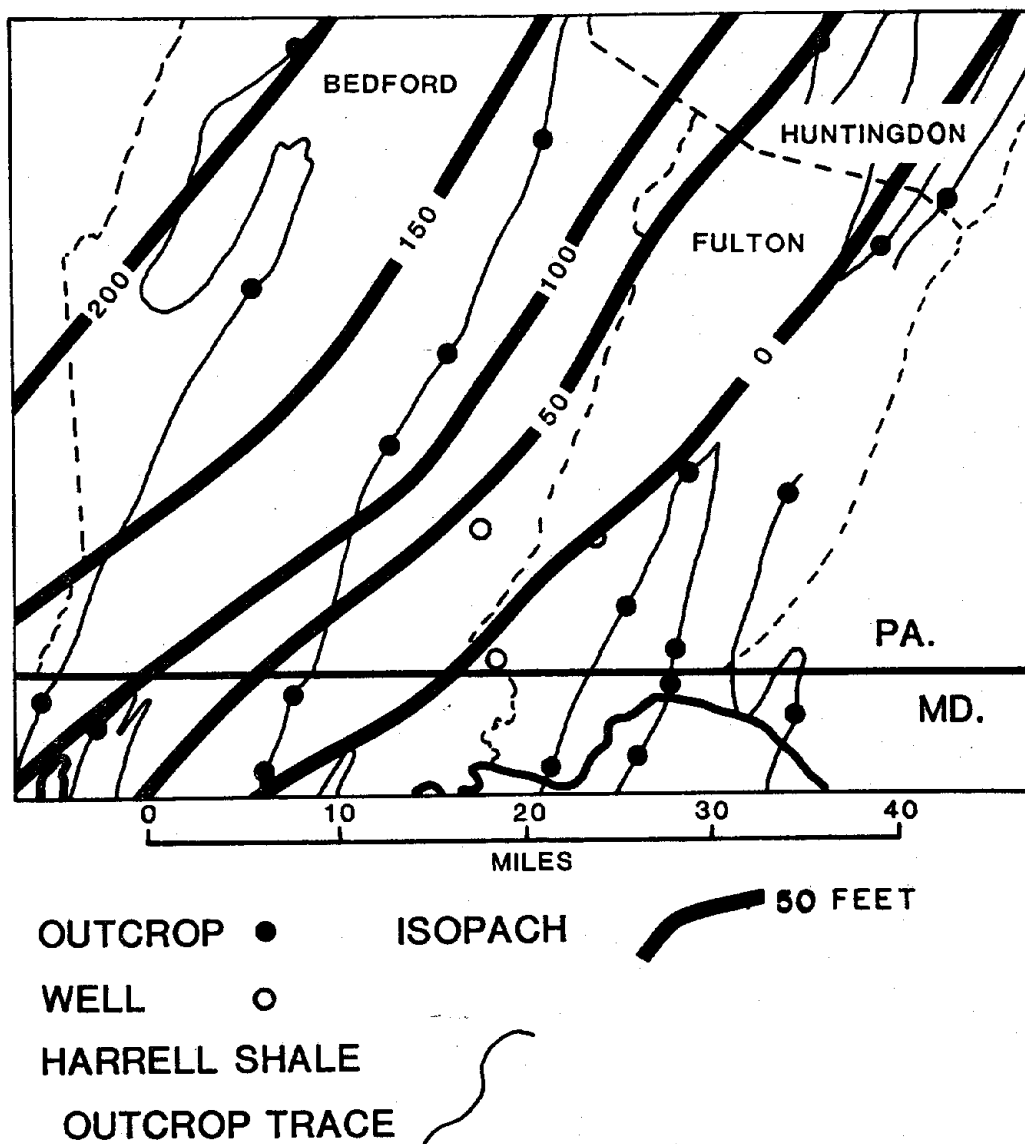


Figure 3. Isopachous map of the Harrell Shale in the field conference area in Pennsylvania and Maryland. The zero isopach outlines the configuration of Perry Bay dark shale sediments and the distal margin of the Fulton Lobe.

## Burket Member

In the same paper in which he named the Harrell Shale, Butts (1918) also designated a basal black shale as the Burket Member of the Harrell Formation. The name is taken from Burket, an Altoona suburb which no longer exists as a separate entity. At Horrell Station, Blair County, Pennsylvania, the Burket is about 83 feet (25 m) of grayish black, platy-weathering, thinly laminated shale resting on the Tully Limestone. Where the Tully is absent or higher in the black shale, the Burket rests on the Mahantango.

The Tully Limestone has been identified (Dennison and Naegele, 1963; Hasson, 1966) as occurring within rather than at the base of the Harrell Shale in certain western outcrops of West Virginia and Maryland. The pre-Tully Harrell Shale (Burket Member) is replaced eastward by Mahantango silty shale. We prefer to extend the use of the Burket Member down to the base of the readily mappable black shale, whether its base occurs at or beneath the difficult-to-map, thin to nodular Tully Limestone in outcrops. The Burket is all post-Tully in the Altoona area south to the vicinity of Bedford, at which location there are a few feet of black shale immediately below the Tully. From there southward to West Virginia the base of the black shale (Burket Member in our nomenclature scheme) drops progressively farther beneath the Tully horizon.

In western outcrops we thus use the name Burket for black, fissile shale either above or below the Tully Limestone or concretions. We have not been able to recognize on a lithologic basis a distinct Burket blacker shale in wells west of the Allegheny Front, so we can separate the Burket Member only in the area in which the Harrell crops out. The eastward disappearance of the Burket coincides with the general configuration of Perry Bay. Apparently the post-Tully Burket grades eastward into the main mass of the lighter-colored Harrell; Butts (1945) earlier noted that the Burket and Harrell alternate east of Tussey Mountain and that these units cannot be separated in that area. We agree with that conclusion.

Southwestward along strike in the Central Belt, the Burket descends beneath the Tully concretions, bed, or Member so that the base of the Burket rests almost down on the Clearville siltstone horizon or the immediately overlying few feet of limestone or calcitic shale of the Pokejoy Member (Hasson and Dennison, 1974) of the Mahantango Formation.

## Tully Limestone

The first report of Tully Limestone in Pennsylvania was by Butts (1918) who identified a foot of limestone containing Chonetes aurora beneath the Burket Shale at Horrell Station as the Tully. Chonetes aurora is considered a Tully guide fossil. A more thoroughly documented Tully occurrence in Pennsylvania was described by Willard (1934), who later expanded the number of known Tully localities in Pennsylvania (Willard, 1935b). In Pennsylvania the Tully is a mappable unit from Bedford northeastward along the Allegheny Front (Heckel, 1969). To the east and southeast in Pennsylvania and Maryland, the Tully is a concretion zone at the base of the Harrell Shale. In extreme eastern outcrops the Tully has entirely disappeared, apparently by facies change into shale. The eastern pinchout of the Tully and Burket parallels the configuration of the southern margin of Perry Bay and the northern distal marine edge of the Fulton Lobe at the time of the Taghanic onlap.

Tully occurrences at the base of the Harrell in Pennsylvania are at Peru Mills, Juniata County, Huntingdon, Huntingdon County, and Eichelbergertown, Bedford County (STOP 7). Bedded Tully occurs at Horrell Station, Blair County, but it is deeply weathered. Hasson recovered limestone containing Chonetes aurora at the Tully position at Horrell Station in 1965 and is satisfied that this is the same unit described by Butts (1918). Other occurrences in Blair County are at Newry and Klahr. In Bedford County the Tully is exposed at Imler and along the Pennsylvania Turnpike west of Bedford (supplementary locality A).

In Maryland a possible Tully bed or concretion zone occurs at Wolfe Mill (STOP 4), Corriganville, Dawson, and McCoolle, all in Allegany County.

#### Mahantango Formation

The name Mahantango Formation was introduced by Willard (1935a) to include the strata between the Marcellus Shale and the Portage Group (now called the Brallier Formation), and is equivalent to the Skaneateles, Ludlowville, and Moscow Formations of the New York outcrop belt. Willard introduced the term because he could not recognize separately the three New York formations in the upper Hamilton Group within Pennsylvania.

The name is taken from the North Branch of Mahantango Creek, Snyder and Juniata Counties, Pennsylvania.

The Mahantango Formation consists of very thickly laminated, perhaps even structureless (bioturbated) silty shale with considerable interbedded siltstone, some sandstone in the extreme east and minor limestone in the west. The name Mahantango replaces Hamilton Formation of earlier geologic reports and is now the official terminology used by the geological surveys of Pennsylvania, Maryland, West Virginia, and Virginia. There are three distinct siltstone units within the Mahantango Formation of the field conference area, and their recognition and correlation constitute the crux of Mahantango stratigraphic problems.

The Mahantango in eastern outcrops is thicker and coarser than to the west because of proximity to the source and approximate coincidence with the axis of the Fulton Lobe. According to the nomenclatural scheme we prefer, in descending order the Mahantango in eastern outcrops consists of an unnamed olive silty shale, the Clearville siltstone member (an informal unit), another unnamed shale, an unnamed siltstone, the Frame Shale Member, the Chaneyville Siltstone Member, and the Gander Run Shale Member. In easternmost outcrops the Mahantango is bounded below by the Marcellus Shale and above by the Brallier Formation. In the extreme east the Clearville becomes conglomeratic sandstone.

The Mahantango Formation of the Central Belt of outcrops consists of silty, thickly laminated, olive-weathering shale with interbedded siltstone and some limestone. Typically the shale weathers to chips, lumps, and splinters, although spheroidal weathering is not uncommon. Southwestward along strike, the Mahantango is replaced from the base upward by grayish black Marcellus Shale; the southwest terminus of silty shale of the Mahantango defines the cutoff between the Millboro and Mahantango Formations as mapping units. The Mahantango also disappears by facies change to the west, and the westernmost silty shale unit marks the Mahantango-Millboro cutoff in the subsurface.

The downward stratigraphic succession in the Mahantango is similar to that described for the Eastern outcrop belt, except that in the Central Belt all units thin and become finer-grained to the west and southwest, and the Pokejoy Member limestone is introduced into the section in the western part of the field conference area.

#### Unnamed Shale Member

Typically the unnamed shale member of the upper Mahantango is silty and weathers into olive to light olive gray lumps and chips. Lamination is generally lacking or poorly developed. This unnamed shale becomes more silty to the east. In the Central Belt beneath the Tully in the area north from Bedford, or beneath the Burket from Bedford southwest along strike, the uppermost Mahantango Formation consists of silty, olive weathering shale similar to that described for the eastern belt, but not as coarse. This olive-weathering shale is quite thin in the vicinity of Wolfe Mill, Maryland (STOP 4); most of the upper part of the shale changes southwestward to grayish black Burket Shale in the outcrop belt along the Allegheny Front.

#### Pokejoy Member

The Pokejoy Member (Hasson and Dennison, 1974) is a very fossiliferous limestone, calcareous shale, or coralline biostromal limestone which occurs just above or on the Clearville siltstone in parts of West Virginia, western Maryland, and Pennsylvania. It is named for its occurrence at Pokejoy Run, Mineral County, West Virginia. The type section was described by Hasson (1966) and Hasson and Dennison (1974).

The member has several lithologic aspects, as noted above, but is consistent in its stratigraphic position as a calcareous unit at or near the top of the Clearville. The areal extent of the Pokejoy Member appears to be limited to the central and western portion of the silty shale or siltstone of the Clearville member.

#### Clearville Siltstone Member

The Clearville siltstone informal member (Cate, 1963) is the uppermost of the prominent siltstones in the Mahantango Formation. The Clearville passes into silty shale with westward facies change, and this silty shale forms the most westward extension of the Mahantango Formation; its subsurface disappearance to the west into black shale defines the westernmost recognizable Harrell Shale, in addition to the western limit of the Mahantango. The Clearville was specifically defined by Cate as the uppermost of two siltstones present in the upper Mahantango of the subsurface of the Clearville, Pennsylvania, quadrangle. An outcrop standard reference section of the Clearville has never been described formally, but we recommend the exposure in Chaneyville (STOP 5) for such a reference section. There the 44 feet (13.4 m) of Clearville siltstone is separated from the 80 feet (24.4 m) of lower unnamed siltstone by about 110 feet (34 m) of silty shale. The lower siltstone and intervening shale are as yet unnamed; the Clearville siltstone has not been formally named, either. We recommend formalizing these three units by establishing a type section and giving them proper stratigraphic names, in order to prevent further confusion and to ease communication. For example Ellison (1965, pl. 2) included both siltstones and the intervening shale as "Uppermost (Clearville) siltstone" and

also placed these beds in the Frame Shale Member. Obviously there is need for clarification of upper Mahantango stratigraphy.

The Clearville siltstone in the Allegheny Front outcrop belt grades laterally westward into grayish black Millboro shale in the subsurface west of the Allegheny Front. The unnamed shale member and the unnamed siltstone member beneath the Clearville also both grade laterally into the Millboro.

#### Frame Shale Member

The Frame Shale Member of the Mahantango was named by Willard (1935c) for Frame School, about 6 miles north of Chaneyville, Bedford County, Pennsylvania. He described the Frame (p. 1279) as "gray or olive sandy shale which carries thick local sandstones and an occasional thin limestone lens." This seems to imply that the Clearville and the other unnamed siltstone in the upper Mahantango were consciously included in the Frame as defined by Willard. Willard never described separately the uppermost siltstone subsequently designated as Clearville by Cate. The Frame Shale, as defined by Willard, extends upward to the base of the Tully, Burket, or Harrell, and the Clearville is a member within a member, clearly a violation of the Stratigraphic Code.

We prefer to redefine the Frame Shale to restrict the Frame to the strata between the top of the Chaneyville Siltstone below and the base of the presently unnamed siltstone about 100 feet (33 m) below the Clearville siltstone as designated by Cate (1963) and illustrated by him in his Figures 2 and 3. The siltstone which we would have mark the upper limit of the Frame Member is also the lower of the two siltstones illustrated and identified as Clearville by Ellison (1965, pl. 2). Restriction of the Frame Member, as we suggest, allows maximum clarity in tracing stratigraphic horizons and avoids violation of the Stratigraphic Code; this is the procedure we followed previously (Dennison and Hasson, 1976).

The Frame Shale Member is a dark, silty shale tongue projecting into the Mahantango Formation from the black Millboro Shale or Marcellus Shale; the Frame is not as dark and is more silty in the east and northeast than the lithology of the Millboro or Marcellus black shale.

#### Chaneyville Siltstone Member

The Chaneyville Siltstone (Willard, 1935c) was named for exposures at Chaneyville, Bedford County, Pennsylvania. The unit was originally designated as Chaneyville Sandstone, but the work was done at a time when all massive clastic units were called sandstone, and the word siltstone was not used as a separate descriptive term in the stratigraphic literature. The Chaneyville was originally described by Willard (1935c, p. 1279) as "...hard, olive-gray, brown-weathering platy to submassive sandstone...." The Chaneyville does not extend as far west into the Appalachian basin as the Clearville siltstone, and the Chaneyville is limited to the Fulton Lobe (Dennison, 1970, p. 66; 1971, p. 1181; Dennison and deWitt, 1972). From Mineral County, West Virginia northward into Pennsylvania the Chaneyville Siltstone pinches out a few miles west of the Allegheny Front. Bedding within the Chaneyville tends to be irregular and indistinct.



### Gander Run Shale Member

The Gander Run Shale is the lowest member of the Mahantango Formation and was named by Willard (1935c) for Gander Run, a stream 6 to 8 miles north of Chaneyville, Bedford County, Pennsylvania. It was originally described as a dark gray, sandy shale, but more properly should be termed a silty, gray shale. A thickness of 850 feet is given by Willard for the member in the type area.

The silty, olive-weathering shale of the Gander Run Member is replaced from the base upward by the grayish black Marcellus Shale both southwest along strike in West Virginia and Virginia and to the west in Maryland and Pennsylvania. Along strike to the southwest, the Frame and Gander Run Members merge into the Marcellus Shale because the Chaneyville pinches out and the two shales are not separable without the coarse wedge of Chaneyville to divide them. The merging of the Frame and Gander Run occurs also in the subsurface west of the Allegheny Front; silty shale persists a few miles westward from the Allegheny Front, and changes facies into black Marcellus or Millboro Shale.

### Marcellus Shale

The Marcellus Shale (Hall, 1839) is the lowest formation of the Hamilton Group in New York; in the eastern Pennsylvania outcrop belt it underlies the Gander Run Shale Member and in the west the Marcellus occurs below the silty shale which forms the basinward projection of the upper part of the Mahantango Formation. Characteristically, the Marcellus is grayish black, thinly laminated, platy- to sheety-weathering shale. The Marcellus noticeably coarsens and becomes lighter in color toward the easternmost outcrops, but continues to classify generally as a black shale.

Along strike to the southwest the blackish Marcellus Shale increases in thickness at the expense of the gray silty shale of the Gander Run Member, replacing that unit from its base upwards. However, where the Mahantango silty shale is no longer present, the Marcellus cannot be recognized as a separate formation, and the entire interval of blackish shales is appropriately designated the Millboro Shale. This same relationship is true across strike also, so that the Marcellus is not separable from the Millboro west of the Mahantango pinchout in the subsurface or in southern outcrop belts.

### Purcell Member

Within the Marcellus is an interval of calcitic shale and limestone which was designated informally by Cate (1963, p. 232) as the Purcell limestone. The term "Purcell Member" seems more appropriate because of the mixed lithology. The Purcell is present almost continuously from central Pennsylvania south to Montgomery County, Virginia, and forms a convenient marker within the Marcellus and Millboro Shales. Dennison has traced the Purcell in the subsurface across Pennsylvania to New York, where the Stony Hollow calcareous siltstone and the Cherry Valley Limestone are projections into the New York exposures of calcareous strata equivalent to the Purcell of the Central Appalachians.

The Purcell member is present within the Marcellus in the Eastern and Central Belts of outcrops and in the Broadtop synclinorium. Within this area the Purcell maintains a remarkable parallelism to the Tioga Bentonite about a hundred feet below the Purcell, suggesting that the Purcell approximates an isochronous band of strata.

Westward in the subsurface the Purcell disappears one or two counties west of the Allegheny Front and is absent in wells farther west.

### Millboro Shale

The name Millboro Shale was proposed by Butts (1940, p. 309) as a mapping unit in Virginia where he could not recognize and separately designate the Marcellus-Naples interval of the Romney Formation (Tioga Bentonite to the base of the Brallier as used here). Butts was careful to specify that the term Millboro was applicable only in the areas where the silty shale of the Mahantango (Hamilton in Butts' nomenclature) was absent, and the dark shales could not be subdivided in mapping. The formation is named for Millboro Springs, Bath County, Virginia, where it is at least 1,325 feet thick and may reach 1,827 feet, depending on the structural character of the rocks in a covered interval at the base of the type section.

In the subsurface the Millboro is all black shale in sample descriptions, with no recognizable Mahantango influence to separate a Harrell and Marcellus interval. The Millboro is thickest immediately west of the Allegheny Front and thins westward. Analysis of gamma ray curves may permit projection of an internal stratigraphy within the Millboro, but this is difficult to relate precisely to outcrop characteristics of the black shale.

### Tully Member

The Tully in the area occupied by Millboro Shale is considered by us to be a member of the Millboro, since it is a thin, traceable lithosome within the black shale sequence of the Millboro Formation. In the subsurface the Tully is a bedded limestone and serves as an excellent marker bed for the driller.

The Purcell Member can also be recognized in outcrop and in the subsurface locally within the Millboro Shale Formation. At a few sites (as at Bullpasture Mountain, Highland County, Virginia), we also can designate the Pokejoy and Landes bedded limestone to concretionary limestone zones within the Millboro.

### Tioga Bentonite

The Tioga Bentonite is an ash fall characterized by 3 sand-size tuffs within a 2-foot (0.6 m) interval in the field conference area. This middle coarse zone occurs at the boundary between the Needmore and Marcellus Shales in the north and at the boundary between the Needmore and Millboro Shales in the south in parts of Virginia and West Virginia. The Tioga ash fall normally produces a brownish (tuffaceous) shale through an interval of about 15 feet (5 m) in the field conference area; this brownish shale commonly contains a fossil hash dominated by *Ambocoelia* and *Styliolina*. The brownish coloration extends for several feet above and below the Tioga middle coarse zone into the adjacent shale formations. In addition to the middle coarse zone, a single 0.1 foot or thinner bed of sand- to silt-size tuff occurs in Pennsylvania and Maryland outcrops, generally about 10 feet (3 m) below the Tioga middle coarse zone, and well within the zone containing brownish, tuffaceous shales admixed with the upper Needmore calcitic shale and limestone facies. This lower, single tuff bed is probably the stratum that has been identified as the "second Tioga" in some wells in New York and northern Pennsylvania.

The Tioga Bentonite is present both in outcrop and subsurface. Over 120 outcrops have been identified in the Appalachians by Dennison. The Tioga has been identified in hundreds of Appalachian basin wells in New York, Ontario, Ohio, Pennsylvania, Maryland, West Virginia, and eastern Kentucky. The conspicuous biotite in the tuff is diagnostic, and the Tioga tuffs produce a distinctive high peak on gamma ray well logs. The Tioga Bentonite is also known in wells in the Illinois basin (Indiana, Illinois, and western Kentucky), and it is probably the Middle Devonian Kawkawlin Bentonite which occurs in the Michigan basin.

The thickness and grain size of the Tioga tuffaceous beds increase eastward, and the source volcano was apparently in the central Virginia Piedmont near Fredericksburg (Dennison and Textoris, 1977).

#### Needmore Shale

The Needmore Shale occurs below the Tioga Bentonite along the Allegheny Front and in all of the Valley and Ridge outcrop belts of the field conference area. In Pennsylvania and Maryland the Needmore overlies the Oriskany Sandstone. To the west the Needmore changes facies into the Huntersville Chert in Virginia outcrops, in West Virginia outcrops and subsurface, and in the subsurface of Maryland and southern Pennsylvania.

In the field conference area three lithologic divisions of the Needmore are readily recognizable. The upper half is called the calcitic shale and limestone facies. It consists mostly of calcitic, medium dark gray, thickly laminated shale which weathers light olive gray and chippy; interbedded with 10 to 20 percent of dark gray limestone in uniform-thickness beds 0.2 to 1.0 feet (0.06 to 0.3 m) thick, which weather to yellowish gray stripes on outcrop. This is a southward extension from the purer limestone known as the Selinsgrove Limestone of north-central Pennsylvania and from the Onondaga Limestone of New York, greatly diluted by shale admixture from a detrital clastic source centered in northeastern Virginia. The calcitic shale and limestone facies is very fossiliferous, with an aerobic fauna (see separate paper by Cathryn Newton in this guidebook).

Downward in the section occurs 10 to 30 feet (3 to 9 m) of calcitic shale facies; this consists of calcitic, medium dark gray, thickly laminated shale which weathers light olive gray and chippy. Most of it is like the shale within the calcitic shale and limestone facies, and has an aerobic fauna. Some of the calcitic shale tends to be thinly laminated and dark gray, with a disaerobic fauna. Strictly speaking, the notably darker shale at Newton Hamilton, Pennsylvania, which Willard (1939) designated the Beaver Dam Member of "black" shale at the base of the Needmore is actually slightly calcitic, disaerobic, and definitely not as black as shales in the lower Needmore of southwestern Bedford County, Pennsylvania (STOP 2), and parts of Maryland, West Virginia, and Virginia. Inners' (1975) use of the Beaver Dam as a lithologic subdivision is probably a real and traceable darker subdivision of the lithology which Dennison (1961) called calcitic shale subfacies south of Pennsylvania.

At the base of the Needmore is western Bedford County, Pennsylvania and Allegany County, Maryland there occurs a truly grayish black, thinly laminated, noncalcitic shale which weathers yellowish gray and platy. This is the black shale facies of the Needmore, to which Dennison (1961) applied the designation

Beaver Dam Black Shale Member prior to examining closely the type exposure of the Beaver Dam in Pennsylvania. This black shale is really quite different from the shale at Beaver Dam, so Dennison now prefers to designate it as simply "black shale facies" of the Needmore. The black shale facies has an aerobic fauna, is noncalcitic, and dark in color compared to the type exposure of Beaver Dam Shale at Newton Hamilton, Pennsylvania. The black shale facies of the Needmore superficially resembles the Marcellus Shale and the Burket Member of the Harrell Shale, but the Needmore black shale facies is slightly more thickly laminated and weathers into stiffer plates than weathered fragments of the Marcellus and Burket shales.

In western outcrop belts chert nodules to bedded chert occur at the top of or at the base of the black shale facies. These represent tongues of Huntersville Chert extending from the west. The chert nodule zone to bedded, shaly chert along the Allegheny Front at the top of the black shale facies can be traced from about 6 miles north of Bedford (supplementary locality A) continuously to U. S. Route 250 in Highland County, Virginia, for a distance of 132 miles. The chert at the base of the Needmore is known along the Allegheny Front outcrop belt only near Scheer, Grant County, West Virginia, and in Bedford County, Pennsylvania, 6 miles north of the Bedford Interchange of the Pennsylvania Turnpike; these localities are separated by 76 miles. In wells just west of the Allegheny Front the chert zone at the base of the Needmore is readily traceable, however. It is not clear whether the chert at the base of the unusually thin Needmore section at Grazierville (in Blair County 2 miles south of Tyrone, Pennsylvania) represents the chert tongue within or at the base of the Needmore, since there is a strong possibility of a pre-Needmore unconformity at Grazierville.

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# STRATIGRAPHIC CORRELATION OF SURFACE AND SUBSURFACE MIDDLE AND UPPER DEVONIAN, SOUTHWESTERN PENNSYLVANIA

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## INTRODUCTION

This paper represents the use of gamma ray logs to correlate the subsurface Middle and Upper Devonian rocks of western Pennsylvania with the strata exposed at the surface in the south central part of the state. Previous investigations by Cate (1963) and by Dennison and Hasson (1976) utilized well-cutting data for subsurface correlations.

The gamma ray logging device is an extremely sensitive scintillometer-type of instrument capable of measuring minute changes in the natural low-level radioactivity of sedimentary rocks. As a result, stratigraphic determinations based on gamma ray logs rest on the radioactive response of the rock, rather than on its color, weathering quality, grain size, and other factors usually taken into consideration in lithologic studies. Because radioactivity is as much an inherent physical characteristic of the rock as is color or grain size, we feel that radioactive response is at least as effective for stratigraphic correlation and mapping as are the other parameters. Differences in correlation between the two techniques will naturally occur. We are convinced that for subsurface work the gamma ray log is in many ways superior to well cuttings because of problems involved in drilling, and with collecting and analyzing the lithologic samples. For best control, however, gamma ray logs and well-cutting data should be used in conjunction wherever possible. See Kelley (1969) for an explanation of the gamma ray log, its operation and usefulness.

Almost all of the natural radiation emitted by sedimentary rocks is due to the radioactive potassium ion ( $K^{40}$ ) found in feldspars, micas, clay minerals, and other common silicate minerals. Elements of the uranium-thorium series are also found in sediments in minor amounts and, to a lesser extent, contribute to the gamma ray response. Therefore, the gamma ray log generally reflects shale content because of the higher proportion of radioactive  $K^{40}$  ions in the clays which compose the shales. Non-shale (i.e. non-clayey) rocks such as "clean sandstones," carbonates and most evaporites have very small amounts of  $K^{40}$  and U-Th elements and may be differentiated from shales by their lower radioactive responses. Some marine black shales are anomalous in that they may have higher than "normal" radioactivity because, under the reducing conditions which allow for preservation of organic material, uranium ions have a tendency to accumulate and become concentrated in the organics in the mud.

We have used a system of cutoffs, shown in Figure 4, to define lithologies on gamma ray logs. A 100% shale base line is chosen where the log section is relatively homogeneously radioactive. A 100% sandstone base line is then picked



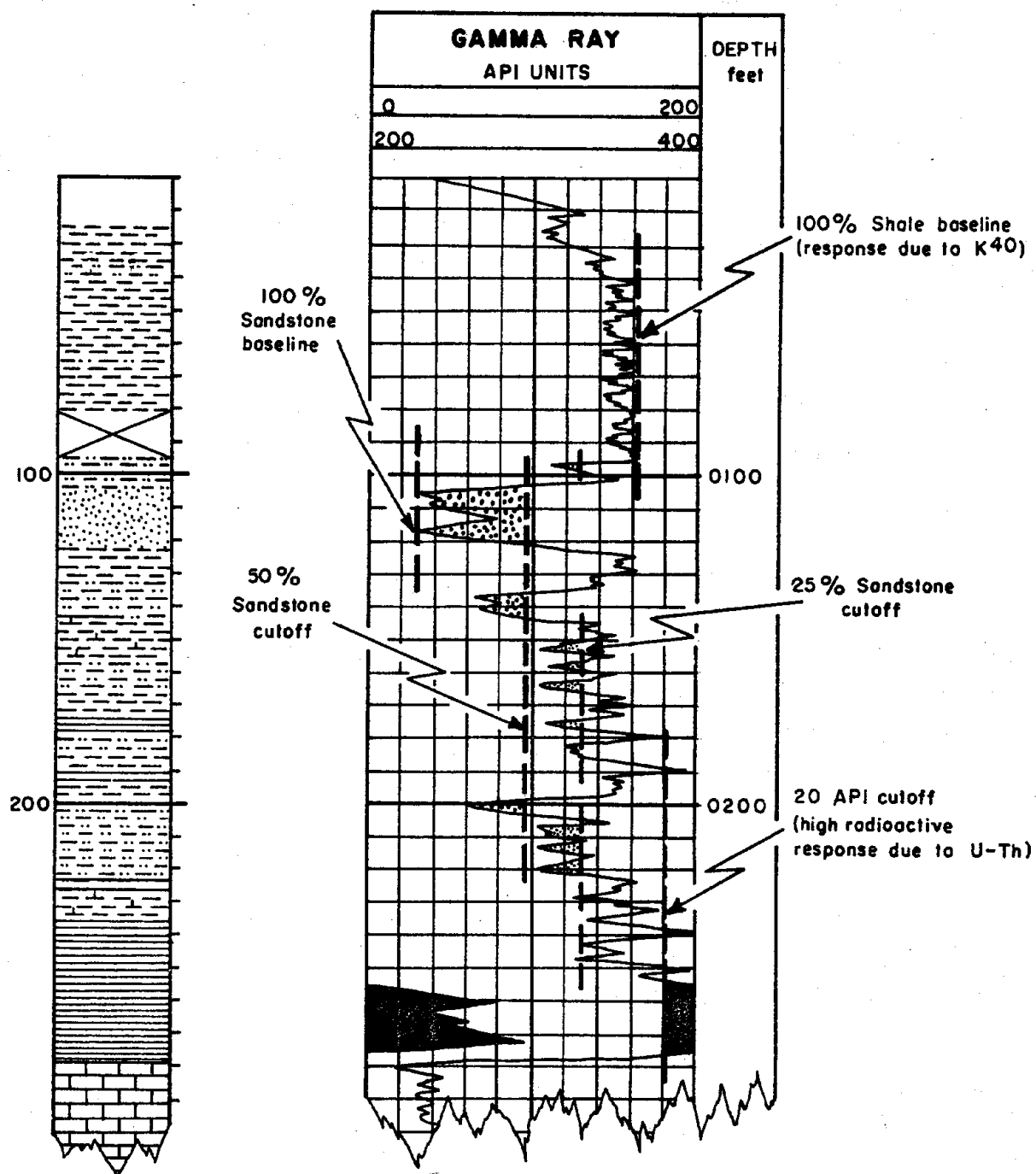


Figure 4. Portions of gamma ray and associated lithologic logs of hypothetical well showing procedure for determining radioactive shale, 50% clean sandstone (sandstone), and 25% clean sandstone (siltstone) cutoffs. See text for discussion. (From Piotrowski and Harper, 1979)

by assuming that the lowest response on the log (usually, in the Oriskany interval) represents a good "clean sandstone" or orthoquartzite. Because the gamma ray response is linear where  $K^{40}$  is the isotope affecting the log response, a sandstone, arbitrarily defined as 50% "clean sandstone," is chosen midway between the sand and shale endpoints. Siltstone is assumed to be midway between sandstone and shale in clay content and is therefore defined by a 25% sandstone cutoff. A radioactive (organic-rich) shale, such as the Marcellus, is picked where the response is greater than 20 API units above the shale base line (because U-Th isotopes are involved, this response is not linear). Carbonates and sandstones, and siltstones and calcareous shales, are indistinguishable on a gamma ray log; therefore, we have supplemented our gamma ray log studies with some lithologic data in the form of commercial sample logs (Geologs), published and unpublished sample descriptions, and driller's records.

#### ACKNOWLEDGEMENTS

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#### STRATIGRAPHY

Subsurface stratigraphic nomenclature used in this paper is taken from a regional investigation of the Middle and Upper Devonian organic-rich shales and Upper Devonian sandstones of western Pennsylvania (Piotrowski and Harper, 1979). Figure 5 is a schematic representation of the relationships in the subsurface Middle and Upper Devonian as we understand it, and correlations among surface and subsurface units in eastern Ohio, central and western New York, and south central Pennsylvania. Figure 6 represents an actual well section showing gamma ray and sample logs, illustrating our use of stratigraphic nomenclature in southwestern Pennsylvania.

#### Tioga Bentonite

The Tioga Bentonite has long been recognized as an excellent marker horizon within the subsurface Middle Devonian of Pennsylvania. Fettke (1952) also suggested that the Tioga was an isochronous boundary which could be used to establish the relationship between the Onondaga Group in Pennsylvania and New York to the Delaware and Columbus Limestones of Ohio. Recently, however, Conkin and Conkin (1975) and Collins (1979) have provided evidence that the "Tioga Bentonite" as reported from the subsurface might in reality be several essentially unrelated tuffaceous layers. This poses serious questions about the rigid stratigraphic utility of the Tioga in the subsurface.

Dennison and Hasson (1976) suggested that a large radioactive peak commonly occurring on gamma ray logs at the base of the Marcellus Formation corresponds to the Tioga Bentonite as seen in well cuttings. Although such a correspondence does occur in some wells from which both geophysical and lithologic logs are available, not all well sample descriptions indicate brown or gray, micaceous shale recognized at the same level as a high radioactive peak on the gamma ray log. This may be a result of collection procedure, lack of weathering, or any number of factors. We have not given a great deal of

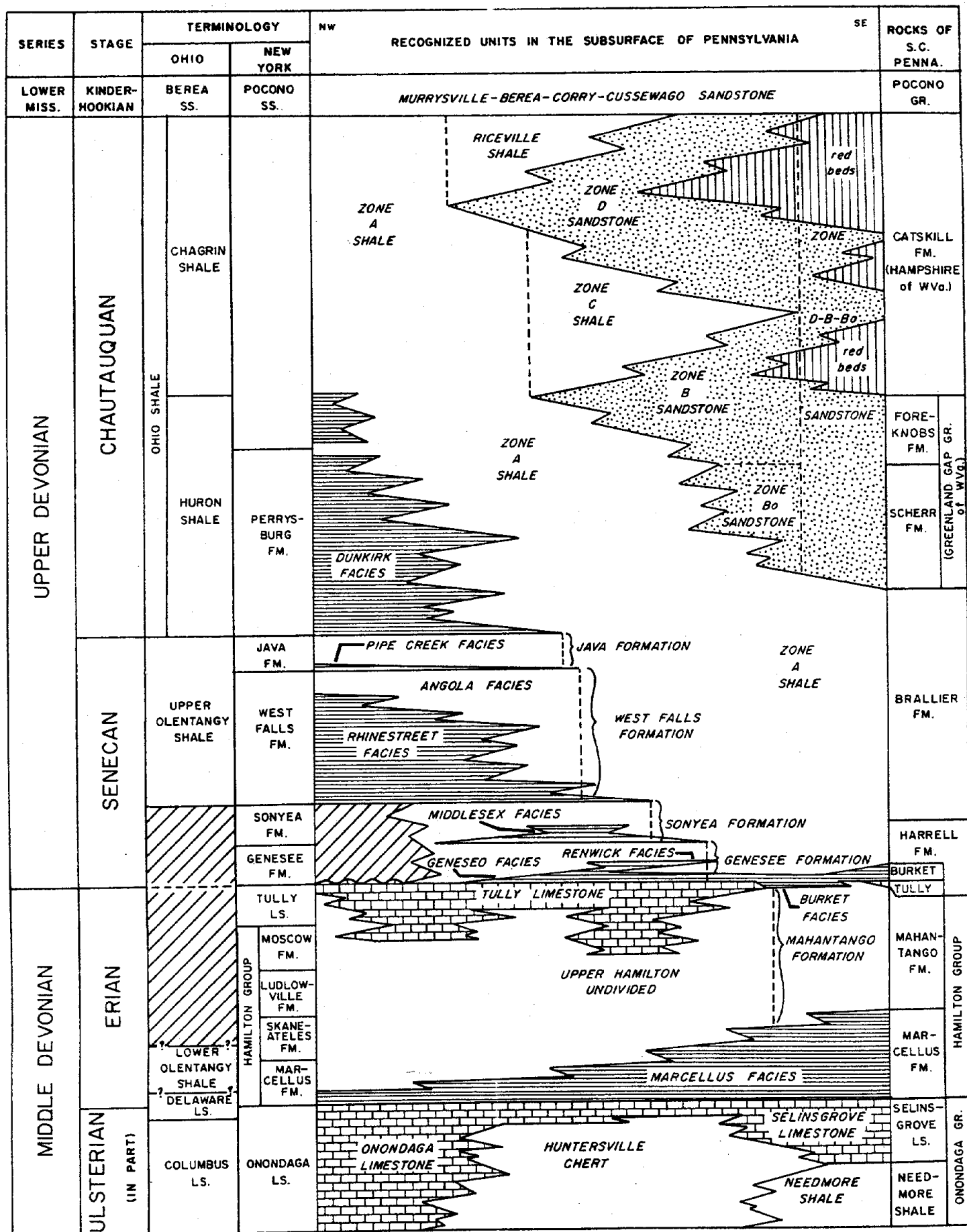


Figure 5. Schematic diagram of Upper and Middle Devonian stratigraphic units from the surface and subsurface of western Pennsylvania. (Adapted from Piotrowski and Harper, 1979)

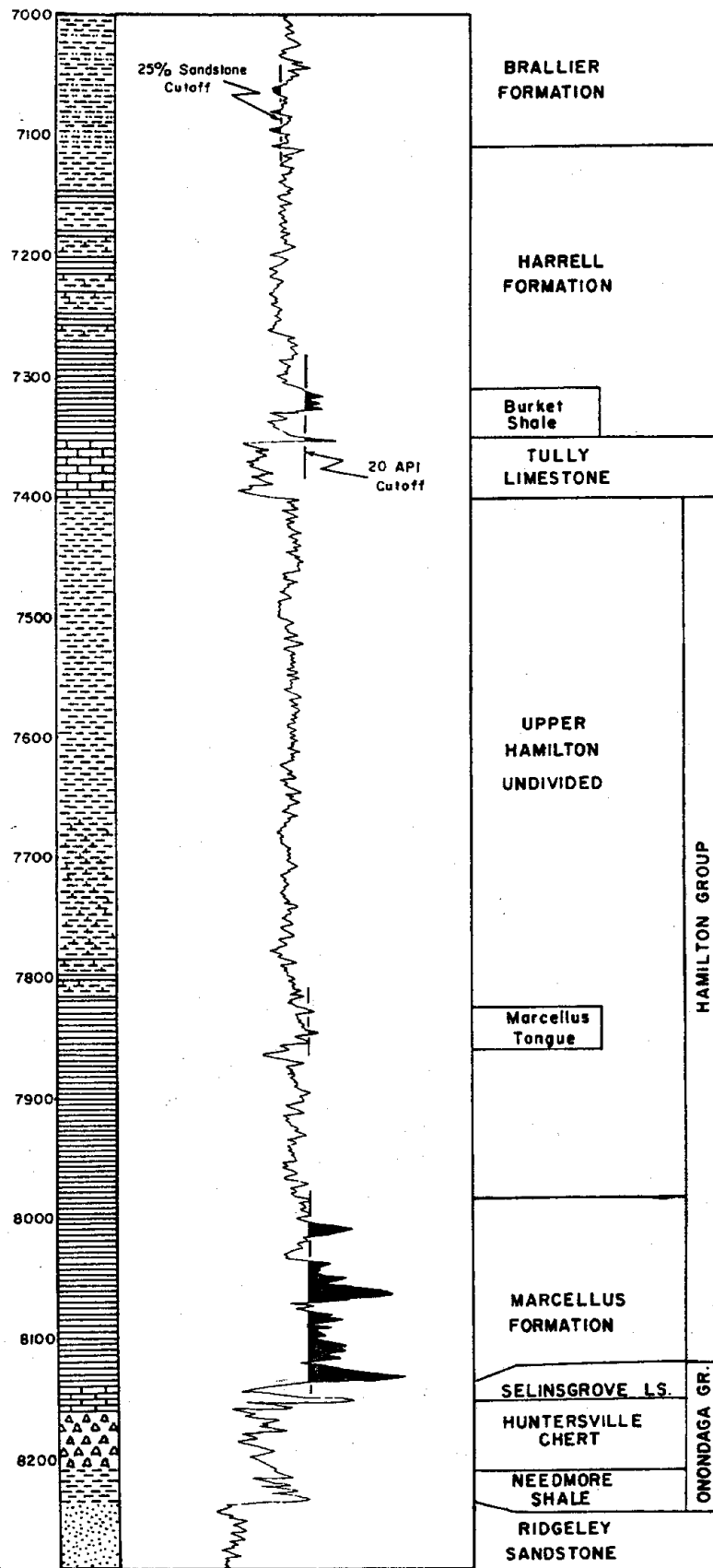


Figure 6. Example of gamma ray and associated lithologic log of well in south central Pennsylvania showing stratigraphic usage.

attention to this matter and can only recommend that further study be made to establish whether or not a bentonite invariably produces a high gamma ray peak.

### Hamilton Group

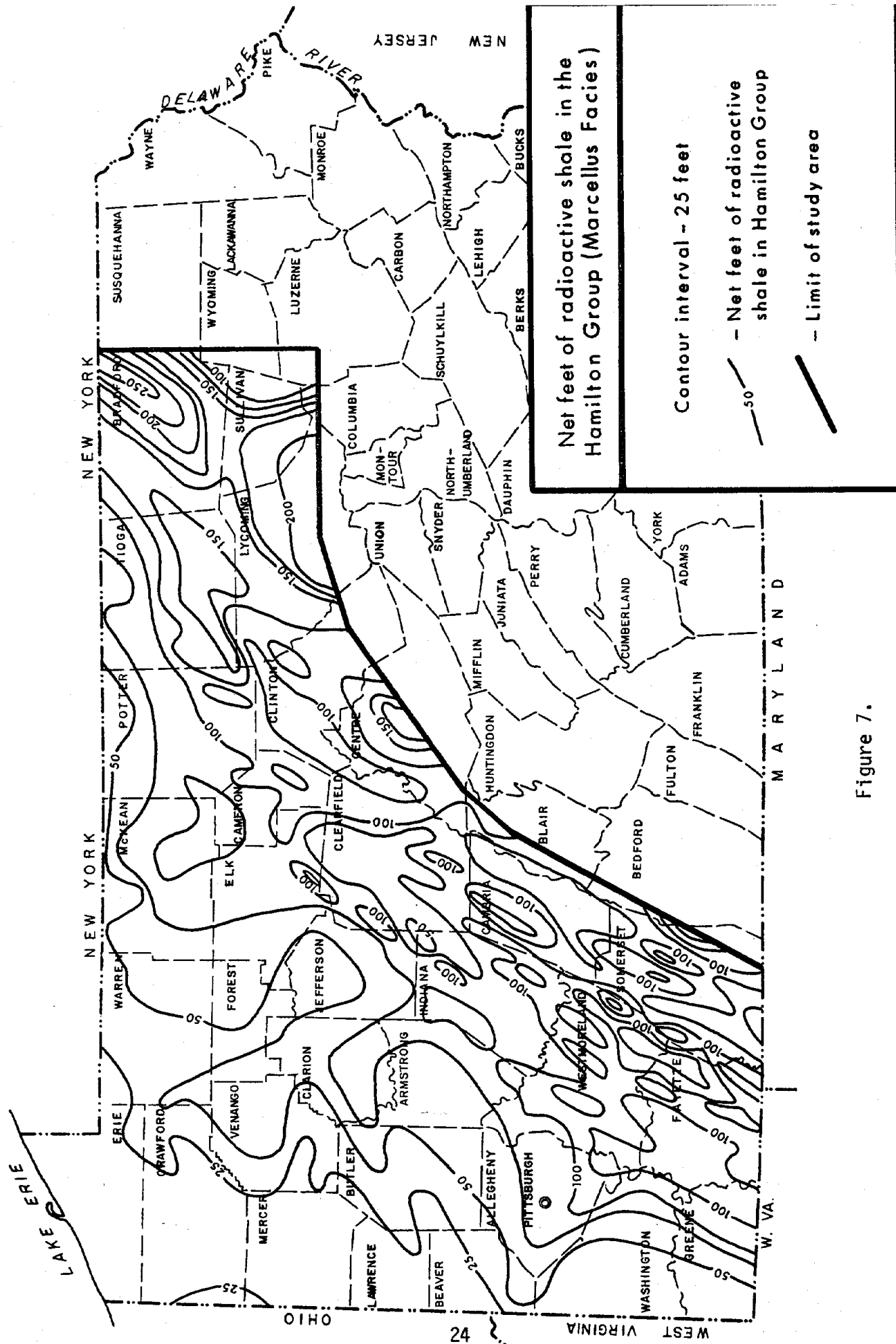
The Hamilton Group of New York is divided into four formations, the basal Marcellus, the Skaneateles, Ludlowville, and the uppermost Moscow (Rickard, 1975). These formations are apparently distinguishable to some extent in the subsurface as well as at the surface, but we have not yet attempted to make such a differentiation. In the past, we used the term "Marcellus facies" or "Marcellus Formation" for all of the strata in the lower portion of the Hamilton having higher than normal gamma ray responses, and "Mahantango Formation" for the upper, non-radioactive part of the Hamilton (Piotrowski and Harper, 1979). We now realize that the name Mahantango should be restricted to the post-Marcellus interval of the Hamilton containing significant siltstones and sandstones, and we refer to the upper non-radioactive interval where siltstones and sandstones are not significant, in most of the subsurface, as "Upper Hamilton Undivided."

The name Millboro Shale was used by Dennison and Hasson (1976) for all of the strata from the top of the Tioga Bentonite to the base of the siltstones of the Brallier Formation in southwest Pennsylvania. This was based on the premise that these rocks, except for the intervening Tully Limestone, constituted a continuous black shale sequence. We cannot recognize color on a gamma ray log; therefore, we do not recognize a continuous and uniform lithology for the Hamilton Group and superjacent strata anywhere in the subsurface of Pennsylvania. We prefer not to use the name Millboro at this time for any of the subsurface strata north of the West Virginia-Pennsylvania border.

### Marcellus Formation

At the outcrop in New York, the Marcellus Formation consists mostly of black, fissile shale bounded by clearly recognizable marker horizons. Absence of these marker horizons in the outcrop in central Pennsylvania results in the name Marcellus being applied to an interval of more or less homogeneous black shales (Willard and others, 1939) which, in some areas, is probably equivalent to the Marcellus, Skaneateles, and basal Ludlowville Formations of New York (i.e., the Marcellus facies of Rickard, 1975, and Harper and Piotrowski, 1978). Because the black shale is not everywhere uniformly radioactive, the Marcellus as we define it in the subsurface does not exactly coincide with the outcrop-defined unit in thickness or extent (Figure 6), and may show a patchy distribution when mapped. For example, an isolith map based on net feet of radioactive shale (Figure 7) shows the Marcellus facies as a predominantly parallel series of isolated thick areas developed along structural trends (see Harper and Piotrowski, 1978, for discussion of this phenomenon).

A calcareous unit within the Marcellus in the subsurface of southern Pennsylvania is known as the "Purcell limestone" (Lytle and others, 1963). The "Purcell" may be continuously present in south central Pennsylvania (Cate, 1963; Dennison and Hasson, 1976), but to the west it gradually thins and loses its character between the Laurel Hill and Chestnut Ridge anticlines. Other, apparently noncontinuous carbonates are known from the approximate horizon of the "Purcell" in central Pennsylvania [White's "Upper Selinsgrove limestone" (Faill and others, 1978)] and from the subsurface of north Pennsylvania (Cherry



**Figure 7.**

Valley Limestone Member of New York), but there is no definite evidence linking these units to the "Purcell."

### Mahantango Formation

Willard (1935) found differentiation of the Hamilton Group strata overlying the Marcellus Formation in central Pennsylvania to be difficult, and he introduced the name Mahantango Formation to replace those of Skaneateles, Ludlowville, and Moscow. Lithologically the Mahantango Formation is predominantly shale, but it does contain significant sandstones and siltstones. Cate (1963) divided the Hamilton Group in the subsurface of Pennsylvania into the Marcellus and Mahantango Formations based on lithology -- shale belonged in the Marcellus, siltstone and sandstone belonged in the Mahantango. Because the coarser clastics were restricted to the eastern portion of the plateau area, the Mahantango was considered to be absent throughout most of the subsurface (the entire Hamilton interval in the western portion of the state was labeled "Marcellus Formation"). Dennison and Hasson (1976) also restricted the use of Mahantango to that sequence of post-Marcellus Hamilton strata containing siltstones and sandstones. Harper and Piotrowski (1978) placed no restrictions on the use of the name Mahantango, preferring to equate it with all of the Hamilton strata above the Marcellus, regardless of lithology. We now follow the terminology of Dennison and Hasson in restricting the Mahantango Formation to those strata of the Hamilton Group containing abundant siltstones, sandstones, and non-radioactive shales.

Willard (Willard and others, 1939) divided the Mahantango Formation of south central Pennsylvania into three members, the lower Gander Run Shale, the middle Chaneyville Sandstone, and the upper Frame Shale. Geologists studying well samples in Bedford and Somerset Counties in the late 1950's and early 1960's noticed a rather persistent siltstone unit in the upper part of the Hamilton (within Willard's Frame Shale Member), which they referred to as "Chaneyville Sandstone" (Lytle and others, 1963). Cate (1963) realized that this was not the Chaneyville of Willard and informally gave it the name "Clearville siltstone." Another siltstone unit below the "Clearville" is at present unnamed, even informally, but it contains a marker unit, some thin limey streaks, which has been called the "oolitic limestone." Lytle and others (1963) believed this limestone to be correlative with the Tully Limestone, but the work of Dennison and Hasson (1976) indicates that the Tully is equivalent to strata significantly higher in the section than the "oolitic limestone." Another limestone occurring in the interval between the Tully horizon and the "oolitic limestone" was named the Pokejoy Limestone Member by Hasson and Dennison (1974) who traced it in outcrop as far north as southern Blair County. However, we have not seen any positive indication of the Pokejoy on gamma ray logs from southern Pennsylvania. Most of the Mahantango Formation members, informal units, and marker beds can be recognized on a gamma ray log, although lithologic logs are needed to distinguish the "oolitic limestone" from the normally noncalcareous siltstone in which it occurs.

Dennison and Hasson determined that the "Clearville siltstone" is the westernmost siltstone of the Mahantango Formation. Our studies indicate that the "Clearville" extends only as far as the axis of the Negro Mountain anticline. Dennison and Hasson correlated siltstones in some wells in south-central Somerset County with the "Clearville." Our gamma ray log study indicates that the siltstone in question is actually stratigraphically higher than the



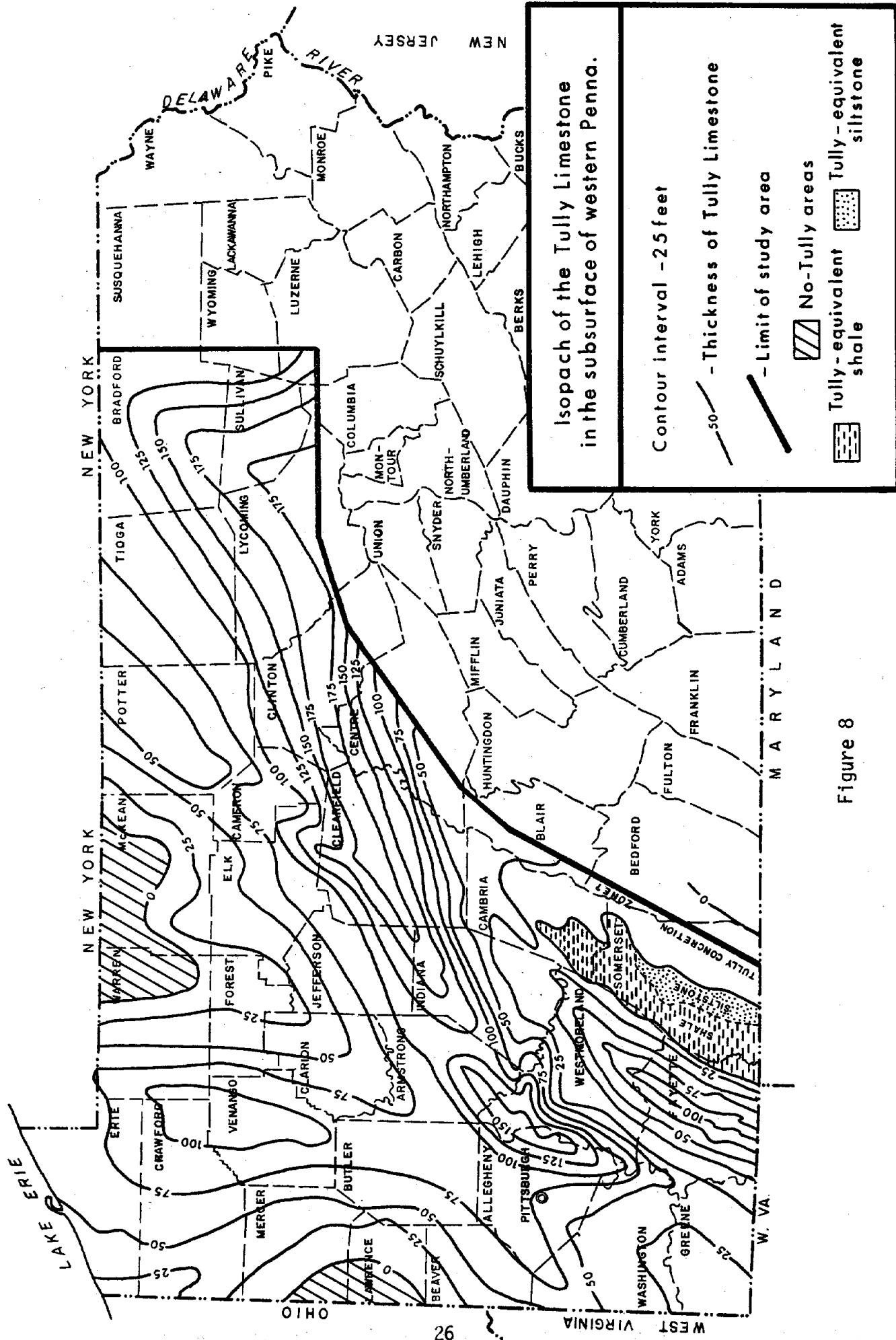


Figure 8

"Clearville" and is actually equivalent to the Tully Limestone which, in this area, is not developed as a carbonate. This siltstone development occurs along Negro Mountain anticline in central Somerset County (Figure 8) and represents the actual westernmost extent of the Mahantango coarse clastics. Because the siltstone as perceived on a gamma ray log disappears at this point, we draw the boundary between the Mahantango Formation and the "Upper Hamilton Undivided" approximately along the western flank of Negro Mountain.

### Tully Limestone

Fettke (1931) is apparently the first to have reported the presence of the Tully Limestone in the subsurface of Pennsylvania. Drillers who encountered the Tully in wells in Tioga County called it the "1000-foot lime" because it occurred approximately 1000 feet above the Oriskany Sandstone (Cathcart and Myers, 1934), and it was here that Fettke (Fettke, 1933) realized that the Tully is an excellent marker horizon within the monotonous clastics of the Middle and Upper Devonian. The Tully, with few exceptions, is not known to produce oil or gas, and has received very little comprehensive study.

Fettke (1935) reported that the Tully was absent in the subsurface west of Bradford in McKean County. He proposed that the prominent carbonate encountered at about the presumed level of the Tully in parts of northwestern Pennsylvania was in fact the Tichenor Limestone Member of the Moscow Formation of western New York. Jones and Cate (1957), using numerous deep well data to construct a combined isopach and lithofacies map of the Tully Limestone, included a thick (up to 125 feet thick in some areas) limestone in northwestern Pennsylvania in the Tully. Tesmer (1957), Kreidler (1963), and Wright (1973) determined that the "Tully" of drillers in southwestern New York is more correctly referred to limestones of the Hamilton Group, particularly the Tichenor, and that this absence of true Tully in southwestern New York can be extrapolated into northwestern Pennsylvania. Heckel (1969, 1973) accepted this premise and excluded the carbonates in Erie and Crawford Counties from his detailed studies of the Tully. More recently, Wallace and others (1977) have followed this example and correlated the limestone in northwestern Pennsylvania with the Tichenor of New York.

Our own studies of the Tully Limestone in the subsurface of Pennsylvania indicate that the thick limestone in Erie, Crawford, and Venango Counties is probably the Tully after all (Harper and Piotrowski, 1978; Piotrowski and Harper, 1979). The limestone is absent in broad areas of Warren and McKean Counties and in the western part of Lawrence and Mercer Counties (Figure 8). However, the limestone can be correlated in a dip section of gamma ray and lithologic logs from Erie County to the outcrop of the Tully Limestone in the south central part of the state (Louis Heyman, unpublished cross section, 1978). Apparently there was a carbonate platform or shelf in northwestern Pennsylvania during Tully time with a "hinge line" connecting the two "no-Tully" areas and forming a Tully "peninsula" perpendicular to regional strike. General thickening of the limestone in parts of Pennsylvania can be explained by accepting the Tully as being partially equivalent to the upper Hamilton Group in those areas; that is, that the Tully, Tichenor, and other limestones cropping out in New York are simply tongues of a thicker "Tully" carbonate unit in northwestern Pennsylvania. The distribution and thickness of the Tully across Pennsylvania can be seen in Figure 9.

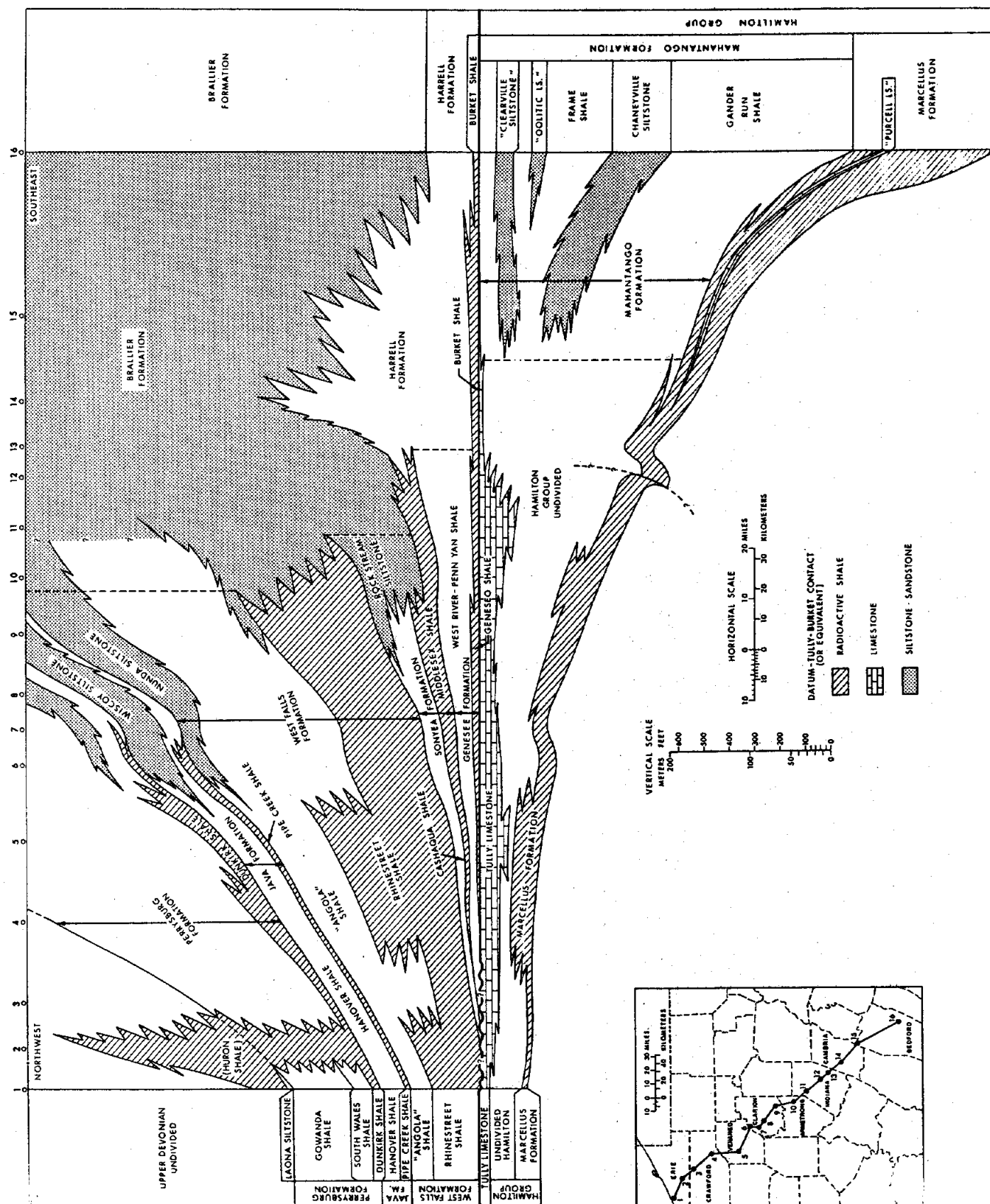


Figure 9. Stratigraphic cross section of western Pennsylvania showing lithologic relationships. Cross section based on gamma ray logs and associated sample descriptions from wells listed in Table 1.

X-Sec. No.	County	Company	Farm	Completed
1	Erie	Worldwide Petroleum	#1 Barney Estate	6/29/60
2	Erie	Columbia Gas Transmission	#1 Reichart-Horne-Foy	10/30/75
3	Crawford	Van Raalte Oil	#1 Tobin	3/16/76
4	Crawford	Columbia Gas Transmission	#1 Eager Beaver Lumber	10/21/75
5	Venango	Pennzoil	#348 Grant Fee	11/12/73
6	Clarion	Amoco Production	#1 Dunn-UNG	5/11/74
7	Clarion	Peoples Natural Gas	#1 Howard	3/ 4/76
8	Clarion	Fairman Drilling	#1 Amsler	9/14/65
9	Clarion	Peoples Natural Gas	#6 Fee	5/20/72
10	Armstrong	Peoples Natural Gas	#1 Wilson	10/ 2/71
11	Indiana	Peoples Natural Gas	#1 Beatty	11/ 3/67
12	Indiana	Delta Drilling	#1 Stewart	12/18/66
13	Indiana	Felmont Oil	#3 Clearfield Coal Co.	8/19/71
14	Cambria	Peoples Natural Gas	#1 Griffith	5/12/69
15	Bedford	Phillips Petroleum	#1 PA Tr. 26-B	7/ 3/61
16	Bedford	New York State Natural Gas	#1 R. Morris	11/ 9/60

Table 1. List of wells supplying gamma ray logs and sample descriptions used to construct Figure 9.  
All information from these wells is in the files of the Pennsylvania Geological Survey,  
Oil and Gas Geology Division.

In southwestern Pennsylvania, the Tully presents several problems which have not yet been resolved. Figure 8 shows an anomalously thickened zone of Tully extending in an almost straight line from Bradford County to Allegheny County. Jones and Cate (1957) show essentially the same feature based on well cuttings. We offer no geologic explanation for this feature because it crosses several major structural features without apparent deviation. If this feature is actually a result of poor control, it could represent a series of parallel thickened areas developed on the anticlines, similar to the distribution of the Marcellus (Figure 7).

The thick Tully area in Fayette and Westmoreland Counties (Figure 8) on the other hand, is not a result of poor control. We (Piotrowski and Harper, 1979) have speculated that this thickened area is the result of carbonate buildup on a tectonically active Chestnut Ridge anticline. To the east of this area, the Tully disappears. It is not eroded here; rather the limestone has become a shale, and even farther east, a siltstone (the siltstone identified by Dennison and Hasson, 1976, as the westernmost extension of the "Clearville siltstone" of the Mahantango Group). The Laurel Hill and Negro Mountain anticlines, like the Chestnut Ridge, may have been active tectonic features at the time of Tully deposition and acted as sediment traps against clastic influx from the southeast by slowing water movement. In this way the carbonate deposition would have been significantly diluted with fine-grained clastics. The Tully may be present east of Negro Mountain, but control is poor and the limestone encountered in the few wells available for study may be relatively isolated lenses (the Tully is not definitely known to be greater than 10 feet thick in this area). Dennison and Naegle (1963) reported a Tully-equivalent calcareous concretion zone along the Allegheny Front in Maryland and West Virginia and it may be that the thin Tully in Somerset and Bedford Counties, east of Negro Mountain, is the subsurface extension of this zone.

#### Tully-Harrell Transition

In Pennsylvania, the Tully is designated both as a formation in its own right, and as a member of two different formations. In the subsurface the Tully has full formation status because of its thickness, lithologic discreteness, mappability, and its stratigraphic utility. In central Pennsylvania, the Tully was relegated to member status in the subjacent Mahantango Formation by Faili and others (1978) because they felt it to be just a calcareous facies within the Mahantango shales, rather than a distinct lithologic unit deposited in a post-Mahantango sea. In south-central Pennsylvania, the Tully is considered to be a member of the superjacent Harrell Formation. Hasson (1972) stated that the base of the Burket Member of the Harrell Formation "changes position relative to the Tully so that the Tully Member occurs within the black Burket Shale rather than at its base." This change in position can also be seen in the subsurface.

While mapping the subsurface Tully Limestone, Piotrowski and Harper (1979) determined that the Tully was absent throughout Somerset and southern Cambria Counties. A thin limestone above the base of the Burket Shale in this area was thought to be a locally developed carbonate within the Burket. In a systematic, well-by-well review of our data, however, we began to suspect that this thin limestone might actually be Tully. Harper correlated a series of wells along the Laurel Hill, Chestnut Ridge and Nolo anticlines and discovered that a "lower Burket" begins to develop prior to deposition of the

Tully (where it occurs) along Laurel Hill (Figure 10). Another area of "lower Burket" was subsequently discovered along Negro Mountain anticline in northern Somerset and southern Cambria Counties. This revised correlation of the Tully-Harrell interval agrees very well with the ideas presented by Dennison and Hasson (1976).

### Post-Tully Formations

Other than mapping the radioactive shales of the Burket Member of the Harrell Formation, we had previously made no attempt at differentiating the recognized surface stratigraphic horizons of central and south central

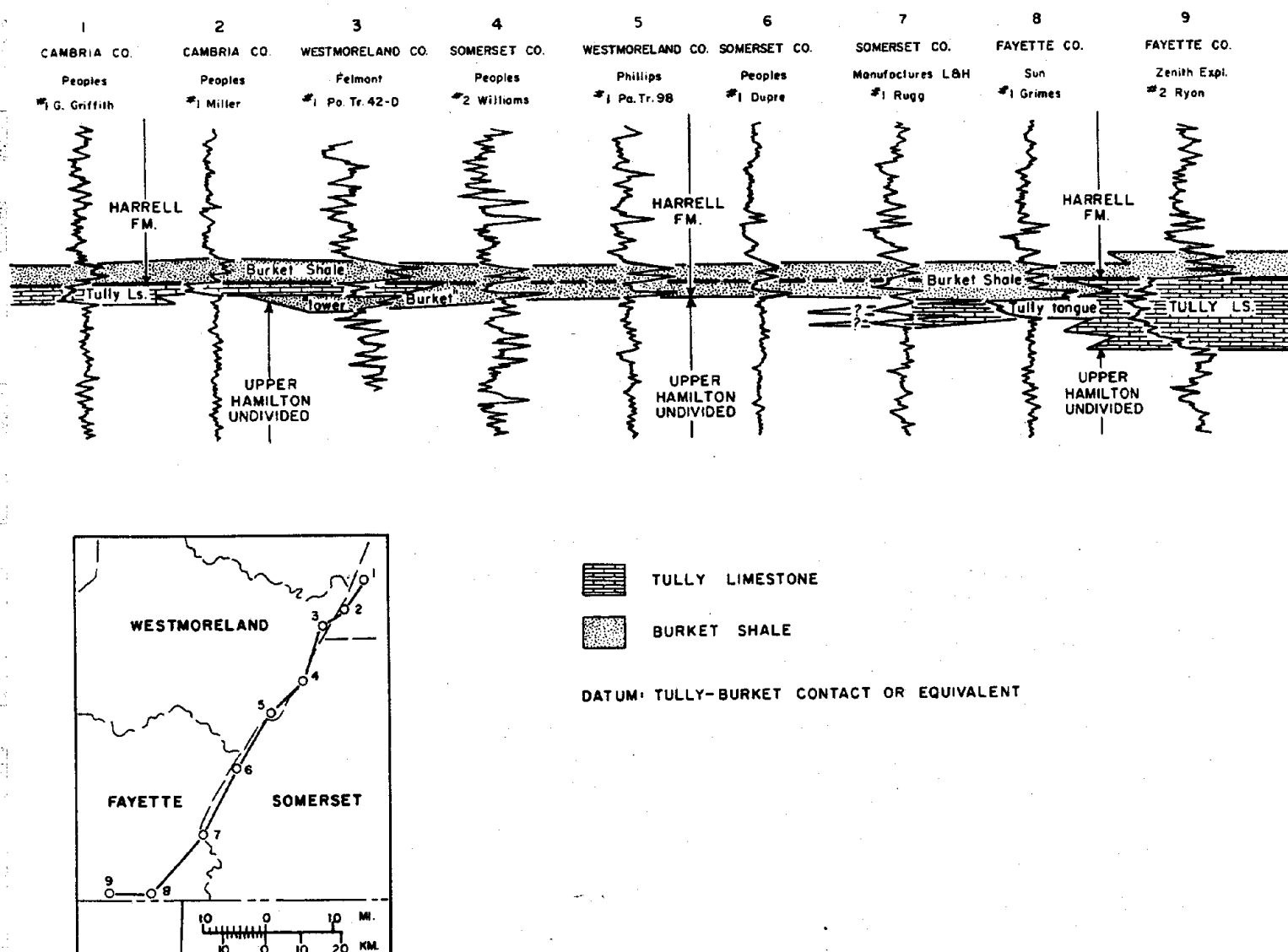


Figure 10. Stratigraphic cross section based on gamma ray logs showing relationship between Tully Limestone and Burket Member of Harrell Formation along Laurel Hill Anticline, southern Pennsylvania.

Pennsylvania. All shales and siltstones between the top of the highest radioactive shale (the Burket Shale in south central Pennsylvania) and the base of the first major sandstone were incorporated into Zone A Shale, and all of the sandstone, siltstone and shale from the base of that first major sandstone to the base of the Mississippian were differentiated into Zone B Sandstone, Zone C Shale, Zone D Sandstone, and Riceville Shale (Figure 5). We are now able to distinguish on the gamma ray log many of the recognized stratigraphic units exposed in south central Pennsylvania, and we have made an attempt to correlate these exposed strata with the subsurface stratigraphic units recognized by Piotrowski and Harper (1979).

#### Harrell Formation

The Harrell Formation of south central Pennsylvania is a medium to dark gray shale with a black shale at the base. Dennison and Hasson (1976), on the basis of well sample descriptions, referred approximately 80 feet of shale below the Tully Limestone in the subsurface of Somerset County to the Harrell. On the basis of gamma ray logs, we place the base of the Harrell at the base of the radioactive Burket Shale. We pick the top of the Harrell at the first significant "siltstone" that can be identified on the log (Figure 6). West of Somerset County the Harrell interfingers with the more organic-rich shales of the Genesee and Sonyea Formations (Figure 9). The Harrell correlates with the lower portion of the undifferentiated Zone A Shale of Piotrowski and Harper (1979).

The Burket Shale Member of the Harrell is an easily recognizable gamma ray marker horizon throughout the subsurface of southwestern Pennsylvania. It is continuous with the Genesee and Renwick Shale Members of the Genesee Formation of New York, which prompted us to use the name "Burket-Genesee-Renwick facies" for these organic-rich, radioactive shales (Piotrowski and Harper, 1979).

#### Brallier Formation

The Brallier Formation is distinguished from the subjacent Harrell Formation by its coarser clastics. The base of the Brallier is placed at the lowest siltstone overlying darker Harrell shales in the areas where they are exposed (Dennison and Hasson, 1976). In the subsurface, we place the boundary at the first significant "siltstone" reading on the gamma ray log. Variations in radioactivity of sediments and the statistical fluctuations inherent in all geophysical logging devices may show small, abrupt decreases in radioactive response in the shale section. These could be interpreted as thin siltstone beds. We prefer, instead, to ignore these small fluctuations and choose the larger, less questionable gamma ray "siltstone" kicks as the base of the Brallier. Because the Harrell has a tendency to be calcareous, the gamma ray study needs to be supplemented with lithologic data in order to be certain that the "siltstone" is not actually a calcareous shale (Figure 6). Lundegard and others (1978) conducted foot-by-foot hand-held scintillometer readings of several exposures of the Brallier in an attempt to use gamma ray profiles for correlating between the surface and the subsurface. They concluded that gamma ray logs are not ideal for correlating the Upper Devonian siltstone-sandstone and shale-mudstone section in the Appalachians.

The Brallier thins northwestward and eventually interfingers with the organic-rich shales and non-organic shales of the Sonyea and West Falls



Formations. The Nunda Siltstone Member of the West Falls Formation and the Wiscoy Siltstone Member of the Java Formation may be upper, more westward extending tongues of the Brallier, but we have no satisfactory evidence to corroborate such a speculation. The Brallier is apparently equivalent to the upper portion of Zone A Shale of Piotrowski and Harper (1979).

#### Post-Brallier Units

The Brallier grades upward into the sandstone, siltstones, and shales of the Scherr and Foreknobs Formations (Greenland Gap Group of West Virginia) (see Figure 5). The Scherr Formation, composed of shale and siltstone with some sandstone where it is exposed, is roughly equivalent to Zone Bo Sandstone of Piotrowski and Harper (1979). The Foreknobs Formation with its massive sandstone and siltstones probably corresponds to at least a portion of Zone B Sandstone. Where the lowermost tongue of the Catskill Formation is absent, the Foreknobs is probably equivalent to the total Zone B Sandstone. The Catskill Formation (Hampshire of West Virginia) can be correlated to the first occurrence of red beds found within the Zone B Sandstone and the Zone D Sandstone (Figure 5).

#### SUMMARY OF DEVONIAN BLACK SHALE STUDY IN PENNSYLVANIA

Most of the stratigraphy for this paper was originally done by us during a comprehensive regional study of the Middle and Upper Devonian radioactive black shales (Piotrowski and Harper, 1979). During the study numerous cross sections, maps, and reports were completed and published by the U. S. Department of Energy's Morgantown Energy Technology Center (METC) in Morgantown, WV, (for a complete listing of these items, see Harper and Abel, in press). The objectives of the Pennsylvania portion of the Eastern Gas Shales Project were to provide a stratigraphic and structural framework for the organic-rich shales, to map their distribution, thickness, and lithologic relationships to adjacent strata, to provide production data on wells penetrating the shales, and to examine the capabilities of the shales as potential producers.

Our studies have shown that there are three major and three minor organic-rich shale facies recognizable in the subsurface of Pennsylvania. The three major facies include the Middle Devonian Marcellus facies of the Hamilton Group, already discussed in this paper, the Upper Devonian Rhinestreet facies of the West Falls Formation (Figure 11), and the Upper Devonian Dunkirk facies of the Ohio Shale-Perrysburg Formation (Figure 12). The minor units, the Burket-Geneseo-Renwick facies of the Genesee Formation, already discussed, the Middlesex facies of the Sonyea Formation, and the Pipe Creek facies of the Java Formation, are all Upper Devonian (see Figures 5 and 9). Each of these organic-rich shales represents the base of an upward and eastward coarsening sequence of clastic sediments deposited in cyclical fashion in the Devonian seas.

The Rhinestreet radioactive shale facies is the lowest of three facies in the West Falls Formation. The upper two units are composed of intercalating non-organic shales (Angola Member) and siltstone (Nunda Member). The Rhinestreet facies is identifiable to about the center of the Plateau area where it becomes diluted with non-organic clastics of the Harrell-Brallier strata and disappears. It reaches its maximum development (greater than 200 net feet of organic-rich, radioactive shale) in a broad belt extending from Beaver and Lawrence Counties

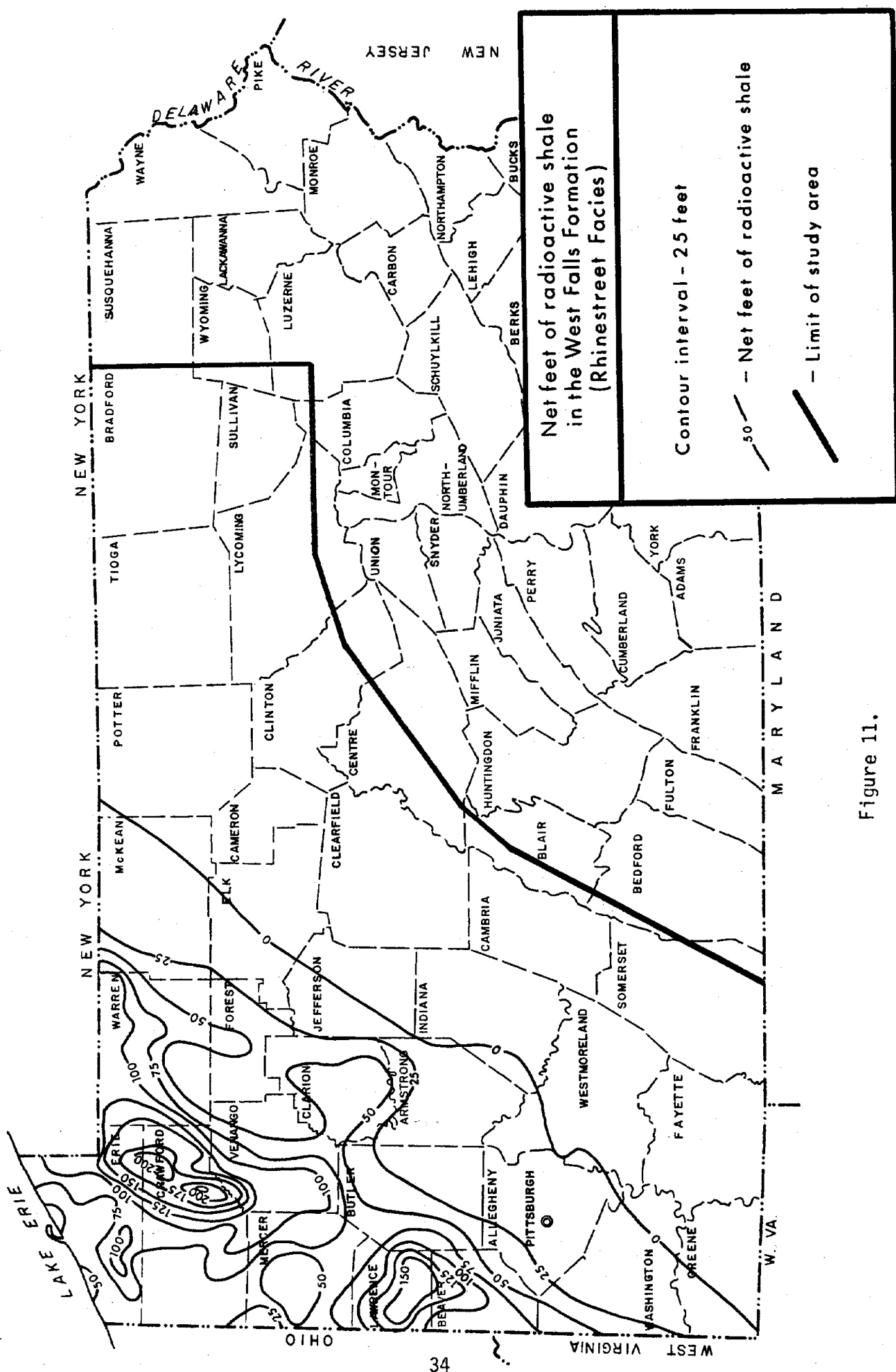


Figure 11.

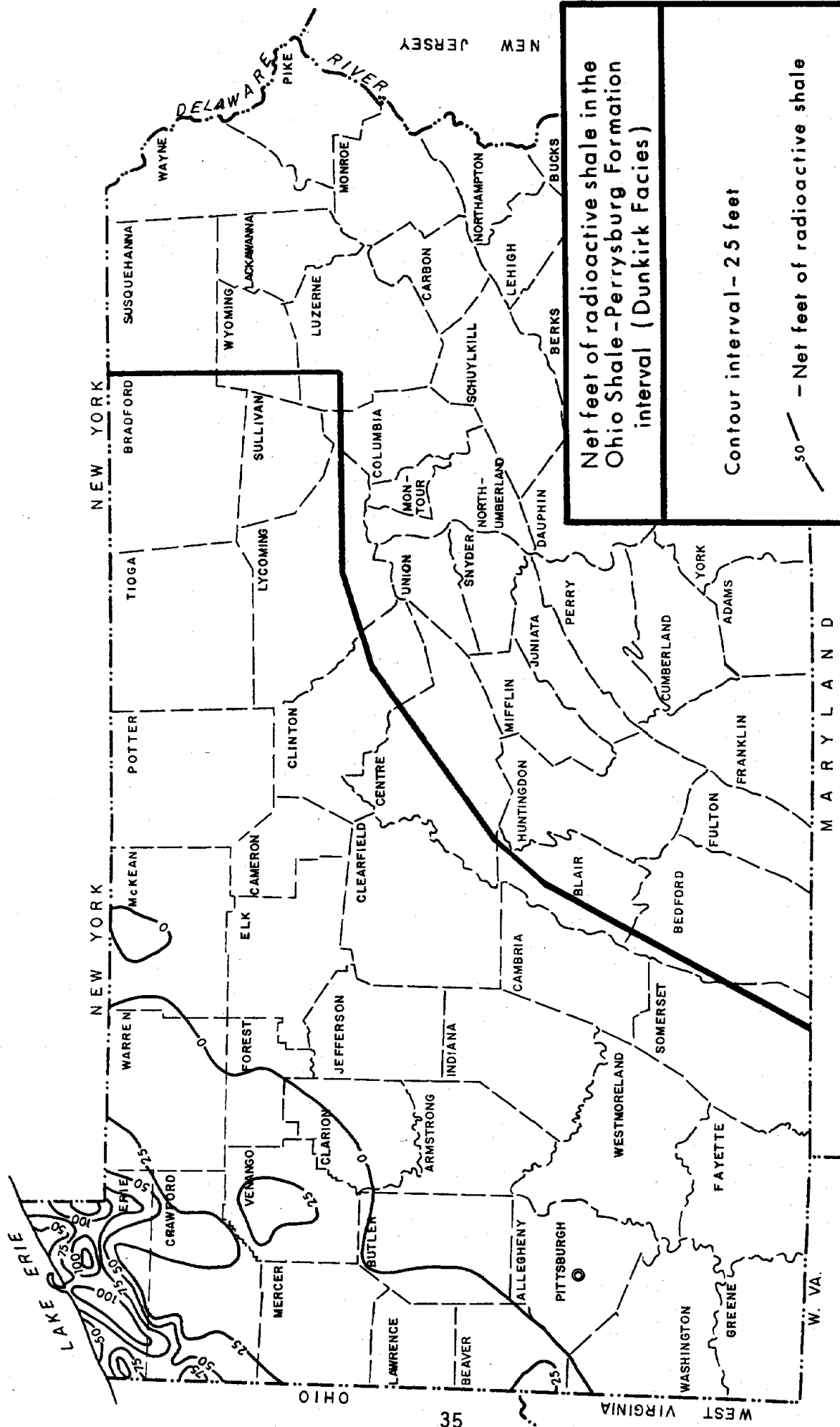


Figure 12.

to Warren and Erie Counties (Figure 11). In northwestern Pennsylvania, where the Genesee and Sonyea Formations are absent due either to erosion or pinch-out, the Rhinestreet sits directly on the Tully Limestone (Figure 9).

The Dunkirk facies is the basal portion of both the Ohio Shale of Ohio and the Perrysburg Formation of New York. In the subsurface of Pennsylvania it represents the intercalation of the predominantly black, organic-rich shales of Ohio and the predominantly non-black, non-organic shales and siltstones of New York. The Dunkirk facies is equivalent to the Huron Member of the Ohio Shale in western Erie and Crawford Counties where the facies attains its thickest development, but thins rapidly eastward and southward until it is equivalent only to the relatively minor (usually less than 40 feet) Dunkirk Member of the Perrysburg Formation. Because the Dunkirk has had a significant gas production history that extends back over 150 years, we believe that it has the most immediate potential for future production capabilities, followed by the older and deeper Rhinestreet and Marcellus facies.

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# THE ONESQUETHAW STAGE IN SOUTH-CENTRAL PENNSYLVANIA AND NEARBY AREAS

by

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## INTRODUCTION

Rocks of the Onesquethaw Stage (Lower-Middle Devonian) in south-central Pennsylvania and nearby areas comprise a complex of intertonguing marine facies that include shale, limestone, chert and bentonite. Four formations, each dominated by one of these lithologies, can be recognized (Figure 13). Analysis

		West				East
DEVONIAN(part)	MIDDLE (part)	Tioga Bentonite				
		"Onondaga" Limestone	Calcareous shale and limestone member(south)	Selinsgrove Limestone Member (north)	Needmore Formation	
	Huntersville Chert	Calcareous shale member				
		Beaverdam Shale Member				

Figure 13. Rock units of Onesquethaw Stage in south-central Pennsylvania and nearby areas.

of the internal lithostratigraphy of the stage is facilitated by its moderate thickness (generally less than 250 feet), by its sharp upper and lower boundaries, and by the occurrence of a convenient time-marker horizon--the Tioga Bentonite--at the top. Paleoenvironmental interpretation is aided by the presence of an abundant, and locally quite diverse, marine fauna. Detailed studies of the Onesquethaw Stage in this area began about forth years ago with the work of Willard (1936, 1939), Swartz and Swain (1941), and Woodward (1943). Recent research by Dennison (1961, etc.), Inners (1975), and Heyman (1977) has clearly illuminated many important relationships within the stratigraphic framework provided by earlier investigators.

Except where removed by post-Alleghanian erosion east of the Allegheny Front, Onesquethawan rocks are everywhere present in the field trip area. They crop out in narrow, lowland belts on the flanks of folds in the Valley and Ridge and are also known from hundreds of gas wells on the Allegheny Plateau. Plentiful subsurface data on the Onesquethaw is insured by its occurrence immediately above the Ridgeley ("Oriskany") Sandstone, the main deep gas target in the Allegheny Plateau region.

### LITHOSTRATIGRAPHY

Two distinct Onesquethawan facies domains--based mainly on lithologies in the lower part of the stage--are approximately defined by a line along the Allegheny Front (Figure 14). Mostly noncalcareous and calcareous shale with scattered limestone interbeds east of the Front is replaced by chert and argillaceous chert to the west. In both areas a thin unit of interbedded argillaceous limestone and calcareous shale occupies the upper part immediately beneath the Tioga Bentonite.

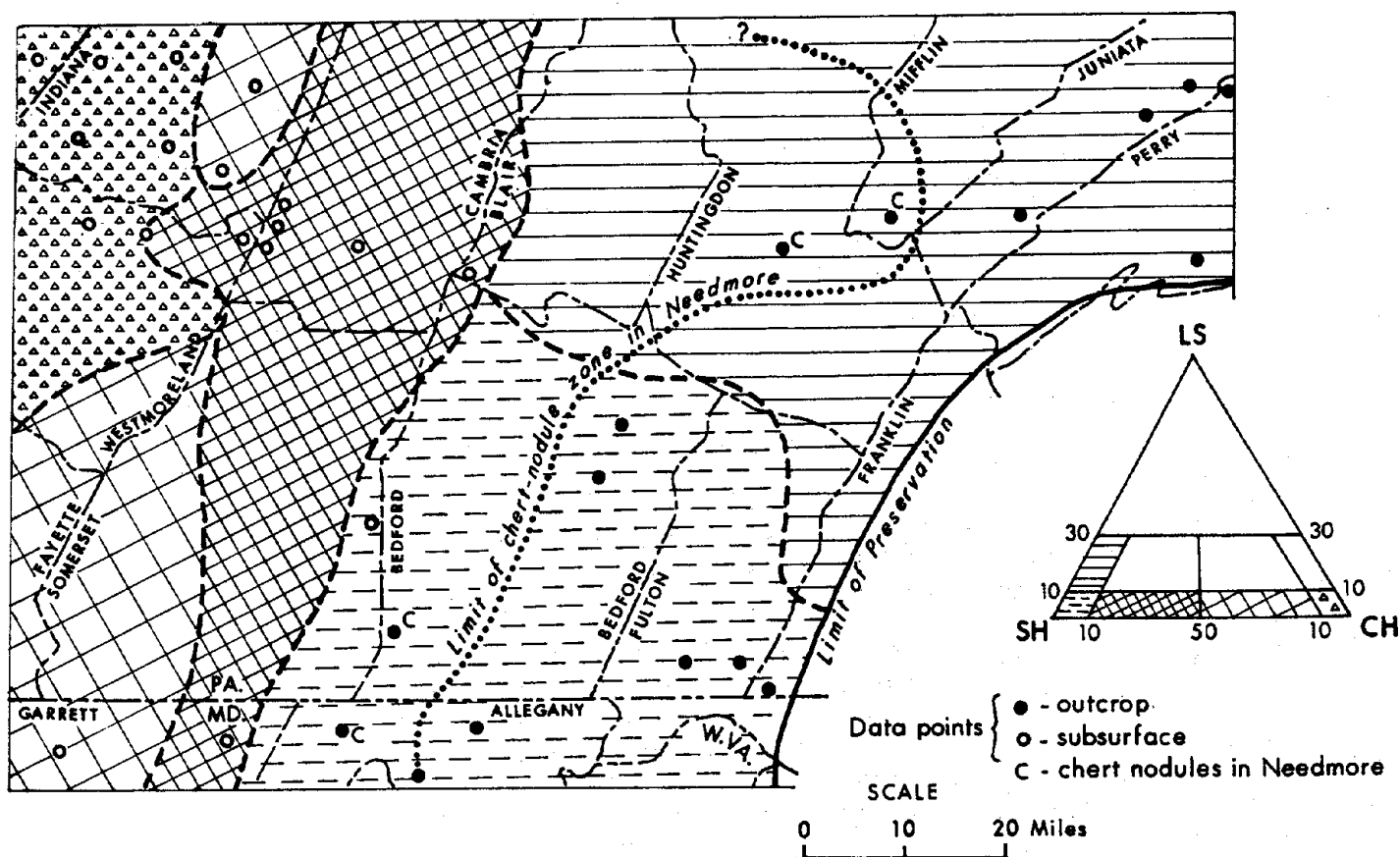


Figure 14. Lithofacies of Onesquethaw Stage.

In south-central Pennsylvania and nearby areas, the thickness of the Onesquethaw stage ranges from less than 50 feet to more than 175 feet (Figure 15). Minimum thicknesses in northern Blair and southeastern Perry Counties, Pennsylvania, are related to disconformities between Onesquethawan and older rocks. The thickening trend evident along the western edge of Figure 15



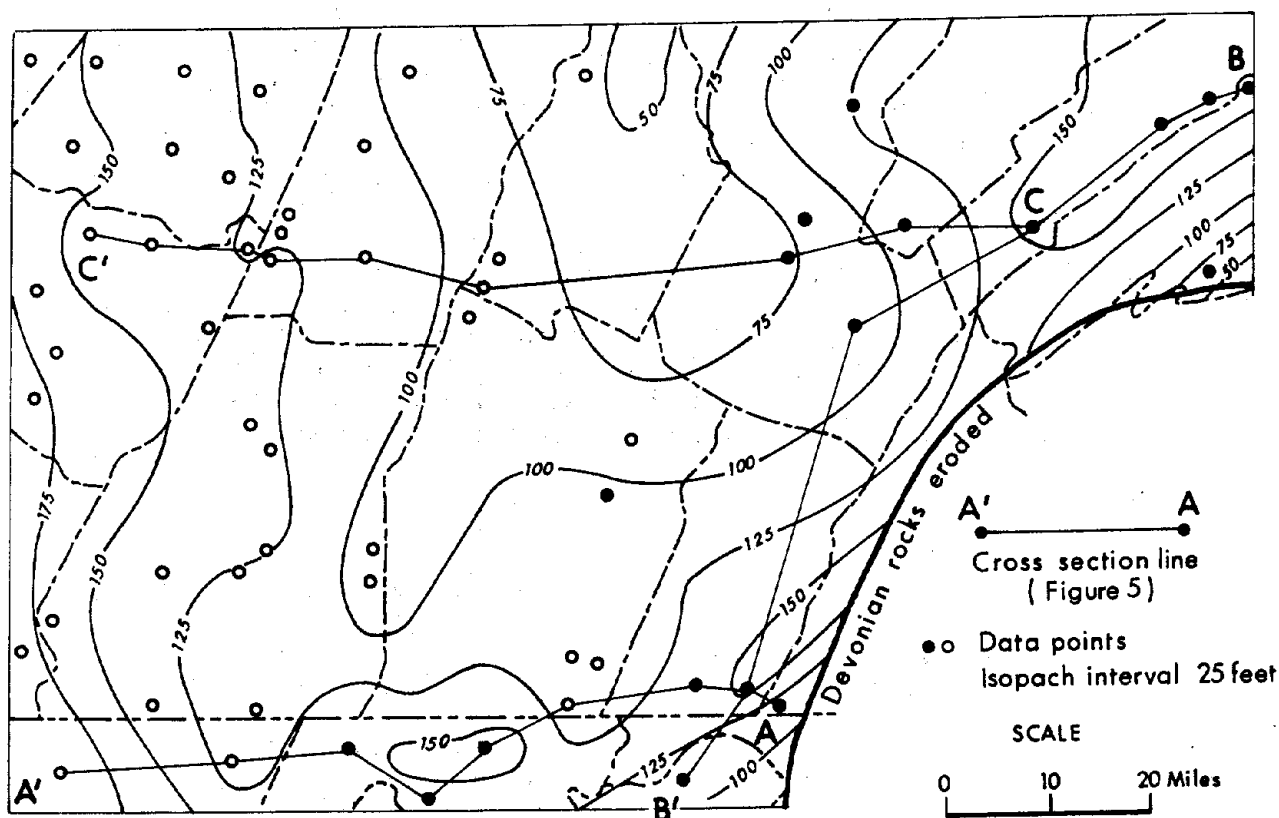


Figure 15. Thickness of Onesquethaw Stage.

reaches a maximum of about 260 feet in the southwest corner of Pennsylvania at approximately the center of the Onesquethawan depositional basin (Dennison and Head, 1975).

Within the area of interest, Onesquethawan rocks everywhere overlie the Ridgeley Sandstone of Deerparkian (Lower Devonian) age and underlie the Marcellus black shale of Cazenovian (Middle Devonian) age. Both contacts are quite sharp and can be readily identified where exposed in outcrops. Obvious changes in well samples and sharp kicks on gamma-ray logs at the top and base of the Onesquethaw provide excellent subsurface control as well.

The lower contact of the Onesquethaw Stage is probably conformable from Mifflin County, Pennsylvania, southwestward into Maryland and West Virginia, but disconformable--or at least paraconformable--in northern Blair County and along the southeast side of the Valley and Ridge from Perry County, Pennsylvania, to Berkeley County, West Virginia (Figure 16). The depositional hiatus in Blair County is but a small part of a widespread disconformity beneath Onesquethawan rocks in western New York (Oliver, 1967) and northwestern and north-central Pennsylvania (Inners, 1975; Heyman, 1977). In the southeastern belt, the presence of phosphate nodules and oolites at the base of the Onesquethaw and/or top of the Deerpark along a contact that otherwise appears conformable suggests the existence of a non-depositional unconformity, or paraconformity. A 0.4-foot bed of fine-pebbly, quartz conglomerate at the top

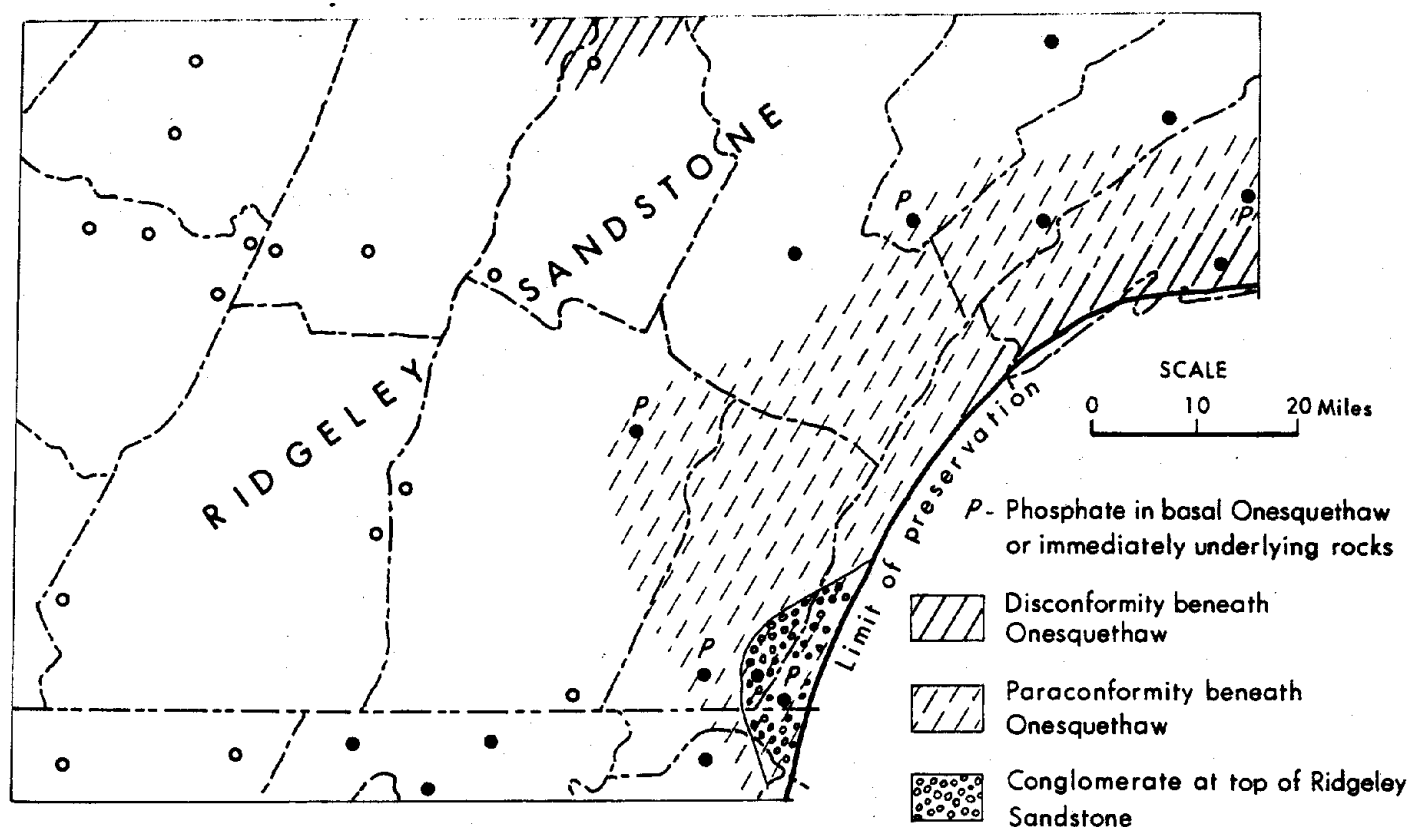
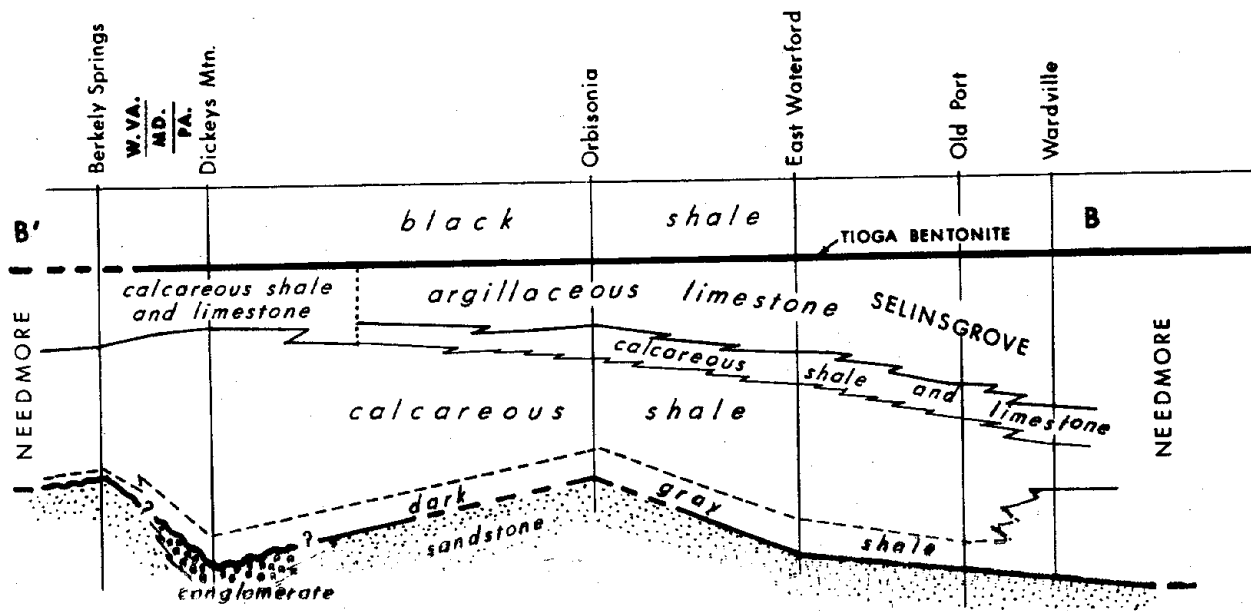
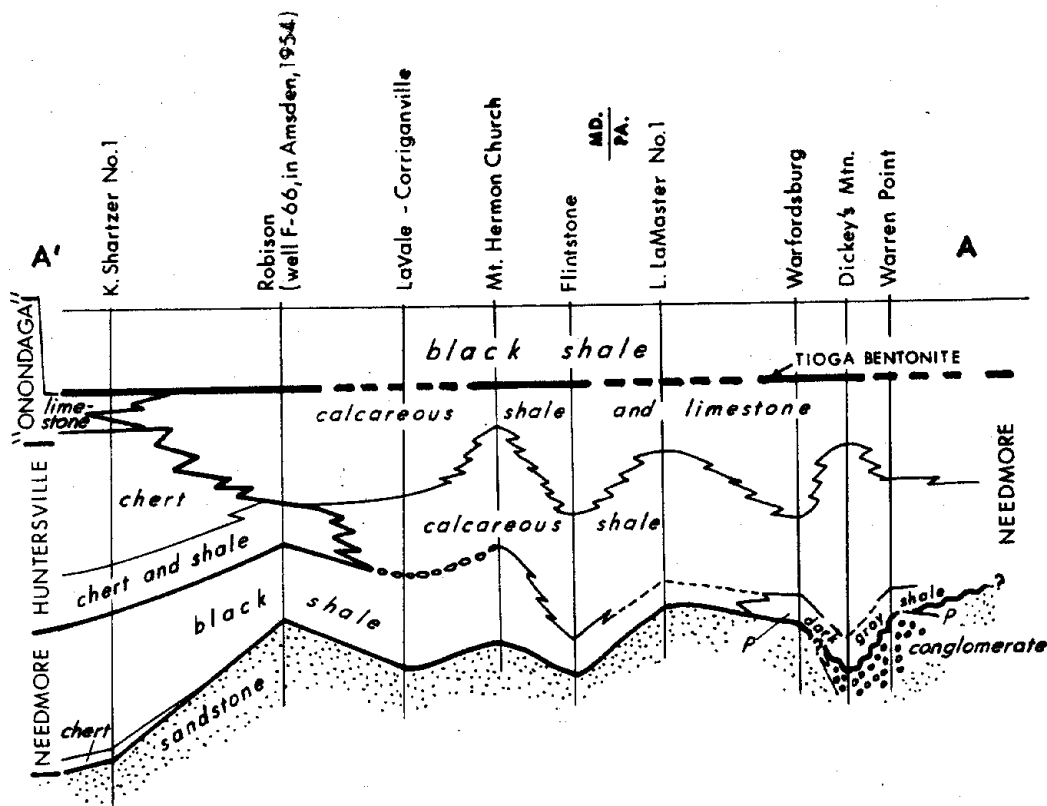


Figure 16. Sub-Onesquethaw geology.

of the Ridgeley Sandstone in extreme southwestern Franklin County (Warren Point) may be a winnowed lag deposit in an area of minor erosional disconformity (Stose and Swartz, 1912). At outcrops further to the northeast and south, this possible diastem increases in magnitude to major disconformity proportions along the southeastern edge of the Onesquethawan depositional basin (Swartz and Swartz, 1931; Dennison, 1961; Inners, 1975).

At the contact with the Ridgeley sandstone, the basal few inches of the Onesquethaw Stage are commonly sandy. These thin transition beds represent a continuous sedimentation change in the central part of the basin and reworked material in the areas of marginal diastems (Dennison, 1961). At numerous outcrop localities, the basal sandy zone and contiguous strata are highly ferruginous. The iron is derived from ground water leaching of pyrite in the Needmore.

The contact of the Onesquethaw Stage with the overlying Marcellus Formation is always conformable. Dark-gray to grayish-black shales (Marcellus) and argillaceous limestones (Selinsgrove-Onondaga) are commonly interbedded through a stratigraphic distance of several feet. In addition, calcareous shales and limy concretions are typically encountered in the lower ten to fifty feet of the Marcellus. The top of the Onesquethaw Stage is defined as the top of the middle coarse mica zone of the Tioga Bentonite (Dennison, 1969). At outcrops this boundary either coincides with, or closely approximates, the contact of the Needmore and Marcellus Formations based on lithologic criteria.



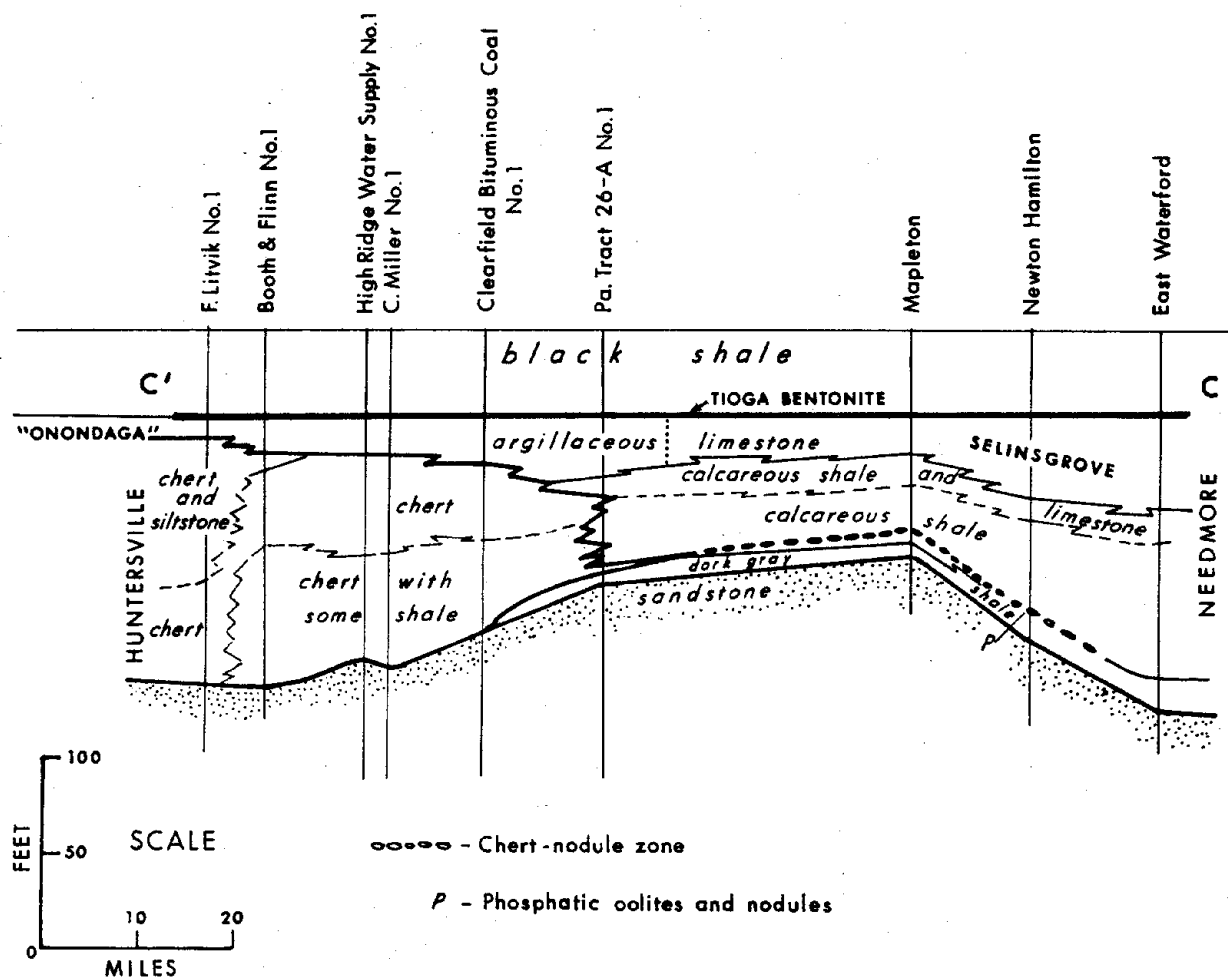


Figure 17. Stratigraphic cross sections of Onesquethaw Stage.

As at the lower contact of the Onesquethaw, concretionary limonite is also locally developed at the upper contact through leaching of pyrite and carbonate in the lower Marcellus and upper Needmore. During the 1800's, limonite at this horizon was extensively mined in Perry County (Claypole, 1885).

The three cross sections of Figure 17 summarize the stratigraphic relationships of the Onesquethawan formations and members to be described in some detail below. Note particularly the rather abrupt appearance of chert in the western portions of sections AA' and CC', the northeastward increase in limestone along line BB', and the ubiquitous presence of the Tioga Bentonite at the top of the stage.

#### Needmore Formation

The Needmore Formation (Willard, 1939) is an extensive argillaceous and calcareous unit that occurs mainly in the Valley and Ridge province from east-central Pennsylvania to southwestern Virginia. The formation nearly everywhere exhibits a gradual upward increase in carbonate content, and it is mostly on this basis that three partially intertonguing members can be recognized (Dennison, 1961; Inners, 1975). These are: (1) a lower, noncalcareous to

slightly calcareous shale member--the Beaverdam Shale Member (Swain, 1958); (2) a middle calcareous shale member; and (3) an upper calcareous shale and limestone member. This trend of upward increase in carbonate has its best development north and northeast of the field trip area where a distinct limestone unit--the Selinsgrove Limestone Member (White, 1883; Willard, 1939)--occupies the upper one-third to one-half of the Needmore.

#### Beaverdam Shale Member

In the lower part of the Needmore throughout south-central Pennsylvania and nearby Maryland and West Virginia is 5 to 50 feet of dark-gray to grayish-black, generally noncalcareous, sparsely fossiliferous, clay shale. Southward from central Bedford and Somerset Counties, Pennsylvania, the Beaverdam is a pyritic, euxinic black shale similar to the stratigraphically higher Marcellus shale (STOP 3). East and northeast of the black shale area, the Beaverdam is somewhat lighter in color, locally slightly calcareous, and commonly contains small (1 to 2 mm), black, phosphatic oolites (Figure 18) and larger (0.2 to 0.3-foot) phosphatic concretions. These phosphate beds have been previously mentioned as indication of a probable diastem along the southeastern margin of the Onesquethawan depositional basin.

Along the Allegheny Front for over 100 miles south of Bedford, Pennsylvania, and extending northeastward at least to southern Mifflin County, a thin zone of chert nodules, 0.2 to 0.3-thick, is rather persistently present near the

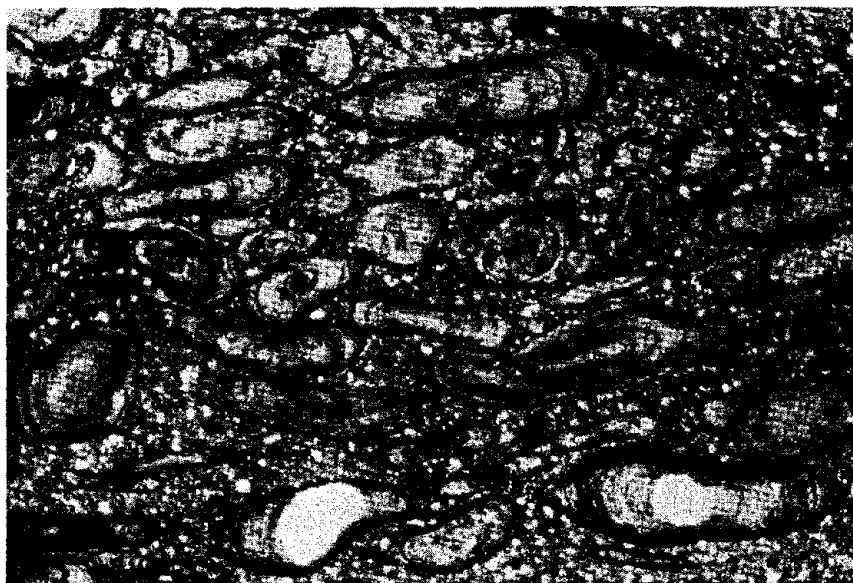


Figure 18. Photomicrograph (plane light) of phosphatic oolites in silty clay shale of Beaverdam Shale Member, from cut on east side of Interstate 70, 1.1 miles northwest of Warfordsburg, Fulton County, Pennsylvania. Nuclei are quartz (light) and pyrite (dark) grains. Flattening of oolites in the plane of bedding is the result of shale compaction.

contact of the Beaverdam Shale Member and the overlying calcareous shale member (Figures 14 and 17; STOP 2). Dennison (1961; 1969) postulates that this discontinuous eastward extension of Huntersville chert defines an isochronous depositional surface.

#### Calcareous shale member

The calcareous shale member is composed predominantly of medium-dark-gray to dark-gray, fossiliferous, calcareous clay shale that weathers pale olive to light olive gray. Nodules and thin beds of medium-dark-gray, fossiliferous marlstone may occur at widely separated intervals, particularly in the upper part. Many horizons are intensely bioturbated. Pyrite is common locally as nodules 0.1-foot in diameter, as a replacement of invertebrate fossils, and as finely disseminated grains in small, tubular horizontal burrows.

Where completely exposed at outcrops in south-central Pennsylvania and Maryland, the middle member of the Needmore is between 30 and 65 feet thick. It may exceed 100 feet in thickness at Dickey's Mountain (STOP 10), but the lower 40 to 45 feet is concealed there.

#### Calcareous shale and limestone member

The upper 30 to 75 feet of the Needmore Formation in the field trip area consists of interbedded thin- to medium-bedded, medium-dark-gray, fossiliferous, calcareous clay shale and argillaceous, micritic limestone. Upon prolonged exposure, the limestone is leached to olive-gray, punky claystone that is often difficult to distinguish from weathered shale. Generally limestone appears to constitute only about 25 percent of the member, but in the well exposed section at Dickey's Mountain, about 40 percent is limestone (Figure 19). Pyrite occurrences resemble those in the underlying calcareous shale member.

Northeast of a rather arbitrary line through northern Bedford and Fulton Counties, Pennsylvania, the bulk of the calcareous shale and limestone member grades into the Selinsgrove Limestone Member (Figure 17, BB'). Limestone constitutes more than 40 percent of the Selinsgrove Member, the beds being somewhat thicker than to the southwest with thinner shale partings. Although much of the Selinsgrove is argillaceous micrite similar to limestone in the calcareous shale and limestone member, some purer beds have insoluble residues of less than 5 percent. In fact, the upper part of the Selinsgrove in the Susquehanna River region is sufficiently pure to have been formerly quarried for agricultural lime--albeit on a small scale. The Selinsgrove has its maximum thickness, 65 to 70 feet thick, in an area centered on northern Juniata County.

#### Tioga Bentonite

Probably the most noteworthy feature of the Onesquethaw in the field trip area is the occurrence of the Tioga Bentonite (Fettke, in Ebright, Fettke, and Ingham, 1949) at the top of the stage. The Tioga is a thin widespread layer of volcanic ash that has been recognized at outcrops and in the subsurface throughout the central Appalachian and northern Interior regions (Dennison, 1961; Dennison and Textoris, 1970).



Figure 19. Calcareous shale and limestone member at Dickey's Mountain section, Fulton County. Note approximately equal thickness of shale and limestone beds. Overturned bedding dips  $80^\circ$  toward S75E.

At outcrops in south-central Pennsylvania and nearby areas, the Tioga Bentonite is a poorly exposed interval of yellowish-brown, micaceous shale associated with brownish-gray, sheety tuffaceous shales. The coarser, more micaceous layers (which may contain mica flakes to medium-sand size and commonly exhibit a blocky fracture) generally occur at the top of the Needmore Formation (Figure 20). These beds have been referred to as the middle coarse mica zone by Dennison (1969).

The coarser layers of the Tioga middle coarse zone exhibit abundant bleached biotite and altered feldspar in a whitish groundmass. The presence of pyrite is indicated by the yellow-brown, rusty weathering coloration. Typical thin sections of these coarse layers are composed of 20 to 40 percent biotite, about 30 percent altered feldspar, 1 to 5 percent quartz, 1 to 2 percent pyrite and 30 to 50 percent groundmass (glass dust that has devitrified mainly to illite [sericite] and minor microcrystalline quartz) (Figure 21; Dennison and Textoris, 1967).

Associated with the Tioga tuffaceous interval are thin, platy beds of dark-gray to grayish-black, bituminous coquinitic limestone composed of myriads of juvenile brachiopods, styliolinids and tentaculitids. The catastrophic demise of these organisms was undoubtedly caused by the ash fall. The finely disseminated pyrite in the tuff beds probably formed in the reducing environment created by their decay (Dennison, 1961).

The thickness of the prominent middle coarse mica zone in the field trip area ranges from 0.6 to 3 feet, whereas the total thickness of the interval



Figure 20. Middle coarse mica zone (mcz) of Tioga Bentonite overlying calcareous shale and limestone member of Needmore Formation (Dn) and overlain by Marcellus black shale (Dma) at Dickeys Mountain section. Zone here is about 1.5 ft thick. Blocky silty to sandy beds are evident just to left of hammer-head. Bedding is overturned.

having detectable Tioga influence is 10 to 16 feet. Individual sandy to silty tuff layers within the middle coarse zone are normally 0.03 to 0.2 feet thick, and sometimes exhibit an upward gradation from fine or medium sand at the base to silt and silty shale at the top. Tuffaceous shale beds outside the middle coarse zone may range up to two feet thick. (J. M. Dennison, personal communication).

#### Huntersville Chert

In the subsurface of southwestern Pennsylvania and adjoining states, the Huntersville Chert (Price, 1929) is mostly dark gray, slightly calcareous, sometimes glauconitic chert, with interbeds of dark gray glauconitic shale and siltstone (Martens, 1939; Fettke, 1940). Dolomite is common as small rhombs scattered through the chert and siltstone (Martens, 1939). The amount of dolomite in the formation increases from east to west (Dennison, 1961).

Just west of the Allegheny Front, from Allegany County, Maryland, to Clearfield County, Pennsylvania, the Huntersville contains significant admixtures of dark gray to black, siliceous and calcareous shale (Figures 14 and 17), a reflection of an intertonguing relationship with the Needmore Formation to the east. The belt of interbedded shale and chert is at least 10 miles wide along the southern border of Pennsylvania, and broadens to about





Figure 21. Photomicrograph (plane light) of sandy tuff of Tioga middle coarse zone, from cut along Conrail tracks, 1.0 mile southwest of Newton Hamilton, Mifflin County, Pennsylvania. (f=feldspar, q=quartz, b=biotite, p=pyrite, g=groundmass)

50 miles in Clearfield, Jefferson and Indiana Counties. Aside from the previously mentioned chert-nodule zone, the only representatives of the Huntersville at outcrops in Pennsylvania are thin bands of chert at the base of the Needmore Formation in Blair and Huntingdon Counties (Swartz and Swain, 1941) and western Bedford County (Dennison, personal communication).

West of the field trip area, the Huntersville thickens from a zero-edge approximately at the Allegheny Front to more than 100 feet in extreme western Maryland and eastern Fayette and Westmoreland Counties, Pennsylvania. The Huntersville has its maximum thickness, about 210 feet in Harrison and Doddridge Counties, West Virginia (Dennison, 1961), about 125 miles southwest of Bedford.

#### "Onondaga" Limestone

As used here the term "Onondaga" Limestone refers to dominantly limy strata that overlie the Huntersville chert and underlie the Tioga Bentonite and Marcellus black shale in the subsurface of southwestern Pennsylvania. Recent work by Heyman (1977) shows that this interval actually consists of representatives of the non-cherty, argillaceous Selinsgrove Limestone and of the cherty Columbus Limestone of Ohio. Columbus-type limestones extend eastward to a sinuous line running from eastern Armstrong County, Pennsylvania, southward to western Garrett County, Maryland. Selinsgrove-type limestones replace the cherty Columbus east of this line and overlie the latter over a wide area to the west. Further west this argillaceous phase becomes cherty as well and correlates with the Delaware Limestone of Ohio (Heyman, 1977).

The combined thickness of the cherty and non-cherty divisions of the "Onondaga" Limestone in southwestern Pennsylvania is generally between 10 and 25 feet, increasing to the east and northeast to 40 feet or more in Somerset and extreme western Blair Counties.

#### PALEONTOLOGY

Outcropping Onesquethawan rocks (Needmore Formation and Tioga Bentonite) in south-central Pennsylvania and nearby areas contain a diverse, but usually not particularly abundant, marine invertebrate fauna that is dominated by brachiopods, cricoconarids, ostracodes, trilobites and gastropods. Minor, but locally conspicuous constituents, are corals, crinoids, and bivalves. Although faunal diversity is greatest in the middle Onesquethaw, abundance of individuals is at a maximum in the coquinitic limestone beds associated with Tioga volcanism in the upper Onesquethaw. A few diagnostic and easily recognized species are illustrated in Figure 22.

The fauna of the Beaverdam shale is sparse, as would be expected from its reducing environment of deposition. Pelagic cricoconarids (styliolinids and tentaculitids) and a few other forms occur in the black Beaverdam (Dennison, 1961), whereas inarticulate (Orbiculoidea sp.) and leptocoeliid (Pacificocoelia acutiplicata) brachiopods are more characteristic of the slightly limy, phosphatic beds.

In marked contrast to the underlying beds, the calcareous shale member contains a large benthonic fauna. Brachiopods, including P. acutiplicata, Ambocoelia umbonata, Anoplia nucleata, and Orbiculoidea sp., are the dominant forms. In fact, P. acutiplicata locally occurs in dense clusters to about 0.2-foot thick and several feet in diameter, later generations having thrived on the firm substrate provided by their forebears. Frequently associated with the brachiopods are trilobites, particularly Phacops cristata, and ostracodes. Loxonemid (Loxonema hamiltoniae) and platyceratid gastropods and nektonic orthocone cephalopods (Michelinoceras subulatum) are common in the dark gray, intensely burrowed shales that are locally developed in the middle to upper part of the member. Thin concentrations of coiled cephalopods (possible ammonoids) about twenty feet above the base of the Needmore Formation at localities in Fulton and Mifflin Counties, Pennsylvania, may define another isochronous surface in the Onesquethaw.

Although many of the invertebrates that characterize the calcareous shale member persist into the lower part of the calcareous shale and limestone member, some important changes in faunal composition are evident. Gastropods and cephalopods virtually disappear, but solitary rugose corals and atrypid brachiopods locally become conspicuous. The relative abundance of P. acutiplicata and A. umbonata shifts decidedly toward the latter.

The upper part of the calcareous shale and limestone member (and the bulk of the Selinsgrove Limestone) contains a more restricted fauna than the underlying beds. Aside from the profuse styliolinids that constitute much of the skeletal material in the limestones (Figure 23), the only common fossils in most of these upper limestone beds are the distinctive "toothed"-trilobites, Odontocephalus aegeria and O. selenourus.

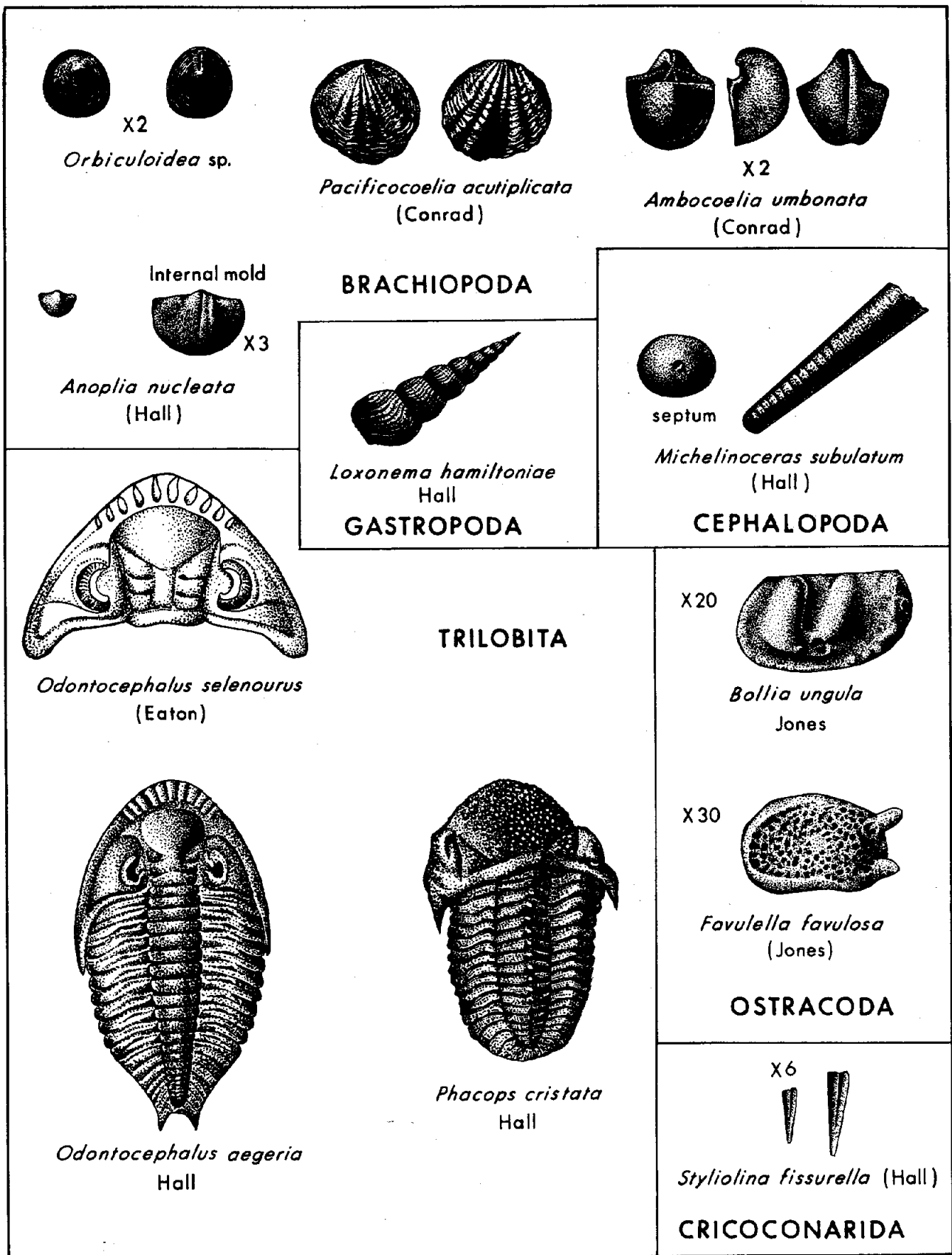


Figure 22. Some diagnostic Onesquethawan fossils in the field trip area (X1, except where noted). Redrawn from various sources by Albert Van Olden.



1 mm

Figure 23. Photomicrograph (plane light) of bioturbated, argillaceous, Styliolina-rich, micritic limestone of Selinsgrove Limestone Member, from cut along Conrail tracks, 1.0 mile northeast of Newton Hamilton. (t=trilobite fragment).

In the uppermost 10 to 15 feet of the Needmore Formation, bituminous, coquinitic limestones and shales rich in styliolinids, tentaculitids, and tiny, probably juvenile, brachiopods, are intercalated with the more typical argillaceous limestone and shale. Such coquinities always appear to occur within the zone of tuffaceous influence associated with the Tioga Bentonite and probably owe their origin both to physical smothering by ash layers and to chemical changes in the sea water induced by the volcanism.

#### ENVIRONMENTS AND HISTORY OF DEPOSITION

During Lower and early Middle Devonian time, the field trip area was part of a broad, stable shelf that extended over much of the central Appalachian and mid-continent regions. Following deposition of Ridgeley sands as shallow subtidal bars and sheets in a shoaling epicontinental sea, the Onesquethaw Stage was initiated by a widespread marine regression.\*

Sedimentation from Deerparkian into earliest Onesquethawan time was continuous over most of the area of presently preserved strata in south-central Pennsylvania and Maryland (Figure 24, a). Minor interruptions related to the sub-Onesquethaw regression probably occurred only in the north and southeast. Terrigenous muds derived from the east were deposited under progressively more reducing conditions from east to west across the area. In the east upwelling,

\*This regression is related to the cratonic sea level withdrawal that resulted in the Wallbridge Discontinuity of Wheeler (1963). (Dennison and Head, 1975.)

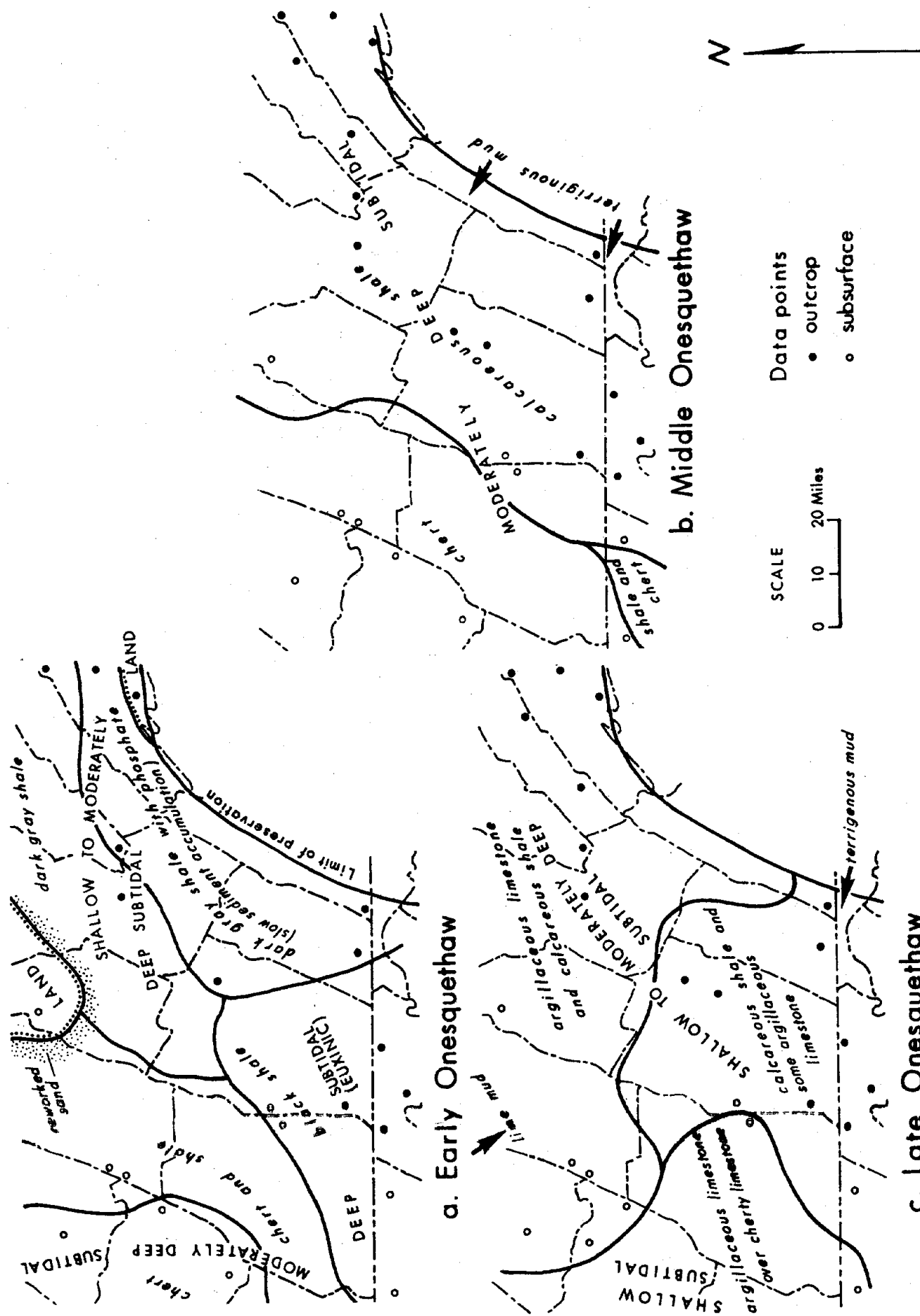


Figure 24. Depositional environments of Onesquethaw Stage.

nutrient-rich waters may have been responsible for deposition of phosphate a few tens of miles seaward of the Onesquethawan shoreline. Weak bottom-currents periodically agitated the phosphatic muds to produce concentrations of phosphatic oolites. It is probable that these currents promoted sedimentary bypassing of this narrow nearshore belt, resulting in an extremely slow rate of deposition and enrichment of the bottom sediments in phosphate.

Further to the west, black muds were deposited under "acidic," reducing conditions in somewhat deeper water than the phosphatic shales. Although benthonic organisms found neither of these areas particularly hospitable, the preservation of pelagic cricoconarids shows that the near surface waters were well oxygenated.

The euxinic muds of the central area graded westward into siliceous oozes and muds that apparently accumulated in shallower, more oxygenated water on the cratonic side of the early Onesquethawan basin (Dennison, 1961).

By middle Onesquethawan time, the sea had again transgressed over the marginal tracts uncovered by the earlier regression (Figure 24, b). Free circulation was restored to the basin, and well-oxygenated, moderately alkaline conditions conducive to the proliferation of shelly organisms prevailed over the entire eastern part of the area. The sea floor there supported a fairly large fauna of filter-feeders (brachiopods, small solitary rugose corals) and shallow deposit-feeders, scavengers, and carnivores (trilobites, ostracodes, and gastropods). Reducing microenvironments within the sediment caused by decay of organic matter resulted in the authigenic precipitation of pyrite, particularly in burrows and around fossil remains.

In the western part of the area, physical and chemical conditions were little changed from earlier times. The area of silica deposition did expand eastward over part of the former site of euxinic sedimentation, however. Although the source of the vast volume of silica that comprises the Huntersville chert is conjectural, at least a portion of it is biogenic in origin, being derived from radiolarian tests and sponge spicules (Dennison, 1961). Occurrence of pyrite and glauconite in the chert indicates deposition in a mildly reducing environment.

During late Onesquethawan time, carbonate deposition attained its maximum extent in the field trip area (Figure 24, c). The influx of terrigenous mud continued in the south, but increasingly more lime mud derived in part from carbonate banks to the northwest and northeast accumulated in the basin. Although even the latest Onesquethawan sediments in south-central Pennsylvania were deposited below wave base, it is probable that the shoaling trend evident earlier in the stage continued to the end. Benthonic organisms--such as brachiopods and corals--thrived in the well oxygenated waters that characterized the early portion of late Onesquethawan time, but a marked decrease in faunal diversity and increase in pyrite content upward marks a return to more reducing bottom conditions. Large odontocephalid trilobites rooted through these rather barren lime muds amid a steady rain of styliolinid needles.

Onesquethawan deposition closed with the laying down of a widespread layer of volcanic ash. The volcanism apparently killed off myriads of organisms that were unable to cope with the sudden, but relatively brief change in chemical and physical conditions within the water column and on the bottom. The ash

was transported by winds from volcanic centers in central Virginia (Dennison and Textoris, 1971).

Following the synchronous deposition of the Tioga Bentonite, black, pyritic, mostly noncalcareous muds were introduced from the east and quickly spread westward over the entire basin. These early Cazenovian muds were probably laid down in relatively deep water to the northwest of highlands which were rising in the first phase of the Acadian Orogeny. Their black color, high pyrite content, and general barrenness indicates a return to the same restricted bottom-conditions that characterized deposition of the similar, but areally less significant, Onesquethawan black shales.

#### ACKNOWLEDGMENTS

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# AEROBIC, DISAEROBIC AND ANAEROBIC FACIES WITHIN THE NEEDMORE SHALE (LOWER TO MIDDLE DEVONIAN)

by

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## INTRODUCTION

Three macrofossil biofacies are qualitatively and quantitatively definable in the Needmore Shale (Lower to Middle Devonian) of the central Appalachian basin. These three faunas can be readily distinguished in the field by the relative abundances of the shelly benthic, shelly epiplanktic and ichnofossil components of the assemblages. Two of the biofacies, which are characterized by the predominance of shelly organisms, also exhibit complex webs of internal cross-correlations using Spearman and Kendall non-parametric correlation coefficients, as discussed in detail by Newton (1978). The macrofossil assemblages observed in the Needmore are: the Phacops biofacies, a relatively high diversity shelly and trace fauna which is found in the calcitic shale and calcitic shale and limestone lithofacies of the Needmore; the Planolites - Chondrites biofacies, an ichnofauna of small diameter grazing traces which generally occupies the lower part of the calcitic shale lithofacies; and the Orbiculoidea - Pacificocoelia biofacies, a sparse fauna of small biconvex brachiopods which is typical of the well-laminated Needmore black shales.

The transitions between the biofacies, from shelly benthic faunas to the traces of the soft-bodied benthos and finally to entirely pelagic assemblages, indicate that, during Needmore deposition, part of the basin was stagnant, anoxic and barren with respect to benthic organisms. Following the models of Rhoads and Morse (1971) and Byers (1977) for biofacies patterns in modern anoxic basins, the boundaries between the Needmore biofacies appear to be controlled by interfaces between the aerobic, disaerobic and anaerobic zones within the water column. Comparison with the modern analogues allows the resolution of paleoenvironmental and paleobathymetric parameters for each of the Needmore faunas.

## FAUNAL GRADIENTS IN MODERN ANOXIC BASINS

Rhoads and Morse (1971) and Byers (1977) have summarized the available field- and experimentally-derived data on the distribution of modern macrobenthic organisms under low-oxygen conditions. Their findings, based primarily on studies in the Black Sea, Gulf of California and California Continental Borderland, reveal a tripartite pattern of benthic biofacies. Metazoans are generally absent in the anaerobic zone, where dissolved oxygen levels fall

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below 0.1 ml/l. In the disaerobic zone (d.o. greater than 0.3 ml/l, but less than 1.0 ml/l), soft-bodied organisms such as polychaetes and nematodes predominate, and calcified forms are essentially absent. The infaunal metazoans of the disaerobic environment are typically reduced in overall body size, and the community is generally of low diversity (Rhoads and Morse, 1971). Aerobic environments, of greater than 1.0 ml/d d.o., show a greater proportion of calcified taxa and an associated increase in overall macrobenthic diversity. Dissolved oxygen levels between 1.0 and 2.0 ml/l are considered marginally aerobic; within this range, average body size and benthic diversity are reduced relative to normally aerobic environments (i.e., 2.0 - 7.0 ml/l d.o.; Byers, 1977).

Utilizing the Rhoads and Morse model for the ideal modern anoxic basin, low-oxygen environments can readily be recognized in the rock record. According to Byers (1977), the pattern of preserved biofacies should consist of: 1) an aerobic zone assemblage of calcified benthic macrofossils, with associated evidence of a burrowing infauna, 2) a disaerobic facies which lacks a shelly component and is instead characterized by small diameter traces formed by soft-bodied or weakly calcified infauna and 3) an anaerobic zone facies devoid of benthic fossils.

Certain constraints should be placed on application of this model to the ancient. In a study of modern benthic biofacies in the disaerobic Santa Cruz Basin of the California Continental Borderland, Edwards (1979) observed that downslope movement of water and sediment via sediment gravity flows can produce patches of aerobic (calcified) faunas within the disaerobic zone. Whenever the Rhoads and Morse model is to be applied to the rock record, the possibility of sediment gravity flows must therefore be eliminated. Edwards also suggested that bioturbation in disaerobic facies may not be preserved if the original sediment is thixotropic; thus massive slope and basinal lithologies should be closely examined before the possibility of biogenic reworking is ruled out.

## THE NEEDMORE ASSEMBLAGES

### Phacops Biofacies

This biofacies, which is found in the calcitic shale and calcitic shale and limestone lithofacies of the Needmore, has both a shelly and a trace fossil component. The dominant calcified form, the phacopid trilobite Phacops cristata variabilis, constitutes slightly more than 46 percent of the shelly macro fauna identified from this biofacies. The remainder of the calcareous fauna is divided among the brachiopods Eodevonaria melonica, Eodevonaria arcuata, Coelospira camilla, Pacificocoelia acutiplicata, and Orbiculoidea media, the high-spined gastropod Palaeozygopleura hamiltoniae, and minor proportions of various other trilobites, brachiopods, gastropods, bivalves, and corals. The average body size of the shelly fossils is small, and they are sparsely distributed within the shales and limestones.

The ichnofossils associated with this fauna are moderate diameter (3-4 mm) Planolites and Chondrites, both grazing tunnels which probably indicate the presence of infaunal marine worms (Hantschel, 1962; Frey, 1975; Kennedy, 1975).

The combination of shelly and trace fossils, which in the Needmore distinguishes the Phacops biofacies, corresponds to the aerobic zone biofacies

of Rhoads and Morse (1971). In particular, the diversity of the calcified macrobenthos points to oxygenated substrate conditions. However, the relative sparseness of the fauna and the relatively small body sizes may indicate marginally aerobic conditions, with d.o. levels between 1.0 and 2.0 ml/l. Among modern faunas, crustaceans, articulate brachiopods, gastropods, and protobranch bivalves are known to persist at reduced body sizes into this slightly less oxygenated environment.

The oxygenated, or aerobic, zone in the Black Sea, the largest of the modern anoxic basins, extends to an approximate depth of 50 m. This should be considered a maximum depth for the Phacops fauna, unless the downslope processes of substrate oxygenation described by Edwards (1979) were active. However, there is no published evidence for sediment gravity flows in the Needmore.

### Planolites-Chondrites Biofacies

An abundance of the ichnofossils Planolites and Chondrites, and an associated extreme sparsity of shelly macrofauna characterize the Planolites-Chondrites biofacies of the Needmore. Within this zone of few calcified fossils, the curvilinear trace Planolites and the dendritic form Chondrites are quite small, averaging approximately 1 mm in diameter. This contrasts sharply with the larger sized (3-4 mm) graving traces characteristic of the Phacops biofacies. The Planolites-Chondrites biofacies occurs chiefly in the lower calcitic shale lithofacies of the Needmore, just above the transition from well-laminated, black shale to less distinctly-bedded, calcitic shale. The increase in bioturbation in the ichnofossil-dominated biofacies of the calcitic shale is probably responsible for the decrease in the distinction of the laminations, following the rule proposed by Byers (1974).

Although body fossils are uncommon in the Planolites-Chondrites biofacies, three brachiopod genera are occasionally observed. These are the acrotretid Orbiculoidea media and the leptocoeliids Pacificocoelia acutiplicata and Leptocoelia flabellites. These brachiopods are considered to have been epiplanktic and therefore not part of the shelly benthos (Newton, 1978).

The predominance of small diameter infaunal traces, in conjunction with the absence of shelly benthic taxa, points to a disaerobic environment for the Planolites-Chondrites biofacies. Analogy with the Rhoads and Morse (1971) model implies dissolved oxygen levels in this facies of 0.3-1.0 ml/l. Comparison with the O<sub>2</sub> stratification in the Black Sea (Byers, 1977) suggests a probable maximum depth range for this fauna of from 50 m to 150 m.

### Orbiculoidea-Pacificocoelia Biofacies

The well-laminated black shales of the Needmore lack trace fossils and contain a sparse shelly assemblage of disarticulated brachiopod valves. In order of relative abundance, the brachiopod taxa represented are the inarticulate Orbiculoidea media, the globose leptocoeliid Pacificocoelia acutiplicata and its close relative, Leptocoelia flabellites. Aside from these brachiopods, the only other identifiable macrofossil component of the fauna is the nautiloid cephalopod, Michelinoceras, which is fairly rare.

Little is known about the life habits of the three brachiopods common in this biofacies. Each of these forms is nearly substrate-independent within the Needmore, occurring in subequal proportions in all Needmore lithofacies. This circumstance, in addition to functional morphologic considerations outlined in Newton (1978), imply an epiplanktic habit for these small globose brachiopods. This view is also substantiated by their preservation as disarticulated, disoriented valves in a substrate which lacks evidence of current or storm activity.

The Orbiculoidea-Pacificocoelia assemblage is here interpreted as a pelagic, epiplanktic macrofauna which accumulated as a thanatocoenose on an anoxic basin floor, rather than dwelling epifaunally. The well-laminated character of the black-shale lithofacies also suggests the absence of either calcified or soft-bodied infauna. Deposition of the Needmore black shales and accumulation of the Orbiculoidea-Pacificocoelia are inferred to have proceeded wholly within the anaerobic zone, where dissolved O<sub>2</sub> levels were probably lower than 0.1 ml/l (Rhoads and Morse, 1971). A minimum depth for the environment of Needmore black shale deposition would be approximately 150 m, according to the Black Sea model of Byers (1977).

#### SUMMARY

The macrofaunas of the Needmore Shale occur in three distinctive assemblages which correspond to layers of oxygenation within a stagnant Lower to Middle Devonian Appalachian basin (Figure 25). The Phacops fauna dwelled in the shallow, nearshore, oxygenated portions of the basin, and graded westward, with increasing depth, into the Planolites-Chondrites worm fauna which was more tolerant of lowered O<sub>2</sub> conditions. The Orbiculoidea-Pacificocoelia biofacies accumulated as a death assemblage on the floor of the anoxic central basin.

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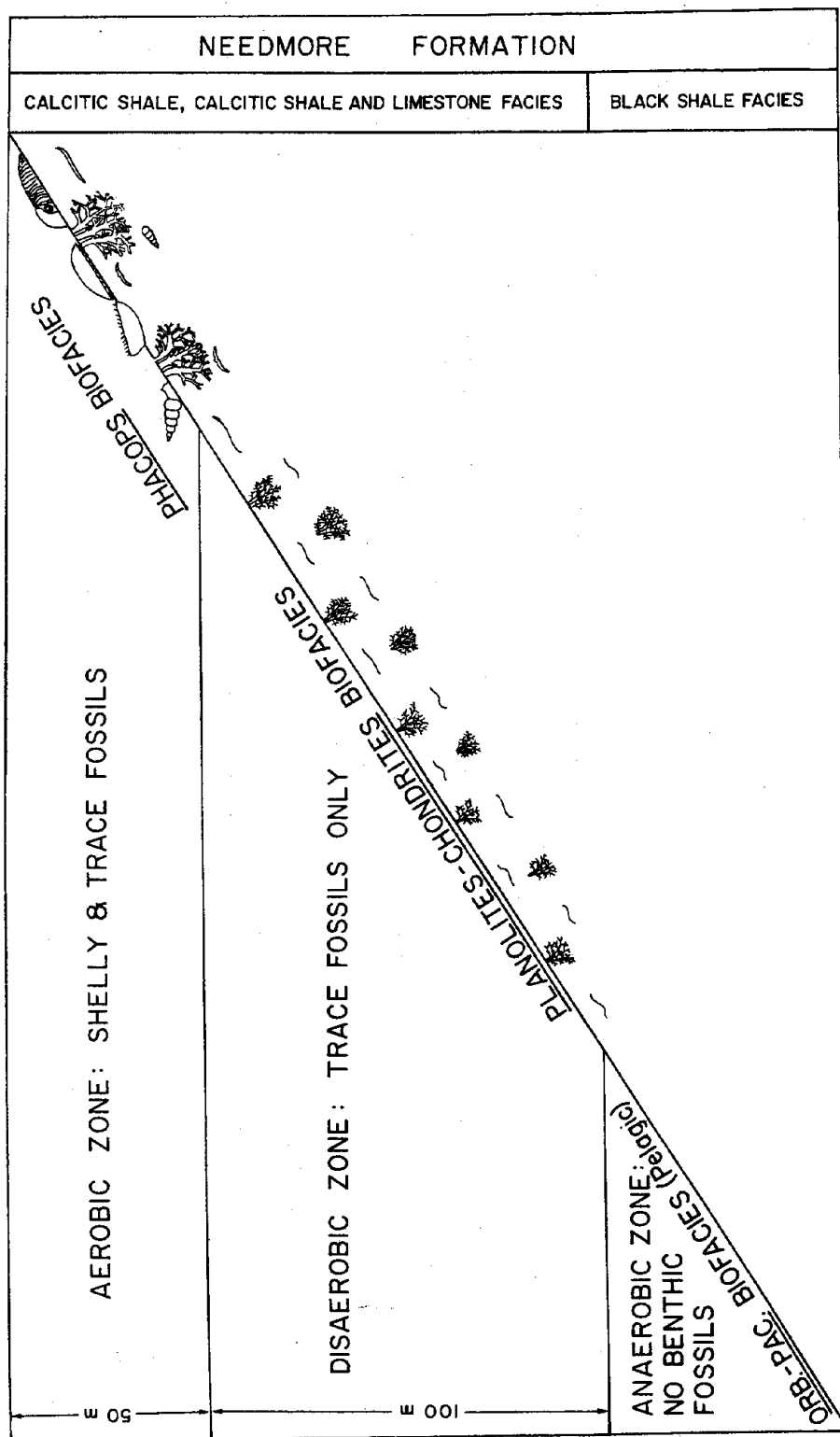


Figure 25. Relation of the Needmore biofacies to zones of oxygenation and to paleobiofacies. Depth of the anaerobic zone is not to scale.

# POLYMICTIC DIAMICTITES IN THE SPECHTY KOPF AND ROCKWELL FORMATIONS

by

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## INTRODUCTION

Polymictic diamictite, a lithified, unstratified, and unsorted mixture of clay to boulders containing multi-lithology clasts, is a rare rock in the Paleozoic sequence of Pennsylvania. The only occurrences known to me are within the Spechty Kopf Formation in central and northeastern Pennsylvania and in the Rockwell Formation in south-central Pennsylvania and northern Maryland (Figure 26). The occurrences in northeastern Pennsylvania have been described and their origin commented upon (Epstein and others, 1974; Sevon, 1969a, b, c, 1973, 1975), but, except for a brief mention of diamictite at LaVale, Maryland (4, Figure 1) (Dennison and others, 1972, p. 66), the other occurrences have received no attention.

Several features of the polymictic diamictite occurrences are known from work in northeastern Pennsylvania, and, based on limited observations by me, appear true for occurrences elsewhere in Pennsylvania and Maryland.

1. The diamictite occurs only within the Spechty Kopf and Rockwell Formations. These formations are laterally equivalent (Edmunds and others, 1979, p. 11), and occur between the Catskill and Pocono or Burgoon Formations.

2. The diamictites appear to be related to the centers of sediment-dispersal systems hypothesized by Sevon (Sevon and others, 1978; Sevon, 1979) (Figure 26).

3. Thickness variations in the Spechty Kopf Formation in northeastern Pennsylvania indicate the probability of an unconformity at the base of the formation. This surface has local relief up to a hundred meters, and diamictite occurs only in areas of greatest relief. Regional information is sparse, but relief on the unconformable surface may be greatest at the present eastern margin of Devonian rock outcrop and nearly non-existent farther west.

4. The diamictites have narrow distribution parallel to depositional strike, but may have considerable distribution normal to depositional strike. Deposits in Carbon County in northeastern Pennsylvania have a width of occurrence of about 3 km parallel to depositional strike (northeast-southwest), but occur over a distance of about 64 km normal to depositional strike (north-south).

5. At many localities, such as Jim Thorpe (1, Figure 26) and along the Lehigh River to the north, only one diamictite bed occurs. At other localities, such as Cressona (2, Figure 26) and Crystal Springs (3, Figure 26), several diamictites are interbedded with well sorted and stratified sandstones.



6. A specific lithologic sequence is associated with the diamictites. All parts of the sequence are not always present, but the parts always occur in the same vertical arrangement. The complete sequence has been previously described in detail (Sevon, 1969c, p. 86-88, units 30-48; 1975, Described Section 4, units 2-19; and Epstein and others, 1974, p. 446, units 30-48), and is summarized as follows:

Top.

Sandstone, fine- to medium-grained, gray, well-sorted, planar-bedded with beds 1 to 10 cm thick, some ripple-bedded surfaces, gradational lower contact.

Laminite, alternating laminae of fine-grained sandstone and claystone, some coarser sand grains and rare small (1 cm) pebbles, some couplets appear to be fining upward, claystone dominates lower part and decreases in quantity upward as sandstone becomes dominant, gradational lower contact.

Pebbly mudstone, dominantly silt and clay, bedding occasionally indicated by shaly parting or sand grains, some rounded clasts up to 10 cm in diameter, gradational lower contact.

Polymictic diamictite, unsorted mixture of clay, silt, sand, and gravel with occasional boulders up to 60 cm in diameter, coarser grains floating in clay matrix, unstratified, homogeneous throughout, weathers by exfoliation, sharp lower contact.

Base.

7. The larger clasts within the diamictite are of diverse lithologies (Sevon, 1969c, p. 10), and more varied in composition than clasts in the underlying Catskill or overlying Pocono-Burgoon. Clasts of metamorphic rocks are common in northeastern Pennsylvania, and clasts of granitic rocks occur at Crystal Springs (STOP 12). The largest clast known, 60 cm diameter at Jim Thorpe (1, Figure 26), is a fine-grained sandstone of unknown affinity. Well-rounded, red and white quartzites are the most common clasts. The larger clasts are several times larger than the largest in adjacent stratigraphic units.

8. Unusual features locally associated with the diamictite include: (1) large load casts at the base of planar-bedded sandstone where it directly overlies diamictite, (2) very large slump structures in the pebbly mudstone, and (3) thick shale above the diamictite and below the planar-bedded sandstone.

## DISCUSSION

Three aspects of the polymictic diamictites seem to be critically inter-related: (1) their restricted stratigraphic occurrence, (2) the nature of their areal distribution, and (3) the origin of the diamictite within the context of the enclosing lithologies.

1. The widespread occurrence of the diamictite within a restricted stratigraphic interval can only be explained by unique sedimentologic events



which effected at least the Pennsylvania and Maryland parts of the Upper Devonian-Lower Mississippian Appalachian Basin at approximately the same time. Correlative sedimentologic events in other areas are not known at present, but I am tempted to correlate the events with those which resulted in deposition of the Squantum "tillite" in Massachusetts (Bailey and others, 1976, and Cameron and Jeanne, 1976).

2. The local areally restricted nature of the diamictites and their occurrence relative to the centers of the sediment-dispersal systems suggest an intimate relationship with the sediment-dispersal systems. The presence of the diamictites in areas of greatest relief on an unconformable surface suggests that the diamictites represent an early phase of sedimentation after a period of erosion.

3. In general, the Spechty Kopf-Rockwell polymictic diamictites resemble tillite, and the occasional association with overlying varve-like laminites makes a glacial origin tempting (Sevon, 1973). However, Pennsylvania and Maryland were presumably much too close to the equator during the Upper Devonian-Lower Mississippian to allow serious consideration of a glacial origin (Woodrow and others, 1973).

The diamictites bear similarities to debris flow deposits, both subaerial and subaqueous, described elsewhere (Lowe, 1972; Lewis, 1976; Sharp and Nobles, 1953; Bull, 1964). Debris flow movement is a particularly appealing mechanism to account for the transport of the outsized clasts.

The vertical sequence described above (6), in particular the pebbly mudstone and the laminite, and the unusual features (8) are best accounted for by subaqueous deposition. Because of their close association to the diamictite and the gradational contacts between various lithologies, a subaqueous origin appears necessary for the diamictite.

#### SEDIMENTOLOGIC MODEL

The following tentative sedimentologic model is suggested to account for the Spechty Kopf-Rockwell diamictites and associated rocks.

During the uppermost part of Catskill deposition, a large alluvial plain extended westward from a highland which had its fall line probably not more than 100 km southeast of the present easternmost Devonian rocks. Deposition on this plain by meandering streams resulted in red fining-upward cycles characteristic of the uppermost part of the Catskill Formation.

Near the end of the Devonian Period, some event, as yet unknown but probably tectonic, resulted in cessation of deposition on the alluvial plain and initiation of erosion along the previous main channels of deposition. This period of erosion was followed by drowning of the newly formed valleys thus creating embayments in the approximate center of each sediment-dispersal system.

Debris flows were generated either within the highland or on the upper part of the alluvial plain and resulted in deposition of diamicton in the center channels of the embayments. Sediment input changed and pebbly muds and laminites were deposited as the embayments began to fill and the shoreline

retreated basinward. Local disturbances resulted in slumping of some muddy deposits. The embayments were filled by a final phase of broad, sand-flat deposition. Fluvial deposition then returned and the former embayments and the remainder of the former Catskill alluvial plain were covered with deposits by braided streams, and a new alluvial plain developed prior to the onset of Pocono-Burgoon sedimentation.

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# ROAD LOG OF FIELD TRIP

## DAY 1

Friday, October 5, 1979

Inc. mil.	Cum. mil.	
0.0	0.0	LEAVE Holiday Inn in north edge of Bedford, Pennsylvania. TURN LEFT onto U. S. Business Route 220. See Figure 27 for general route map and Table 2 for a summary of the rocks exposed along the route.
2.6	2.6	Village of Cessna.
0.2	2.8	End of Business Route 220 and junction with Pennsylvania Route 56 West. CONTINUE STRAIGHT ahead on U. S. Route 220 northbound.
0.8	3.6	Outcrops of Tonoloway Limestone.
1.1	4.7	Road follows crest of Black Oak Ridge formed by nearly vertical Oriskany Sandstone.
2.0	6.7	SUPPLEMENTARY LOCALITY A on right at intersection of U. S. Route 220 and Pennsylvania Route 869 East. See Figure 28 for stratigraphic column, showing Huntersville Chert intertonguing with Needmore Shale and a complete exposure of Oriskany Sandstone. Exposure was planted with grass after highway completion.
0.5	7.2	Exposure of Mahantango Formation on west side of highway at village of St. Clairsville.
2.5	9.7	Quarry in Helderberg Limestone with abandoned kiln, commonly used decades ago to prepare burnt lime for agricultural fertilizer (also used for whitewash and as disinfectant for barns).
0.9	10.6	TURN LEFT at Zelda's Drive-In Restaurant toward Imler on unnumbered road.
1.8	12.4	Crossroads in village of Imler. CONTINUE STRAIGHT ahead toward Weyant.
0.8	13.2	Buses park on left to let off passengers.

### STOP 1. Imler

Discussants: Kenneth Hasson  
John Dennison  
Richard Jolley

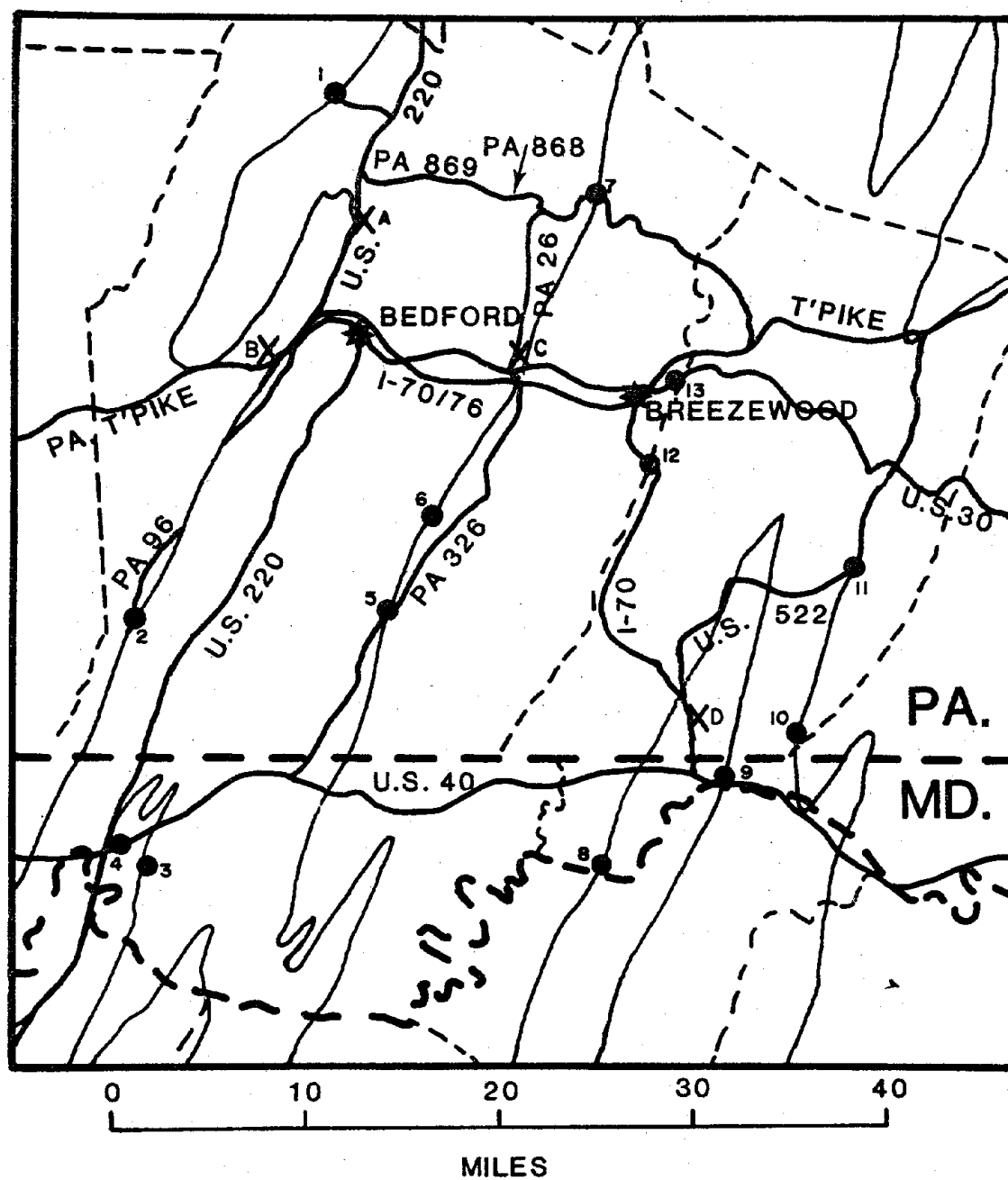


Figure 27. Map of field conference area showing major roads and field trip outcrop localities.

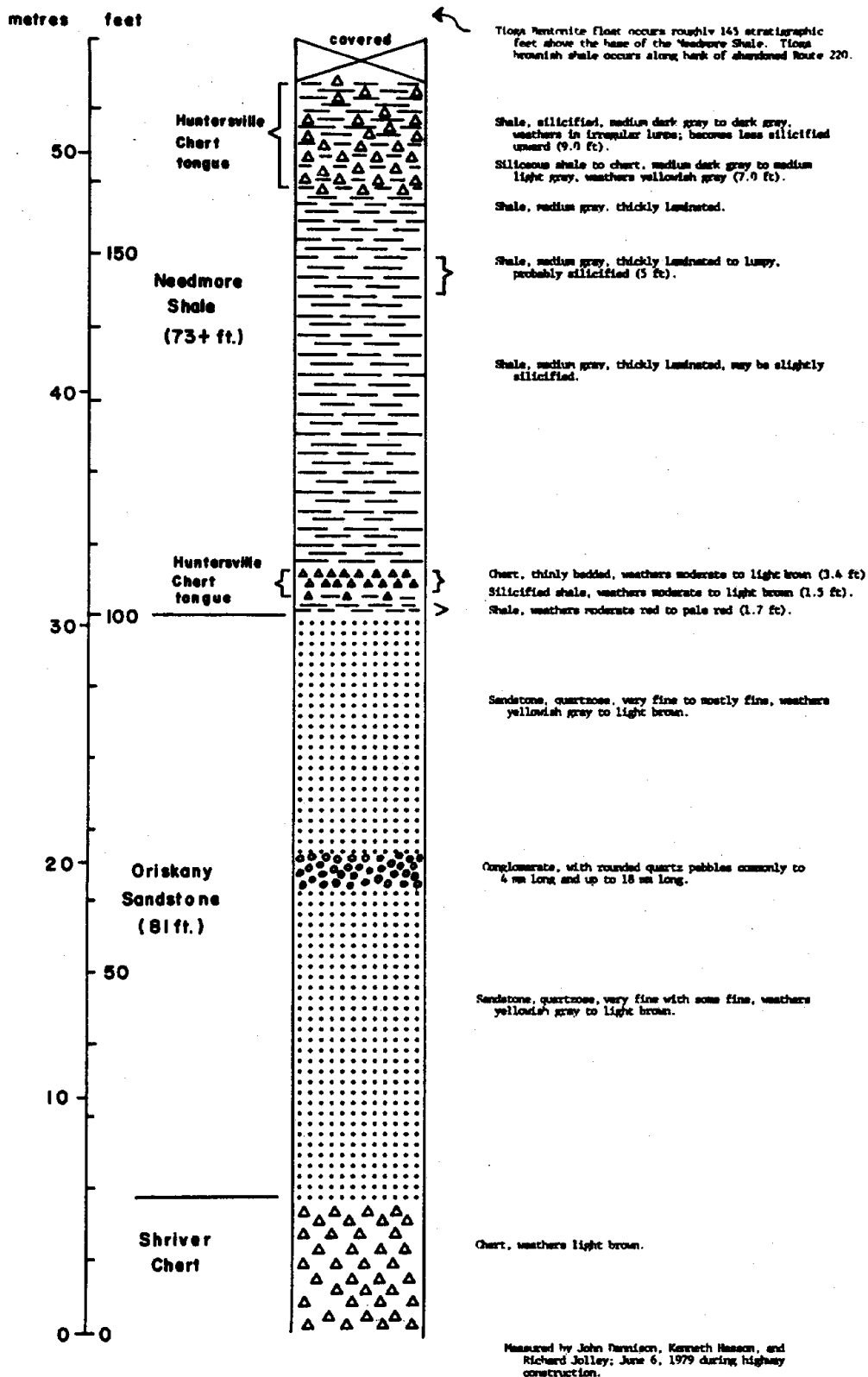


Figure 28. Supplementary Locality A. Section of Oriskany Sandstone, Needmore Shale, and tongues of Huntersville Chert exposed in access cuts along U. S. Route 220 six miles north of Bedford Interchange of Pennsylvania Turnpike, Bedford County, Pennsylvania. (Section measured by John Dennison, Kenneth Hasson, and Richard Jolley during road construction in June, 1979.)

See Figures 29 and 30 for details of this exposure.

Siltstones at electric pole #91 are the lower unnamed siltstone in the upper part of the Mahantango Formation. Along the road leading to the right between electric poles #93 and 94 is an unnamed shale, which is overlain by the Clearville siltstone member of Mahantango Formation (the name is not yet formal, so it is not capitalized in accord with the Stratigraphic Code).

The group should then walk along the highway across Scrubgrass Creek to the exposure of Tully Limestone. This section illustrates the Mahantango-Tully-Harrell-Brallier succession (Figure 30) in which the olive silty shales of the Mahantango are directly overlain by Tully Limestone. Conodonts from this limestone suggest equivalence with the New York Tully.

The grayish black Burket Member of the Harrell Shale overlies the Tully and is succeeded by the dark gray Harrell Shale upper portion. This is, in turn, overlain through a transitional zone of olive-colored silty Harrell Shale, by the siltstones and shales of the Brallier Formation.

- |     |      |  |
|-----|------|--|
| 0.2 | 13.4 | Buses should drive ahead 0.2 mile to park along left side of road at crossroads to await geologists after STOP 1.  |
| 0.5 | 13.9 | Intersection in village of Weyant. TURN RIGHT (south) on Route 869.  |
| 2.6 | 16.5 | Covered bridge on left.  |
| 1.3 | 17.8 | TURN RIGHT in village of Osterburg.  |
| 0.3 | 18.1 | TURN LEFT.   |
| 0.2 | 18.3 | TURN RIGHT onto U. S. Route 220 southbound.  |
| 1.5 | 19.8 | Pass again Supplementary Locality A (see Figure 28).   |
| 4.1 | 23.9 | TURN RIGHT in Cessna onto U. S. Route 220 southbound.  |
| 0.3 | 24.2 | TURN LEFT and follow U. S. Route 220 southbound.   |
| 2.6 | 26.8 | Pass interchange labeled State Police and Pennsylvania Turnpike. This exit leads toward Bedford Holiday Inn. CONTINUE STRAIGHT ahead on U. S. Route 220.                                       |
| 1.2 | 28.0 | EXIT RIGHT onto U. S. Route 30 West and proceed toward Greensburg.   |
| 2.6 | 30.6 | Cross railroad tracks.   |
| 0.1 | 30.7 | View of water gap of Raystown Branch of Juniata River at Wolfburg is visible back to left (at 8 o'clock). Trace of Bedford fault (of Transylvania fault system) passes through this water gap. |
| 0.8 | 31.5 | TURN LEFT from U. S. Route 30 onto Pennsylvania Route 31 toward Manns Choice.  |

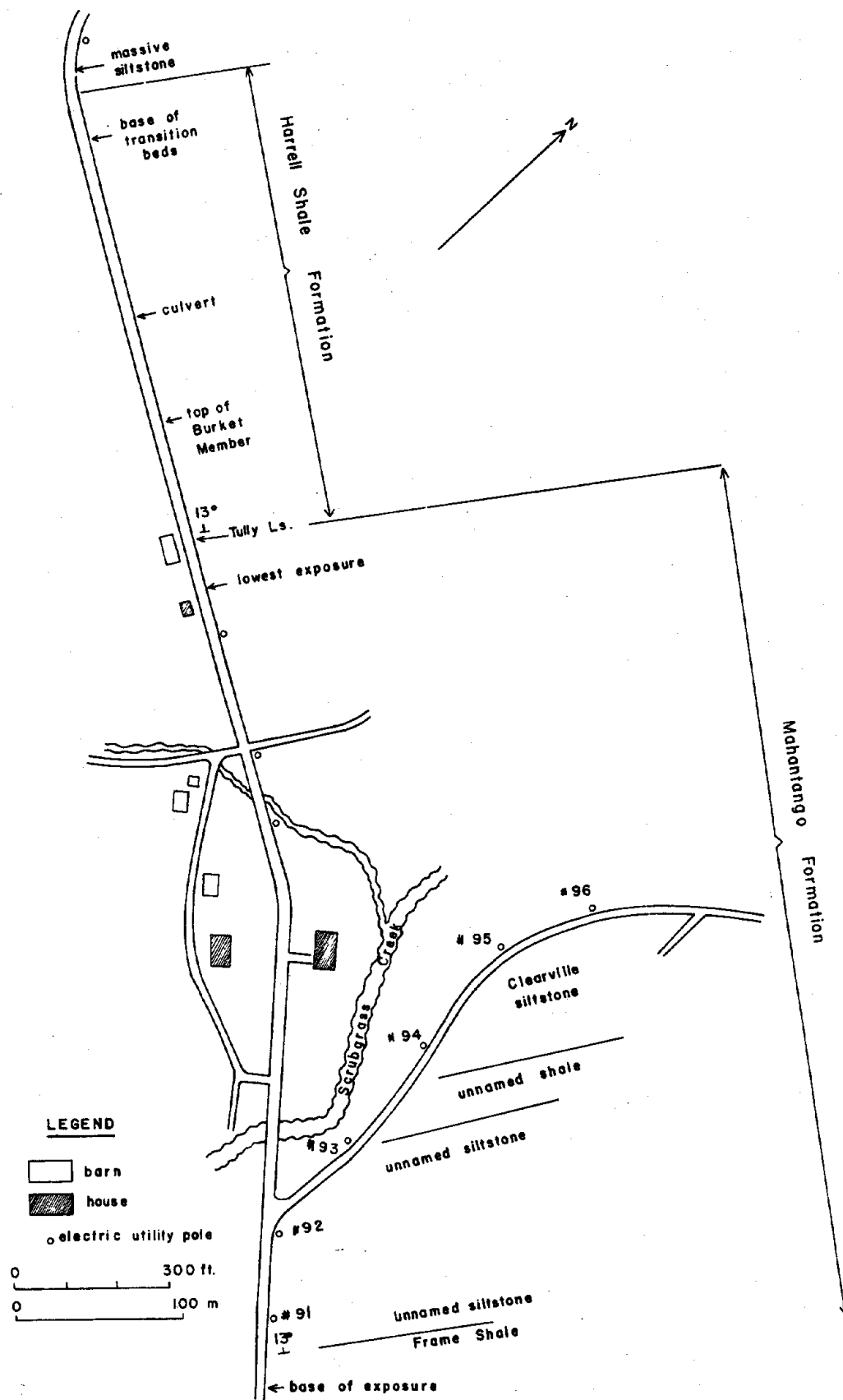


Figure 29. Sketch map of Devonian Shale outcrops 0.8 mile west of Imler, Bedford County, Pennsylvania.



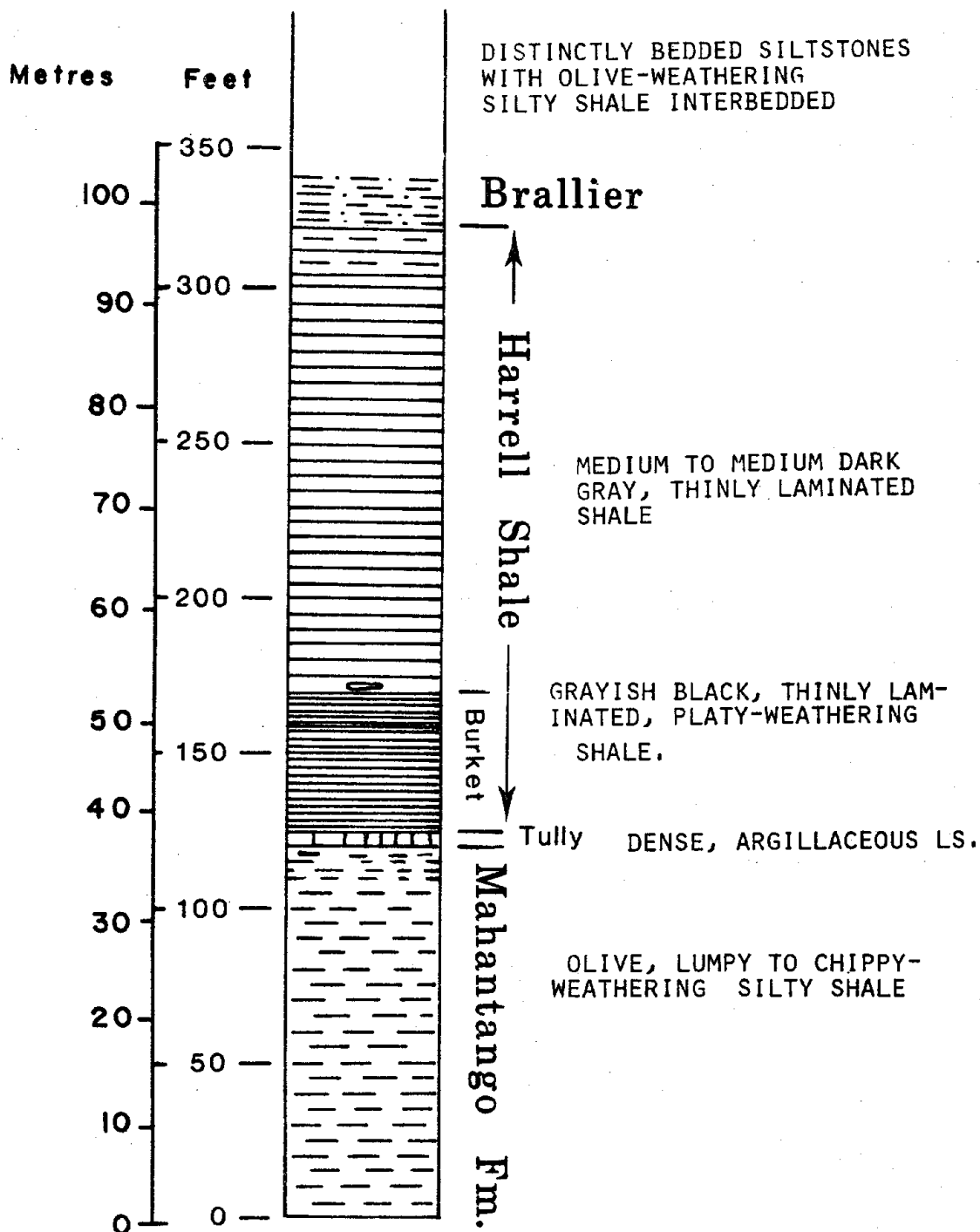


Figure 30. Details of Harrell Shale and enclosing strata 0.8 mile west of Imler, Bedford County, Pennsylvania. The Tully-Harrell succession is typical of the region south and east of Altoona, in the characteristic development of Harrell Shale and its Burket Member. (Measured by Hasson and Dennison.)

- 2.1 33.6 Along the Pennsylvania Turnpike 0.3 mile to right (west) is a section of Mahantango Formation described by Ellison (1965, Pennsylvania Topog. and Geol. Survey General Geology Rept. G48, p. 239-242). Details of the Harrell Shale in this road cut are shown as SUPPLEMENTARY LOCALITY B (Figure 31). At this locality there are two feet of black shale below the Tully Limestone. The significance of this is that from here southwestward the Tully is no longer at the base of the Burket Member of the Harrell Shale, but instead the Tully occurs within the Burket (as Hasson and Dennison apply the stratigraphic nomenclature).
- 1.3 34.9 Junction of Pennsylvania Routes 96 and 31 at Manns Choice. PROCEED SOUTHBOUND on Route 96.
- 2.2 37.1 Intersection with side road leading east 1.4 mile to Sulphur Springs Hotel dating from 1886. Hotel is situated in upper part of Reedsville Shale in breached dome of Wills Mountain anticline. Mary Martin No. 1 well was drilled 6,676 feet deep near hotel by Kerr-McGee in 1963.
- 1.9 39.0 Brallier Formation exposed on right. Village of Buffalo Mills to the east is the site of several small quarries in the Keyser Limestone on the ridge on the north side of the village.
- 0.9 39.9 Red barn with hex sign is southern limit in this valley of Pennsylvania Dutch culture.
- 0.2 40.1 Village of Bard.
- 2.5 42.6 Village of Madley. Light-colored scar on Buffalo Mountain to left (east) is abandoned quarry operated by Leap Ganister Rock Company of Hyndman. The Tuscarora Sandstone was quarried for ganister refractory purposes.
- 0.1 42.7 Dennison has observed Tioga Bentonite at Needmore-Marcellus contact in shale float along right highway bank at Lybarger Church.
- 0.7 43.4 Abundantly fossiliferous Mahantango silty shale and mudrock exposed in cuts on west side (right) of highway.
- 0.2 43.6 Burket Member black shale occurs at back on right (west) side of road.
- 1.6 45.2 Village of Fossilville on left (east). Fossilville was named for the fossiliferous hematitic iron ores associated with the Keefer Sandstone Member of the Mifflintown Formation which was mined many years ago about 0.5 mile from the village. The iron ore was known locally as the "fossil" ore because it contained marine fossils, and the village was named for the locally exploited ore. The ore was used for several short-stack blast furnaces during the mid Nineteenth Century.

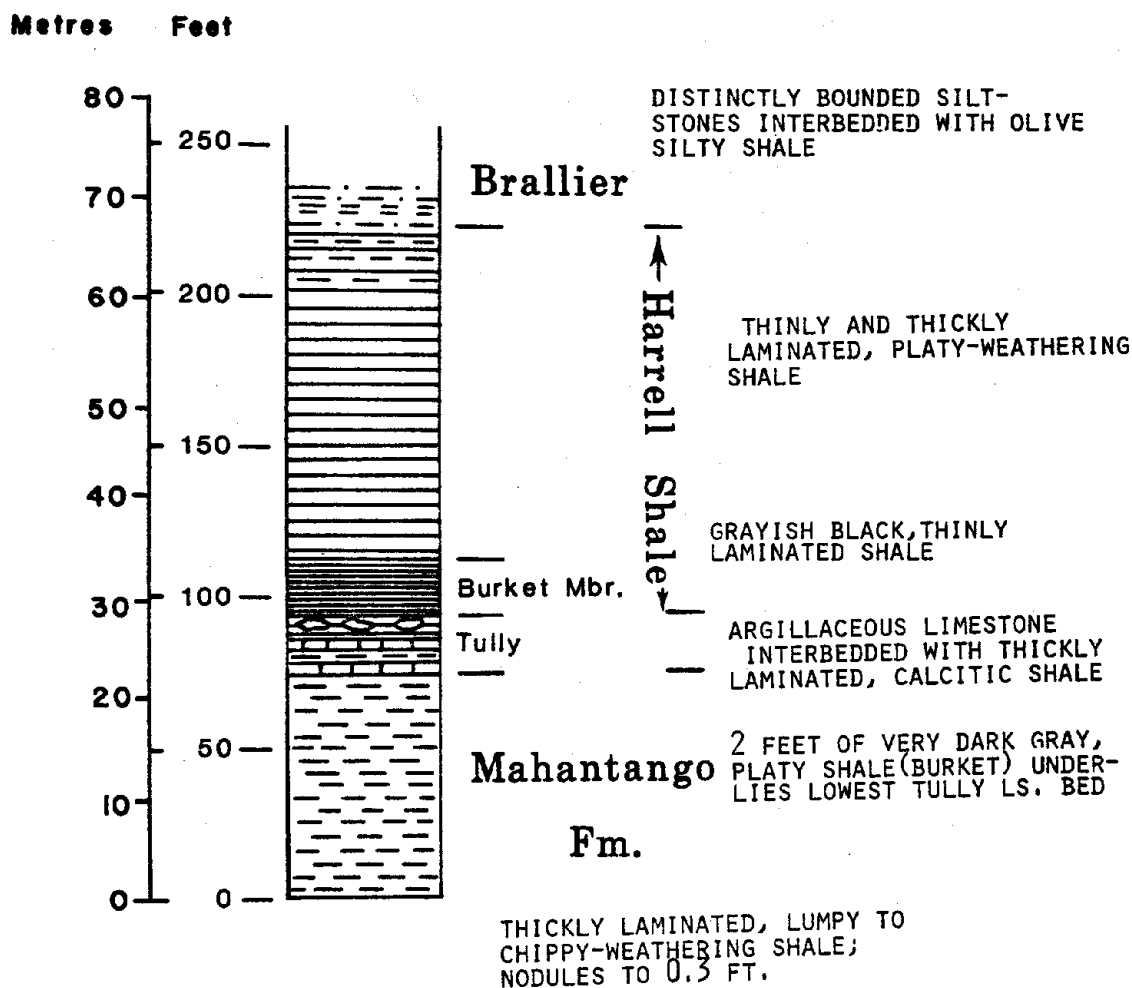


Figure 31. Supplementary Locality B. Stratigraphic column of Harrell Shale and associated strata along Pennsylvania Turnpike 7 miles west of Bedford, Bedford County, Pennsylvania. From this point southward along the Allegheny Front the Tully Limestone occurs within the black shale which Hasson and Dennison assign to the Burket Member, rather than at the base of the Burket like at Imler. (Section measured by Hasson and Dennison.)

- 2.5    47.7    Sign marking sharp bend to left (15 mph).
- 0.2    47.9    TURN sharply to LEFT and continue on Route 96.
- 0.1    48.0    TURN RIGHT from Route 96 onto paved road.
- 0.1    48.1    Stop buses beside mailbox and unload passengers. Field trip will proceed on foot 0.3 miles to top of hill to parking area on right side of road opposite VFW Club.

## STOP 2. Hyndman.

Discussant: John Dennison

See Figure 32 for map of outcrop geology at this locality.

This stop provides an opportunity to walk through a fairly continuous section, exposed nearly along strike, of the interval from the upper Shriver Chert through the lowest Marcellus Shale. The Needmore Shale here exhibits the black, anaerobic shale at its base, definitely blacker than the very dark gray and slightly calcareous, disaerobic shale at Newton Hamilton, Pennsylvania, which was named the Beaver Dam Member black shale by Willard (1939, Pennsylvania Geol. Survey Bull. G19). In a separate article by Cathryn Newton in the present guidebook, the significance of this anaerobic fauna is examined. Considering the absence of a truly black shale facies in the Needmore six miles north of Bedford at Supplementary Locality A (Figure 28), one is tempted to ask whether the Transylvania fault system was tectonically active during the Devonian, with deeper water in a down-dropped block extending south into Virginia along the present Allegheny Front outcrop trend.

This exposure also displays an intertongue of Huntersville chert at the contact between the black shale and the calcitic shale facies of the Needmore Shale. This chert nodule zone can be traced for 128 miles to the south to Bath County, Virginia, and merges westward in the subsurface into the Huntersville Chert. There is a possibility that the roadside shale quarry with black shale is a fault repetition of the strata at the base of the Needmore.

- 0.2    48.3    Reboard buses at top of hill opposite VFW Club.
- 0.3    48.6    Cross tracks of main line of Baltimore and Ohio Railroad connecting Cumberland and Pittsburgh via Connellsville.
- 0.1    48.7    Cross Wills Creek on bridge built in 1882.
- 0.1    48.8    BEAR LEFT.
- 0.3    49.1    Blinker light in town of Hyndman. Rejoin Route 96 southbound, and CONTINUE STRAIGHT ahead.
- 0.1    49.2    Abandoned quarry on right is in Keyser Limestone, a reminder of the Nineteenth Century when Hyndman was an important quarry town. Stone from the Hyndman quarries was shipped to Pittsburgh for blast-furnace flux. Hyndman also contained a ceramic factory which manufactured fire brick from Pennsylvanian-age

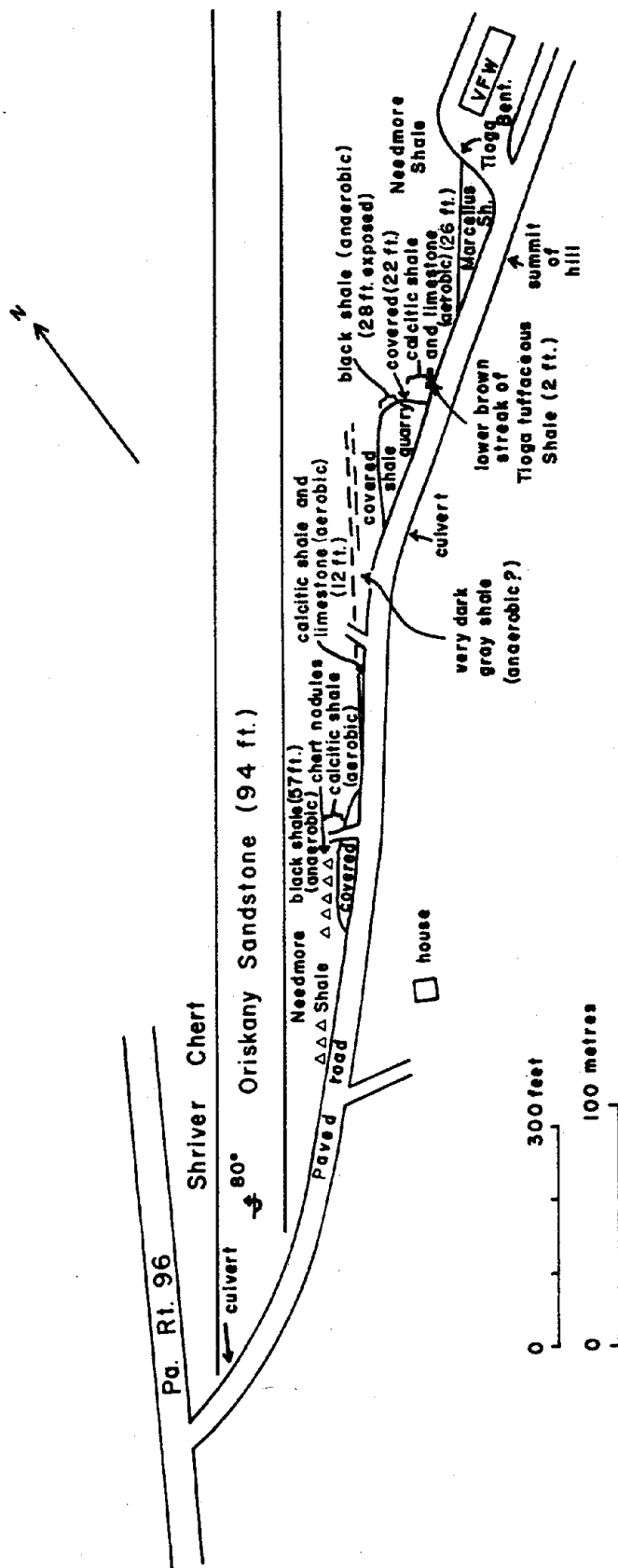


Figure 32. Sketch map of field stop at north edge of Hyndman, Bedford County, Pennsylvania.  
(Prepared by John Dennison and Lee Avery).

flint clays mined in the Wellersburg basin a few miles to the west and refractory brick from ganister quarried locally in the Tuscarora Sandstone.

- 0.2    49.4    Abandoned quarry on left was in Keyser Limestone.
- 1.6    51.0    Long exposure of steeply dipping, fossiliferous, calcitic shale and limestone facies of upper Needmore Shale. The fauna is aerobic, and the trilobite Phacops cristata is locally abundant. Some bedding surfaces are marked by the ichnofossil Taonurus caudagalli.
- 1.1    52.1    Roadside quarry on right in Mahantango Formation.
- 2.0    54.1    Village of Stringtown.
- 0.3    54.4    Oriskany Sandstone on right dips east on limb of small anticline. Syncline to east of road contains exposures of Purcell Member of Marcellus Shale and Needmore Shale.
- 2.0    56.4    Straight ridge on skyline to left is crest of Wills Mountain, an anticlinal ridge formed by Tuscarora Sandstone.
- 0.4    56.8    Enter Maryland. Pennsylvania Route 96 becomes Maryland Route 35, as highway continues straight ahead.
- 0.1    56.9    Center of Ellerslie, Maryland. At one time, Ellerslie contained a large fire brick and ceramic plant which utilized flint clays from the Lower Kittanning coal zone, with mines 1.8 miles to the west at top of the Allegheny Front.
- 0.7    57.6    Marcellus Shale on right.
- 1.2    58.8    Enter Corriganville. In an exposure along a small stream in north edge of Corriganville the Tully Limestone occurs definitely within the black shale of the Burket Member of the Harrell Shale, rather than at the base of the Burket (using the stratigraphic nomenclature scheme advocated by Hasson and Dennison).
- 0.3    59.1    Junction of Maryland Routes 35 and 36. TURN LEFT onto Route 36 and follow valley of Jennings Run. A section of the Upper Devonian was measured along Jennings Run for the 1913 volume on the Devonian of Maryland, published by the Maryland Geological Survey. This locality is not the type section of the Jennings Formation, a name used for Upper Devonian marine shales and sandstones. The type area of the Jennings Formation is Jennings Branch and Jennings Gap in western Augusta County, Virginia (Darton, 1892, Am. Geologist, v. 10, p. 10-18). No specific reference section in Augusta County has ever been measured, and the name Jennings Formation has been superseded in western Allegany County Maryland by Harrell Shale, Brallier Formation, Scherr Formation, and Foreknobs Formation.
- 0.3    59.4    Large quarry on left is in Helderberg and Tonoloway Limestones.

(A detailed description of the quarry is contained in the Guidebook for 37th Annual Field Conference of Pennsylvania Geologists, 1972, p. 59-62).

- 0.1 59.5 Half way up hill to right is the famous Cumberland Bond Cave with a diverse Pleistocene vertebrata fauna discovered while excavating a cut for the Western Maryland Railway in 1912.
- 0.5 60.0 Quarry on left is in Tuscarora Sandstone. It was once used for glass sand, but now produces sand for construction purposes.
- 1.2 61.2 Traffic light at junction of Maryland Route 36 and U. S. Route 40. PROCEED EASTWARD on Route 40 through The Narrows, the water gap of Wills Creek through the Wills Mountain anticline, outlined by the white arch of Tuscarora Sandstone.
- 0.8 62.0 Cross Wills Creek, from whence comes the name of the Silurian Wills Creek Formation.
- 0.1 62.1 Exposures on left are redbeds of Juniata Formation beneath white Tuscarora Sandstone.
- 0.2 62.3 Type section of Silurian Rose Hill Formation is on opposite side of Wills Creek to right. The name comes from the Rose Hill Cemetery overlooking the valley.
- 0.1 62.4 TURN LEFT at traffic light and follow U. S. Route 40 eastbound.
- 0.6 63.0 Red square tower of Allegany County Courthouse marks site of Fort Cumberland (1754), the seat of French and Indian War activities by General Braddock and Colonel Washington. Braddock started his famous march with the British redcoats from here on June 11, 1755 in his ill-fated attempt to capture Fort Duquesne (now Pittsburgh).
- 0.3 63.3 CONTINUE STRAIGHT ahead on U. S. Route 40.
- 0.2 63.5 TURN very sharply to LEFT and follow U. S. Route 40 eastbound.
- 0.7 64.2 CONTINUE STRAIGHT AHEAD beneath concrete highway overpass. DO NOT continue to follow Route 40. CONTINUE STRAIGHT AHEAD on Willow Branch Road toward Community College.
- 1.0 65.2 Allegany Community College on left.
- 0.5 65.7 STOP at T-intersection and then TURN LEFT.
- 0.6 66.3 BEAR LEFT at intersection, following highway up the hill.
- 0.4 66.7 Brallier Formation near axis of Evitts Creek syncline.
- 0.4 67.1 CONTINUE on main road, BEARING RIGHT.
- 0.2 67.3 Park buses on right at pulloff beside church.

LUNCH STOP. Please avoid the tombstones. Clean up all lunch trash.

STOP 3. Mt. Hermon Church.

Discussants: John Dennison  
Kenneth Hasson

In the older geologic literature this locality is known as the Williams Road section, from an old name applied to the road which passes the church.

See Figure 33 for cross section sketch of this outcrop.

In 1958 the Needmore was better exposed, so that in his dissertation Dennison (1960, p. 91-93) was able to record the following sequence, highly generalized below:

Marcellus Shale (100+ feet)  
Tioga Bentonite (3 feet)  
Needmore Shale (131 feet)  
    calcitic shale and limestone facies (19 feet)  
    calcitic shale facies (51 feet)  
    black shale facies (61 feet)  
Oriskany Sandstone (6+ feet)

Float of the Tioga Bentonite, with sand-size mica was visible in presently covered interval near the houses. The Purcell Member limestone and calcitic shale within the Marcellus black shale is unusually well-exposed here, although the golf-ball shaped barite nodules do not seem to occur here.

After the field stop, reboard the buses to retrace route back to Route 40.

1.5	68.8	Cross bridge.
0.1	68.9	TURN RIGHT at intersection.
1.4	70.3	TURN RIGHT just before concrete overpass, entering U. S. Route 40 eastbound. (This is same location as cumulative mileage 64.2).
1.0	71.3	Pass beneath Hillcrest Drive overpass.
0.5	71.8	Pull buses off right side of highway at concrete drain, and unload passengers for STOP 4. <u>Stay off</u> the pavement at all times, and follow guided geologic tour of hillside on right.

Buses proceed straight ahead; road log is directions for bus drivers.

STOP 4. Wolfe Mill.

Discussants: Kenneth Hasson  
John Dennison  
Richard Jolley



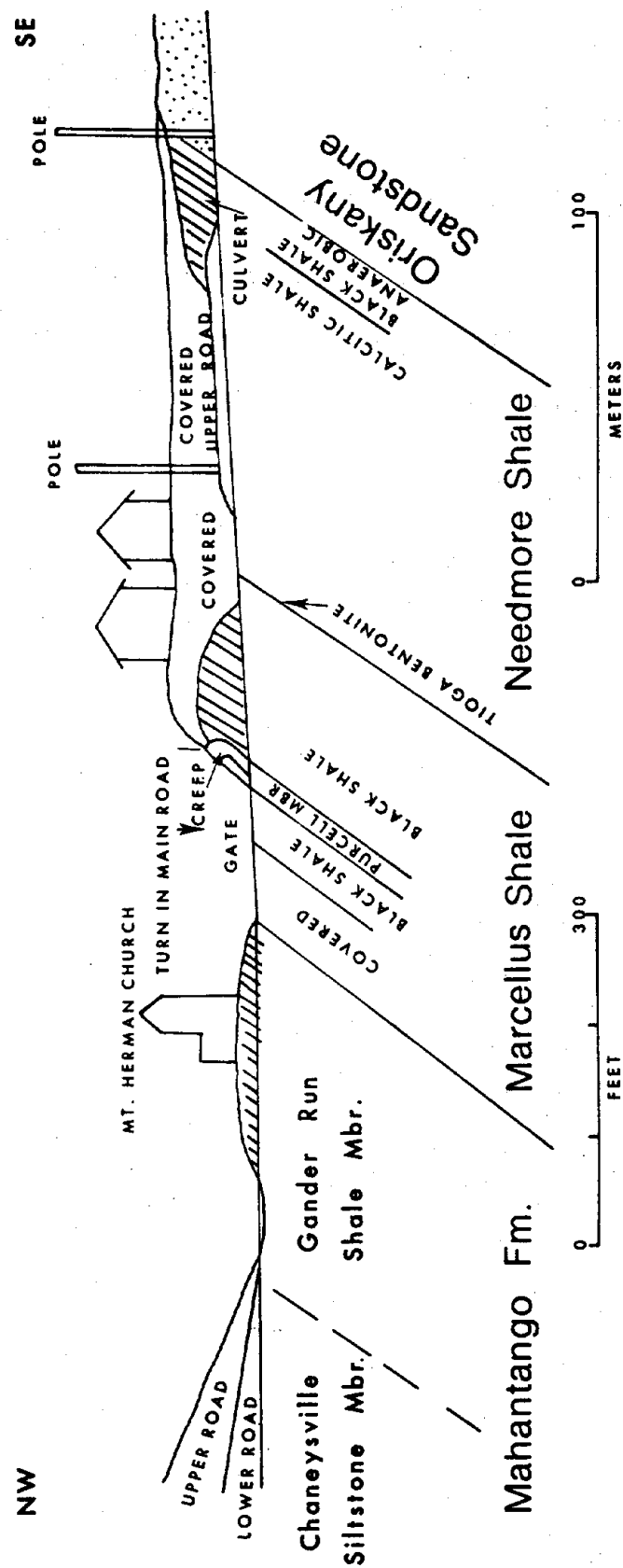


Figure 33. Sketch of outcrop at Mt. Herman Church, located 2 miles east of Cumberland, Allegany County, Maryland. (Prepared by John Dennison and Lee Avery.)

See Figure 34 for a cross section at this stop and Figure 35 for details of Harrell Shale stratigraphy.

The exposure along Route 40, when fresh in 1966, showed the upper part of the Clearville siltstone, with the overlying Pokejoy Member represented by two fossiliferous limestone beds 6 feet apart. These limestones contain corals, trilobites, and brachiopods. The Pokejoy is succeeded by 16 feet of olive-weathering, silty shale (unnamed uppermost shale of Mahantango Formation).

The grayish black shale of the Burket is thin here; the base is transitional and intertongued with Harrell gray shale lithosomes (labeled B and H in stratigraphic column of Figure 35). The lower Burket contains a 0.1 foot pyrite bed, which has now weathered to a limonite and white sulfate mineral streak which is a distinctive marker.

The Tully is represented by a 0.8 foot limestone bed, 16 feet above the top of the Mahantango olive, chippy- to lumpy-weathering shales. At the top of the Route 40 exposures the Brallier siltstones commonly have cross-laminations. The massive siltstone at the very base of the Brallier Formation is prominent throughout the Cumberland area.

This locality was the site of a Civil War battle on August 1, 1864, known as the Battle of Folck's Mill. The mill was along the National Pike (now Route 40) about 0.2 mile beyond the lowest elevation visible along that highway. The hill held up by the Brallier Formation where the buses unload was occupied by four companies of West Virginia Infantry and a battery of the 1st Illinois Light Artillery. The 156th Ohio Infantry occupied the hill held up by Mahantango siltstones to the west of where the buses unloaded. These troops faced Confederate forces situated to the east beyond Folck's Mill, consisting of the 2nd Maryland Light Artillery and four regiments of the Virginia Cavalry.

After examining the Route 40 exposures, follow the field trip leaders on foot to Maryland Route 396 to walk along the cross section diagrammed in Figure 34. After walking through the section, reboard the buses at cumulative mileage 72.5.

- |     |      |  |
|-----|------|--|
| 0.3 | 72.1 | EXIT from U. S. Route 40 and TURN RIGHT at Colonial Manor Motor Lodge sign.  |
| 0.1 | 72.2 | TURN RIGHT at stop sign and proceed up hill.   |
| 0.1 | 72.3 | TURN RIGHT and proceed beneath Route 40 overpass.  |
| 0.1 | 72.4 | STOP SIGN. TURN LEFT toward U. S. Route 220.   |
| 0.1 | 72.5 | TURN buses around at road intersection and park buses on road shoulder. REBOARD BUSES here after walking through STOP 4. |
| 0.1 | 72.6 | TURN RIGHT toward U. S. Route 40 eastbound.  |
| 0.1 | 72.7 | TURN LEFT toward U. S. Route 40 eastbound.   |
| 0.1 | 72.8 | TURN LEFT toward U. S. Route 40 eastbound.   |

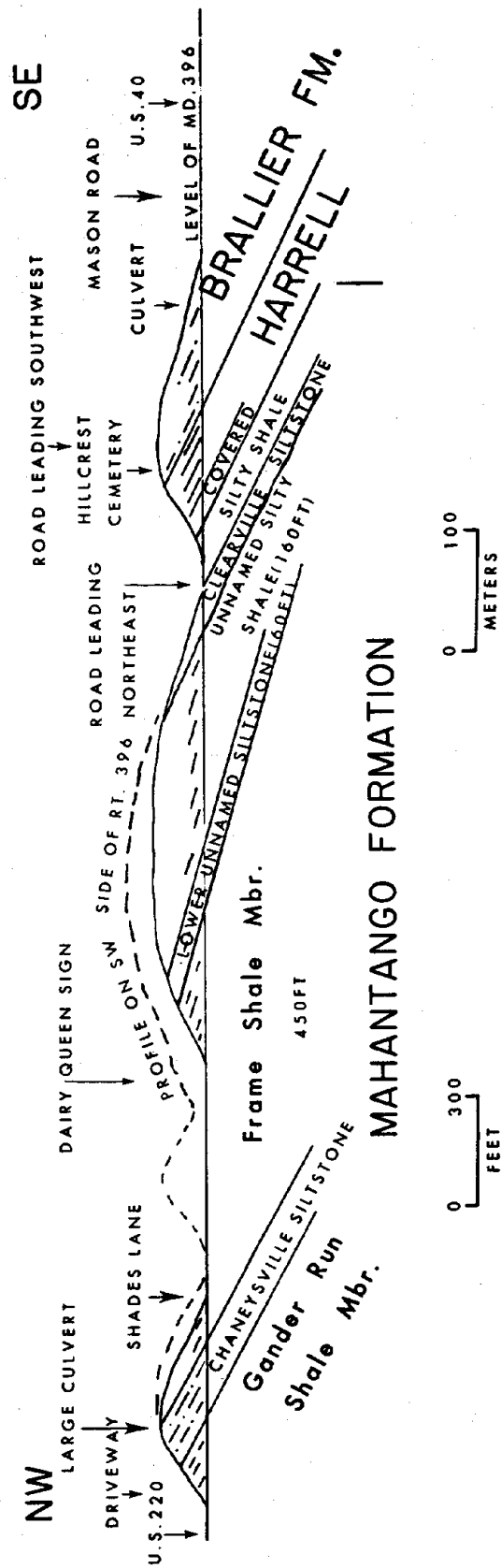


Figure 34. Sketch of cross section of exposures at Wolfe Mill, located 2 miles northeast of Cumberland, Allegany County, Maryland. (Prepared by John Dennison and Lee Avery.)

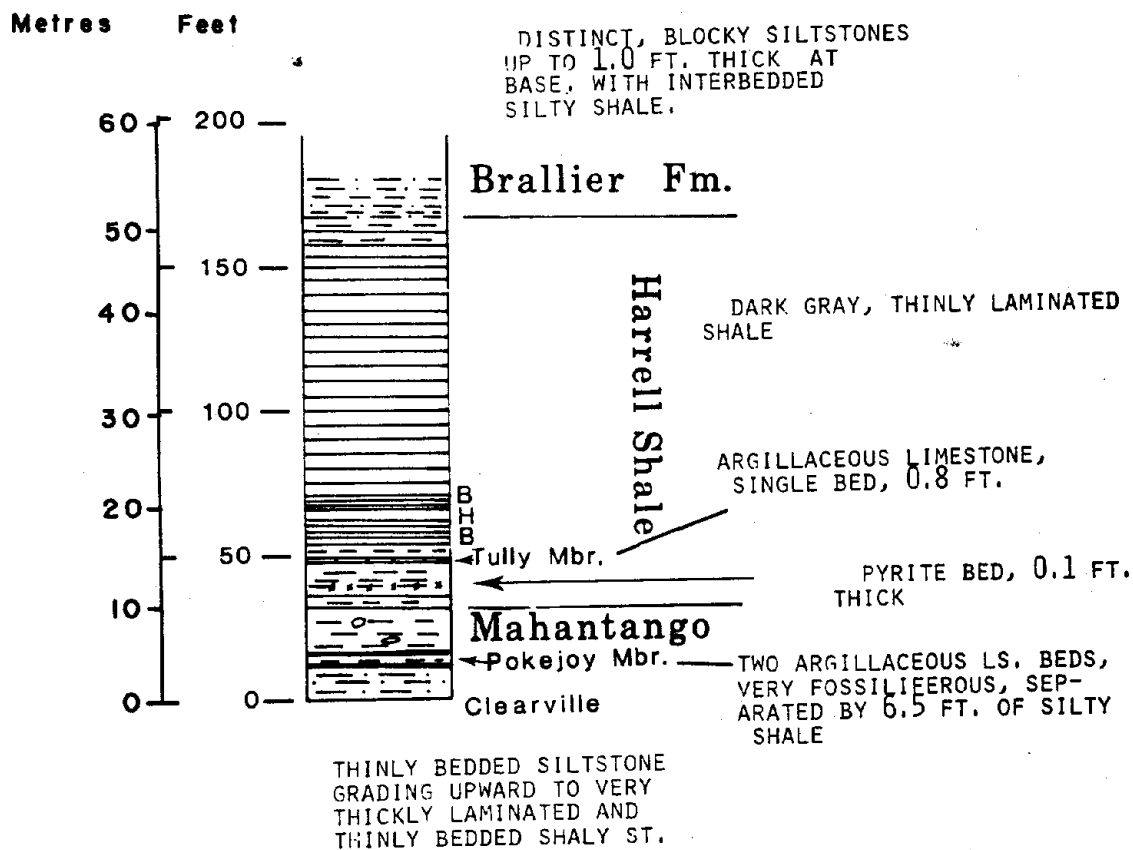


Figure 35. Details of Harrell Shale and associated strata along U. S. Route 40 at Wolfe Mill, located 2 miles northeast of Cumberland, Allegany County, Maryland. (Measured by Kenneth Hasson and John Dennison.)

- 0.1 72.9 STOP SIGN. TURN RIGHT onto U. S. Route 40 eastbound.
- 1.0 73.9 Rose Hill Formation on left.
- 2.5 76.4 Keefer Sandstone at top of Rose Hill Formation on left.
- 0.3 76.7 Deformed McKenzie Formation on left.
- 2.3 79.0 Crest of Martin Mountain is formed by syncline of Oriskany Sandstone.
- 0.9 79.9 Tonoloway Limestone at rest area scenic overlook.
- 3.1 83.0 TURN LEFT at yellow blinker light at Flintstone crossroads. Proceed toward Chaneyville along Chaneyville Road.  
  
Flintstone is named for the Shriver Chert exposures. (This is not the type locality for the TV show by the same name).
- 0.2 83.2 BEAR RIGHT across concrete bridge at intersection.
- 1.6 84.8 CAUTION at bottom of hill, because road makes sharp left turn.
- 0.1 84.9 Enter Pennsylvania, and road becomes Pennsylvania Route 326 northbound. Cross Big Inch pipeline.
- 2.9 87.8 Bloomsburg Formation on left with Skolithus.
- 2.2 90.0 BEAR RIGHT at intersection and follow Route 326 toward Chaneyville. Road passes through Black Valley Gap in Warrior Ridge, a homoclinal ridge formed by Oriskany Sandstone.
- 1.4 91.4 Brallier Formation.
- 4.0 95.4 Chaneyville Siltstone type section on right.
- 0.1 95.5 Park buses on right to unload passengers.

STOP 5. Chaneyville.

Discussants: John Dennison  
Richard Jolley  
Kenneth Hasson

See Figure 36 for cross-section of exposures at Chaneyville. This is the location of the type section of the Chaneyville Siltstone Member near the middle of the Mahantango Formation. The description by Ellison published in 1965 (Pennsylvania Topog. and Geol. Survey General Geology Rept. G48, p. 230-233) was actually measured in 1956 prior to the highway construction which now exposes most of the Chaneyville in a deep cut. Is the fracturing style of the Chaneyville of such a nature that this siltstone has potential for a low-yield gas reservoir lithology with fracture porosity?

All three siltstone members of the Mahantango Formation are fairly well

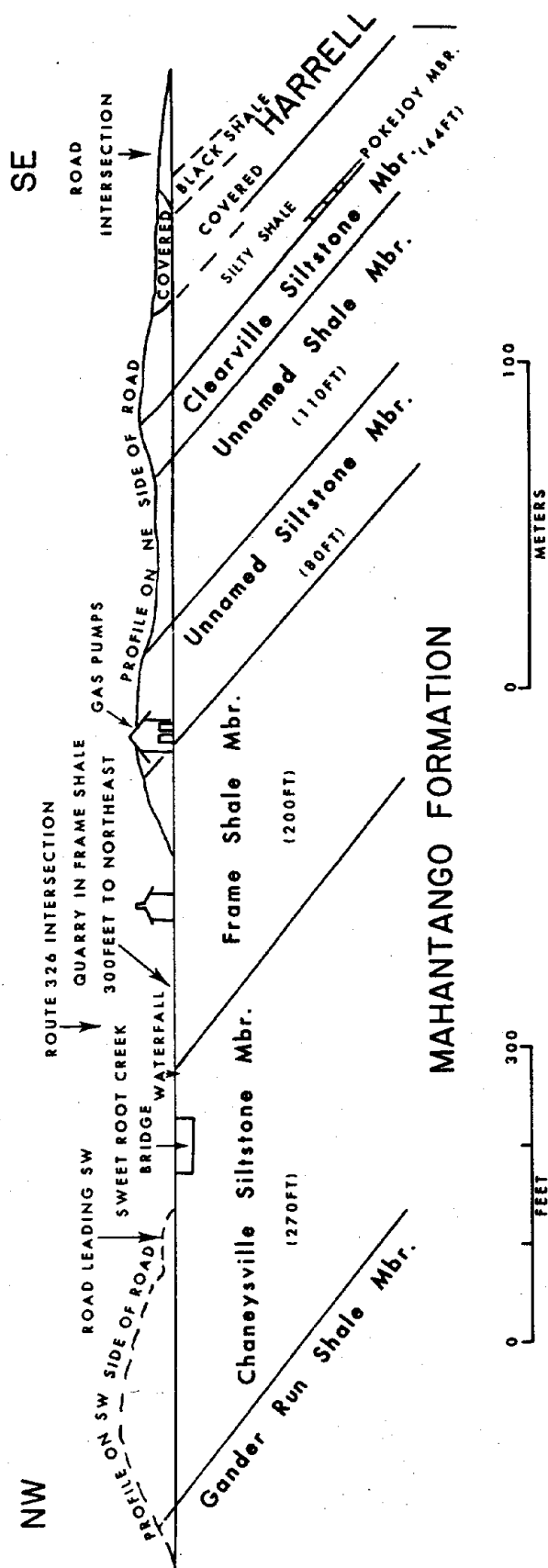


Figure 36. Sketch of exposures at Chaneyville, Bedford County, Pennsylvania. (Cross section prepared by John Dennison and Richard Jolley.)

exposed here, and their relations to the type Chaneyville are clearly displayed. It is therefore suggested that this set of exposures should be designated as the outcrop reference section for the restricted Frame Shale Member, for the 80 feet thick presently unnamed siltstone member, for the 110 feet thick unnamed shale member, for the Clearville siltstone member (informally named for the subsurface of the Clearville Quadrangle by Cate, 1963, Pennsylvania Topog. and Geol. Survey General Geology Rept. G39, p. 229-240) and for the uppermost unnamed silty shale of the Mahantango, just beneath the Harrell Shale. The exposures at STOP 6 (Milk and Water Ridge) fill in most of the intervals which are covered at Chaneyville.

- 0.1    95.6    TURN LEFT at intersection in the heart of Chaneyville, and proceed along wide paved road with yellow stripe.
- 0.6    96.2    TURN LEFT from paved road onto unpaved Milk and Water Ridge Road. Strata at intersection are Brallier Formation.
- 1.5    97.7    Mahantango Formation on right.
- 0.2    97.9    BEAR RIGHT, following main road.
- 2.7    100.6    Dirt road on left has road bank exposure of Chaneyville Siltstone and very weathered Tioga Bentonite. PROCEED STRAIGHT AHEAD on main dirt road.
- 0.2    100.8    Park buses on left side of road at intersection to unload passengers.

#### STOP 6. Milk and Water Ridge.

Discussants: Kenneth Hasson  
Richard Jolley  
John Dennison

See Figure 37 for cross-section sketch of this exposure. Figure 38 illustrates the Harrell Shale.

The unnamed siltstone and overlying mudstone beneath the Clearville siltstone are exposed here. The Pokejoy Member limestone bed has been mostly removed by geologic sampling. The Pokejoy Member is possibly represented by two leached zones, some 13 feet apart; the lower is a limy siltstone, and the upper a 0.2 foot thick crinoid stem fossil hash. There is some suggestion of Harrell-type shale intertongues in the lower part of the Brallier, indicated by the letter H in the columnar section of Figure 38. Does the 209 feet thick bundle of siltstones generally over a foot thick in the basal Brallier represent an eastern equivalent to the basal Brallier siltstone exposed at Wolfe Mill (STOP 4)?

Reboard buses and proceed straight ahead to northeast.

- 0.4    101.2    PROCEED STRAIGHT AHEAD along main road (side road leads to farm house).
- 0.4    101.6    Mahantango Formation on right.

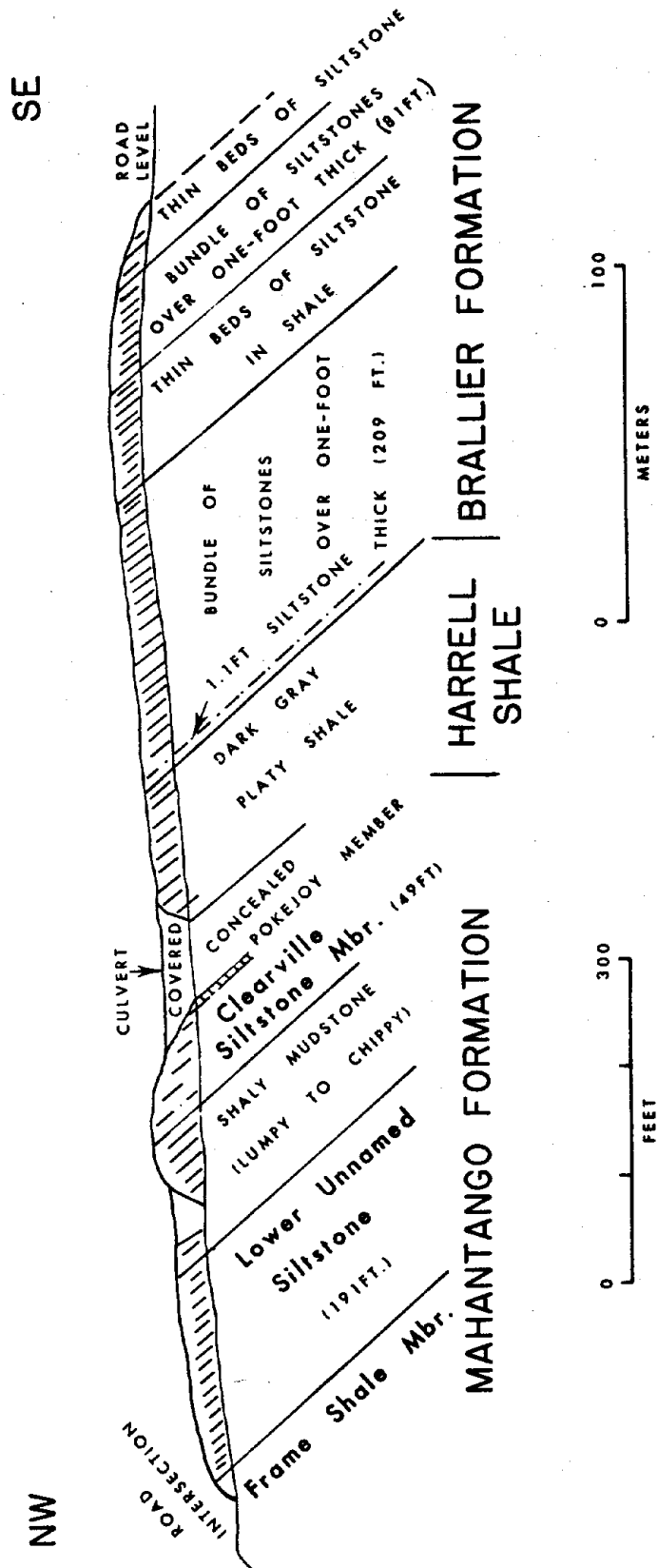


Figure 37. Sketch of strata exposed at Milk and Water Ridge five miles northeast of Chaneyville, Bedford County, Pennsylvania. (Cross section prepared by John Dennison and Richard Jolley.)



Metres Feet

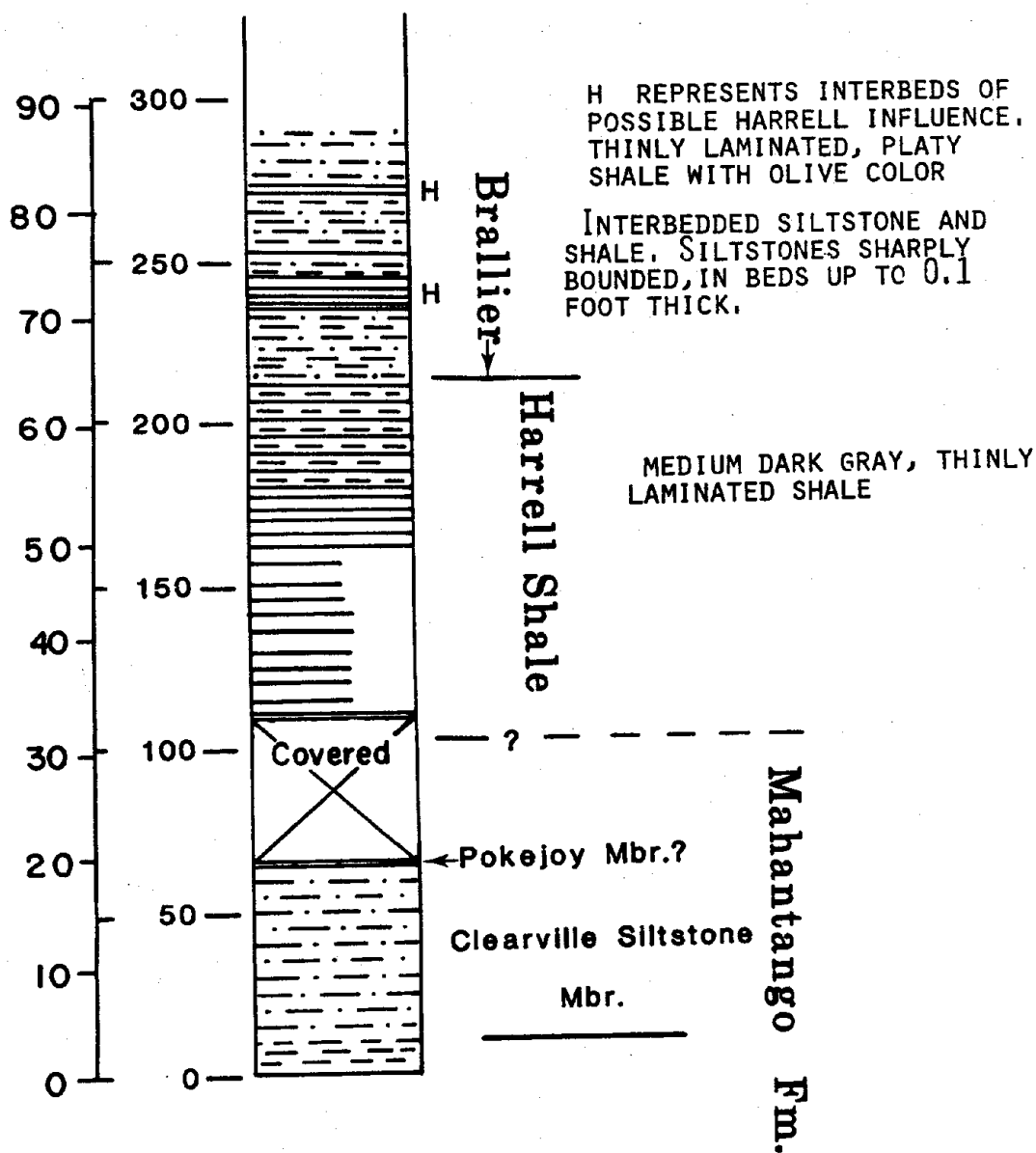


Figure 38. Details of Harrell Shale and associated strata at Milk and Water Ridge five miles northeast of Chaneyville, Bedford County, Pennsylvania. (Section measured by Kenneth Hasson and John Dennison.)

- |     |       |   |
|-----|-------|---|
| 1.1 | 102.7 | Junction with paved road, PROCEED STRAIGHT AHEAD, Summit of Milk and Water Ridge, held up by siltstones of the Brallier Formation.          |
| 0.1 | 102.8 | CONTINUE AHEAD on paved road.   |
| 1.1 | 103.9 | Cross gas pipe line.  |
| 0.3 | 104.2 | STOP SIGN at intersection. CONTINUE STRAIGHT AHEAD.   |
| 2.6 | 106.8 | BEAR LEFT at Y-intersection, following main road.   |
| 3.2 | 110.0 | Entering town of Everett.   |
| 0.4 | 110.4 | STOP SIGN. Turn left and cross bridge.  |
| 0.1 | 110.5 | TURN LEFT at intersection with U. S. Route 30, and proceed toward Bedford. Cliff straight ahead at T-intersection is Helderberg Limestone.  |
| 5.8 | 116.3 | Juniata Formation redbeds overlain by white Tuscarora Sandstone at the Narrows of Raystown Branch of Juniata River through Evitts Mountain. |
| 0.1 | 116.4 | TURN RIGHT onto U. S. Route 30 Bypass leading through north edge of Bedford.  |
| 1.9 | 118.3 | TURN RIGHT from U. S. Route 30 Bypass onto U. S. Route 220 Bypass northbound toward Altoona.  |
| 2.2 | 120.5 | EXIT from U. S. Route 220 Bypass on road leading toward Pennsylvania Turnpike and State Police.   |
| 0.5 | 121.0 | STOP SIGN at T-intersection. TURN LEFT.   |
| 0.1 | 121.1 | TURN LEFT into parking lot of Bedford Holiday Inn.  |

#### END OF FIRST DAY OF FIELD TRIP

Table 2. General summary of rocks exposed in trip area

<u>Mississippian System</u>	(2,000 feet)
Mauch Chunk Formation	(970-1,000 feet)
Greenbrier Limestone	(0-200 feet)
Pocono Group	(920 feet)
Burgoon Sandstone	(400 feet)
Rockwell Formation	(520 feet)
<u>Devonian System</u>	(7,400-9,000 feet)
Hampshire Formation (Catskill Formation)	(2,060-2,500 feet)
Greenland Gap Group	(2,410-2,830 feet)
Foreknobs Formation	(1,450-1,560 feet)
Red Lick Member	(43-69 feet)
Pound Sandstone Member	(23-37 feet)
Blizzard Member	(472-494)
Briery Gap Sandstone Member	(28-39 feet)
Mallow Member	(870-930 feet)
Scherr Formation	(960-1,270 feet)
Brallier Formation	(1,800-2,200 feet)

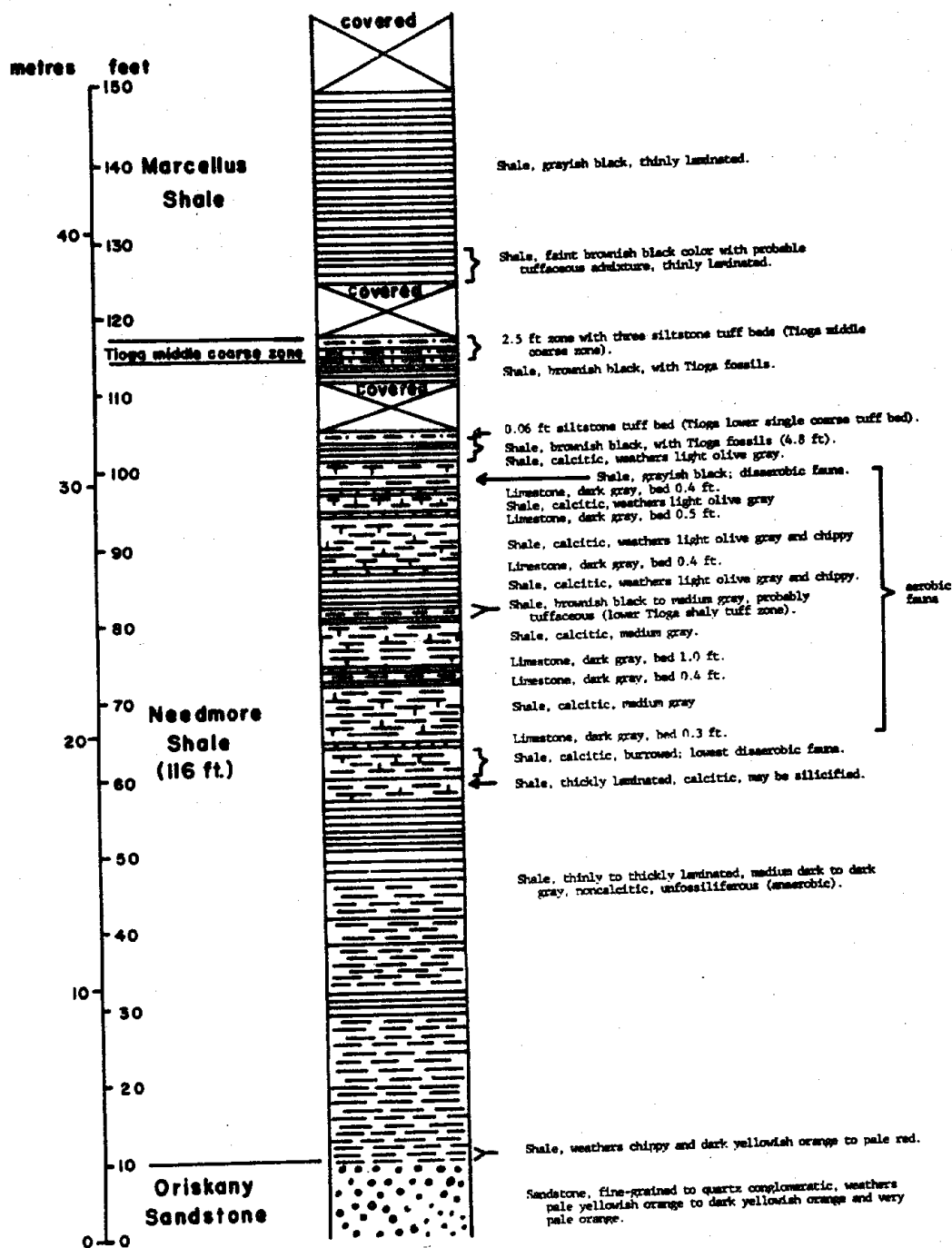
Table 2 (continued).

	Harrell Shale (0-240 feet)
	Burket Member (0-160 feet)
	Tully Member (0-10 feet)
	Mahantango Formation (600-1,250 feet)
	Pokejoy Member (0-10 feet)
	Clearville Siltstone Member (10-60 feet)
	Frame Member (200-400 feet)
	Chaneyville Siltstone Member (100-270 feet)
	Gander Run Shale Member (300-850 feet)
	Marcellus Shale (450-800 feet)
	Purcell Member (shale and limestone) (20-50 feet)
	Tioga Bentonite (3 feet)
	Needmore Shale (120-140 feet)
	Oriskany Sandstone (30-180 feet)
	Helderberg Group (460 feet)
	Shriver Chert (85-160 feet) Licking Creek Limestone (118 feet)
	Mandata Shale (15-30 feet)
	Corriganville Limestone (formerly New Scotland Limestone) (27 feet)
	New Creek Limestone (formerly Coeymans Limestone) (15 feet)
	Keyser Limestone (upper part) (Total Keyser Formation 280-300 feet)
	LaVale Limestone Member (35 feet)
	Jersey Shore Limestone Member (100 feet)
	<u>Silurian System</u> (2,200 feet)
	Keyser Limestone (lower portion)
	Beyers Island Limestone Member (160 feet)
	Tonoloway Limestone (460-600 feet)
	Wills Creek Formation (400-480 feet)
Mifflintown Fm. (310 feet)	Williamsport Sandstone (25-35 feet)
	Bloomsburg Formation (0-65 feet)
	McKenzie Formation (250 feet)
	Clinton Group (610 feet)
	Rochester Shale (28 feet)
	Keefer Sandstone (8-20 feet)
	Rose Hill Formation (420-575 feet)
	Cresaptown Iron Sandstone Member (10-30 feet)
	Tuscarora Sandstone (350-525 feet)
	<u>Ordovician System</u> (5,400 feet)
	Juniata Formation (600-1,000 feet)
	Bald Eagle Formation (530 feet)
	Reedsville Formation (1,300 feet)
	Coburn Formation (50 feet)
	Salona Formation (160 feet)
	Nealmont Formation (86 feet)
	Benner Formation (87 feet)
	Hatter Formation (61 feet)
	Loysburg Formation (1,000 feet)
	Nittany Formation (1,000 feet)
	Larke Formation (200 feet)
	<u>Cambrian System</u> (2,300 feet)
	Mines Formation (200 feet)
	Gatesburg Formation (1,500 feet)
	Warrior Formation (600+ feet) (base omitted by faulting)

DAY 2

Saturday, October 6, 1979

Inc. mil.	Cum. mil.	
0.0	0.0	EXIT from parking lot of Bedford Holiday Inn, TURNING RIGHT onto U. S. Route 220 Business southbound.
0.1	0.1	TURN RIGHT toward U. S. Route 220 Bypass. STAY in lane leading toward Cumberland.
0.7	0.8	MERGE with U. S. Route 220 Bypass and HEAD SOUTHBOUND.
2.3	3.1	Intersection of U. S. Route 220 Bypass and U. S. Route 30 East. EXIT toward Everett.
1.0	4.1	Bedford business district on right.
1.5	5.6	White strata are Tuscarora Sandstone underlain by red Juniata Formation at the Narrows of Raystown Branch of the Juniata River through Evitts Mountain.
3.0	8.6	Core of anticline with Cambrian Gatesburg and Mines Formation in center of overthrust anticline.
2.3	10.9	White cliffs of Tuscarora Sandstone which forms Tussey Mountain.
0.3	11.2	Enter Everett.
0.3	11.5	Cliff of Helderberg Limestone on left (this is same location as mileages 110.5 (Day 1) and 152.6 (Day 2) on cumulative road log).
0.5	12.0	Traffic light at intersection of U. S. Route 30 and Pennsylvania Route 26. Turn left onto Route 26 northbound.
1.1	13.1	Road cuts on right are site of SUPPLEMENTARY LOCALITY C, showing section of Needmore Shale (see Figure 39). The siliceous beds present in the lower Needmore Shale at Supplementary Locality A (six miles north of Bedford) are absent here, and the anaerobic shale facies of the Needmore is not nearly as dark as at STOP 2.
2.2	15.3	Quarries on right are in Oriskany Sandstone in Warrior Ridge.
5.9	21.2	Junction of Pennsylvania Route 36 and Pennsylvania Route 26. CONTINUE AHEAD on Route 26.
1.5	22.7	Cross ridge held up by Oriskany Sandstone.
0.2	22.9	Needmore Shale on left.



Section measured by John Dennison and Richard Jolley on June 8, 1979 during highway construction.

Figure 39. Supplementary Locality C. Details of Needmore Shale and associated strata in cuts of U. S. Route 30 By-pass through Warrior Ridge one mile north of Everett, Bedford County, Pennsylvania. (Section measured by John Dennison and Richard Jolley during highway construction in June, 1979.)

- |     |      |  |
|-----|------|--|
| 0.8 | 23.7 | Marcellus Shale on left.   |
| 0.5 | 24.2 | Mahantango Formation chippy shale.   |
| 0.3 | 24.5 | Crossroads at Eichelbergertown. TURN RIGHT and unload buses. Buses should go ahead one block to right and turn around; then park along road at intersection. |

STOP 7. Eichelbergertown.

Discussants: Kenneth Hasson  
John Dennison  
Richard Jolley

This outcrop shows the easternmost Tully in the area, and illustrates how one lithology is replaced by another near the Perry Bay margin. The limestones contain conodonts of the *Polygnathus varcus* zone (Tully). The interdigitation of the Tully and Harrell lithosomes extends through some 53 feet. Tully Limestone is absent in the next eastward outcrops. The Burket Member black shale is absent this far east; however, there are some rather dark shales in the lower Harrell.

Also to be seen here are Clearville siltstone and the unnamed upper shale member of the Mahantango. The contact between the Tully and Mahantango is quite clear at this locality. The columnar section for this stop is shown in Figure 40.

Reboard buses, and retrace route along Pennsylvania Route 26 to Everett.

- |      |      |  |
|------|------|--|
| 12.5 | 37.0 | TRAFFIC LIGHT in Everett at junction of Pennsylvania Route 26 and U. S. Route 30. TURN LEFT onto U. S. Route 30 eastbound. (This site is same as cumulative mileage 133.1 (Day 1) and 152.2 (Day 2).   |
| 0.1  | 37.1 | TRAFFIC LIGHT. CONTINUE STRAIGHT AHEAD on U. S. Route 30 eastbound, rather than continue on Pennsylvania Route 26 south-southbound.  |
| 3.4  | 40.5 | Catskill Formation redbeds (non-marine facies of Upper Devonian).  |
| 4.4  | 44.9 | Enter village of Breezewood.   |
| 0.5  | 45.4 | Junction with Interstate 70. TURN RIGHT onto I-70 eastbound.   |
| 1.5  | 46.9 | Catskill Formation redbeds.  |
| 2.1  | 49.0 | Leave Bedford County, and enter Fulton County at gap of Brush Creek through Rays Hill. The opposite lane of I-70 at this site is the location of STOP 12 at cumulative mileage 134.6 of this road log. |
| 0.8  | 49.8 | Mauch Chunk Formation redbeds.   |

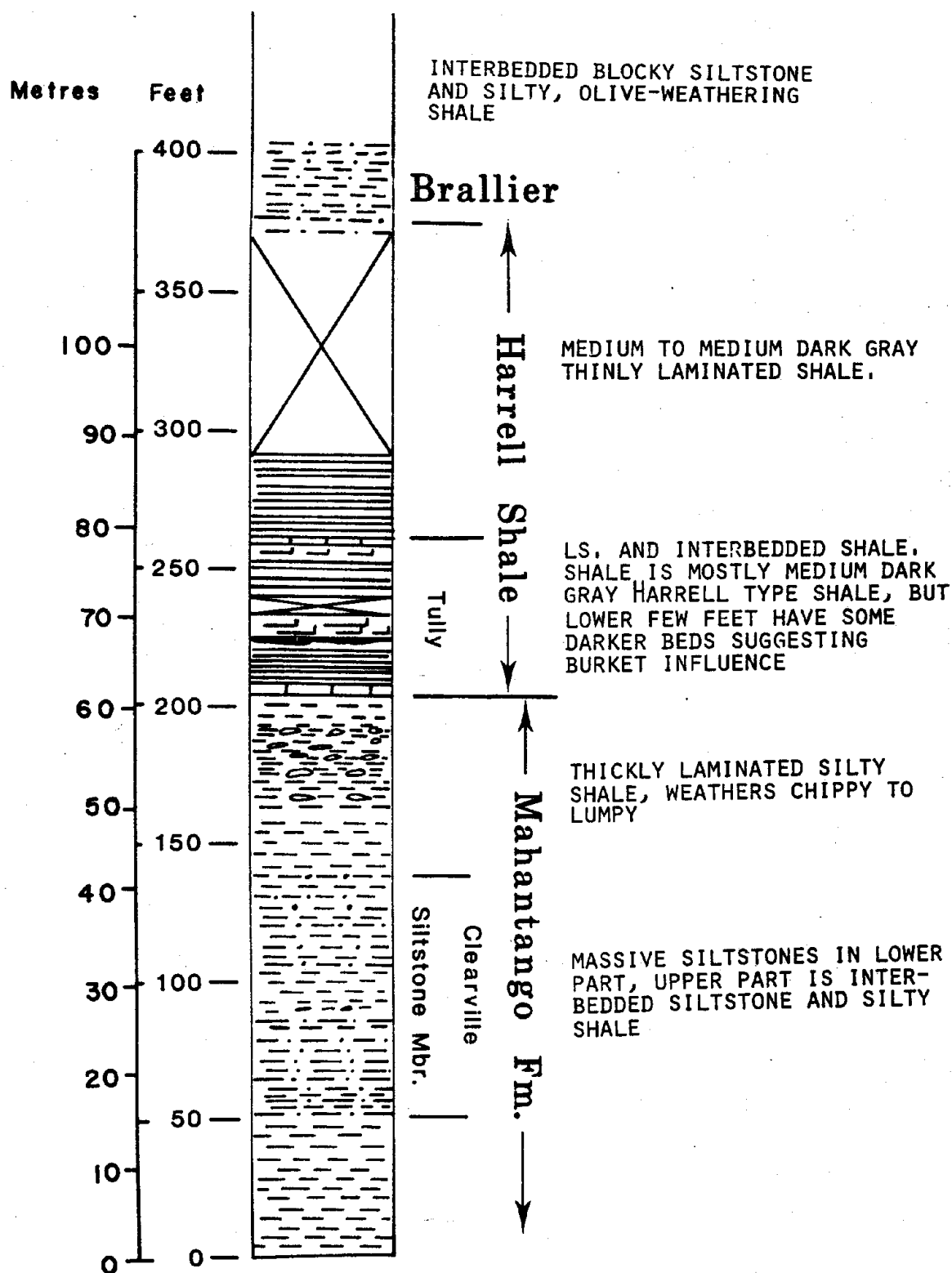


Figure 40. Columnar section of Harrell Shale and associated strata at Eichelbergertown, Bedford County, Pennsylvania. (Section measured by Kenneth Hasson and John Dennison.)

- 1.6 51.4 Rest area on right side of I-70.
- 3.1 54.5 Summit of Town Hill mountain capped by west-dipping Pocono Group.
- 1.6 56.1 Linear ridge on skyline to left is Sideling Hill, a synclinal ridge capped by Pocono Group.
- 1.2 57.3 Redbeds on right are Catskill Formation.
- 2.4 59.7 Catskill Formation redbeds.
- 4.6 64.3 Folds in Brallier Formation on left.
- 0.3 64.6 Brallier Formation rests directly on Mahantango Formation, with no sign of dark shales of Harrell Formation. This relationship is found at several places on the Fulton Lobe in extreme eastern outcrop belts (see STOP 9, for example).
- 0.3 64.9 Mahantango Formation on right.
- 0.2 65.1 Mahantango Formation.
- 0.3 65.4 Purcell Member limestone and shale on left overlies black shale of lower Marcellus Shale Formation, which overlies Tioga Bentonite, Needmore Shale, and Oriskany Sandstone.
- See columnar section for SUPPLEMENTARY LOCALITY D (Figure 41). This is designated as outcrop reference section for Purcell.
- 1.4 66.8 Quarry on left is in Helderberg Limestone. Town on right is Warfordsburg.
- 2.2 69.0 Leave Pennsylvania, and enter Maryland.
- 0.4 69.4 EXIT RIGHT from I-70 onto U. S. Route 40 westbound toward Cumberland.
- 0.4 69.8 Bloomsburg redbed tongues in Silurian carbonates.
- 1.8 71.6 Tonoloway Ridge with orchards on right is source of name of Tonoloway Limestone.
- 0.2 71.8 Large quarries on left are in Helderberg Limestone and Oriskany Sandstone in Tonoloway Ridge.
- 1.4 73.2 TURN LEFT from U. S. Route 40 onto Woodmont Road. PROCEED STRAIGHT AHEAD across Maryland Route 144 and follow Woodmont Road along Devonian shale strike valley. Follow paved road until unloading for STOP 8.
- 2.0 75.2 Intersection with Long Hollow Road. BEAR RIGHT on main road. Strata on right are Chaneyville Siltstone Member of Mahantango Formation.



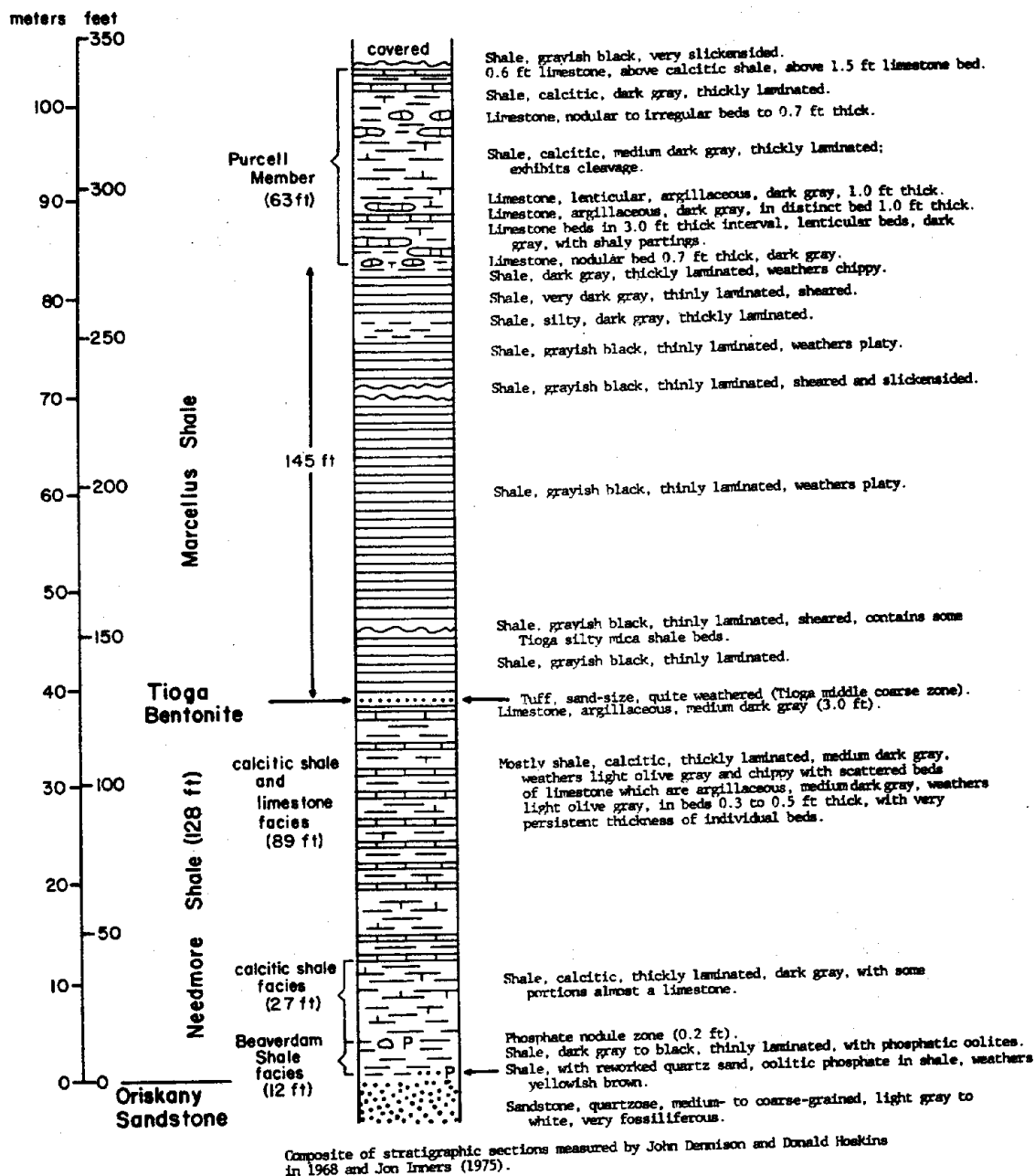


Figure 41. Supplementary Locality D. Exposures along Interstate 70 0.8 mile northeast of interchange with U. S. Route 522 at Warfordsburg, Fulton County, Pennsylvania. Composite of section measured by Jon Inners (1975) and section measured by John Dennison and Donald Hoskins in 1968.

- 0.2 75.4 Clearville Siltstone underlain by unnamed silty shale member.
- 1.1 76.5 PROCEED STRAIGHT AHEAD at T-intersection.
- 2.8 79.3 CAUTION. Steep hill drops road to level of Potomac River.
- 0.2 79.5 Marine (?) redbeds in upper part of Brallier Formation.
- 0.1 79.6 Stop buses, and unload passengers. Then turn around buses and wait here until after STOP 8.

Walk 0.5 mile to east along Deneen Road through Brallier Formation outcrops (including Parkhead Sandstone Member), and then offset along abandoned railroad tracks beside Chesapeake and Ohio Canal to examine the lower Brallier and Mahantango Formations. This walk along the road is the type section of the Woodmont Shale Member of Jennings Formation of older reports of the Maryland (1913); these Woodmont and Parkhead strata are now mapped as Brallier Formation with a Parkhead Sandstone Member.

STOP 8. Woodmont.

Discussants: John Dennison  
Kenneth Hasson  
Richard Jolley

See cross-section sketch in Figure 42 for general stratigraphic setting.

The exposure of Brallier Formation deflected by creep has been illustrated in several geology textbooks.

Figure 43 shows details of the Brallier-Mahantango Formation contact. True Harrell Shale is absent this far east on the Fulton Lobe, and the Brallier rests directly on the Mahantango Formation. Some darker shales in the lowest Brallier may represent feeble tongues from the west of Harrell dark gray shale lithology, but this dark shale is certainly too weakly developed and too interbedded with siltstones to designate separately as Harrell Shale Formation.

After STOP 8 the buses should retrace paved road to U. S. Route 40.

- 4.4 84.0 INTERSECTION with Long Hollow Road. BEAR LEFT on main road.
- 2.0 86.0 TURN RIGHT onto U. S. Route 40 eastbound.
- 3.6 89.6 ENTER Route I-70 eastbound toward Hagerstown.
- 1.2 90.8 Pull buses onto right shoulder of I-70.  
DO NOT UNLOAD BUSES.

STOP 9. Discussants: John Dennison  
Kenneth Hasson  
Richard Jolley

Outcrops of Brallier-Mahantango Formation contact are visible from both sides of buses on both sides of highway.

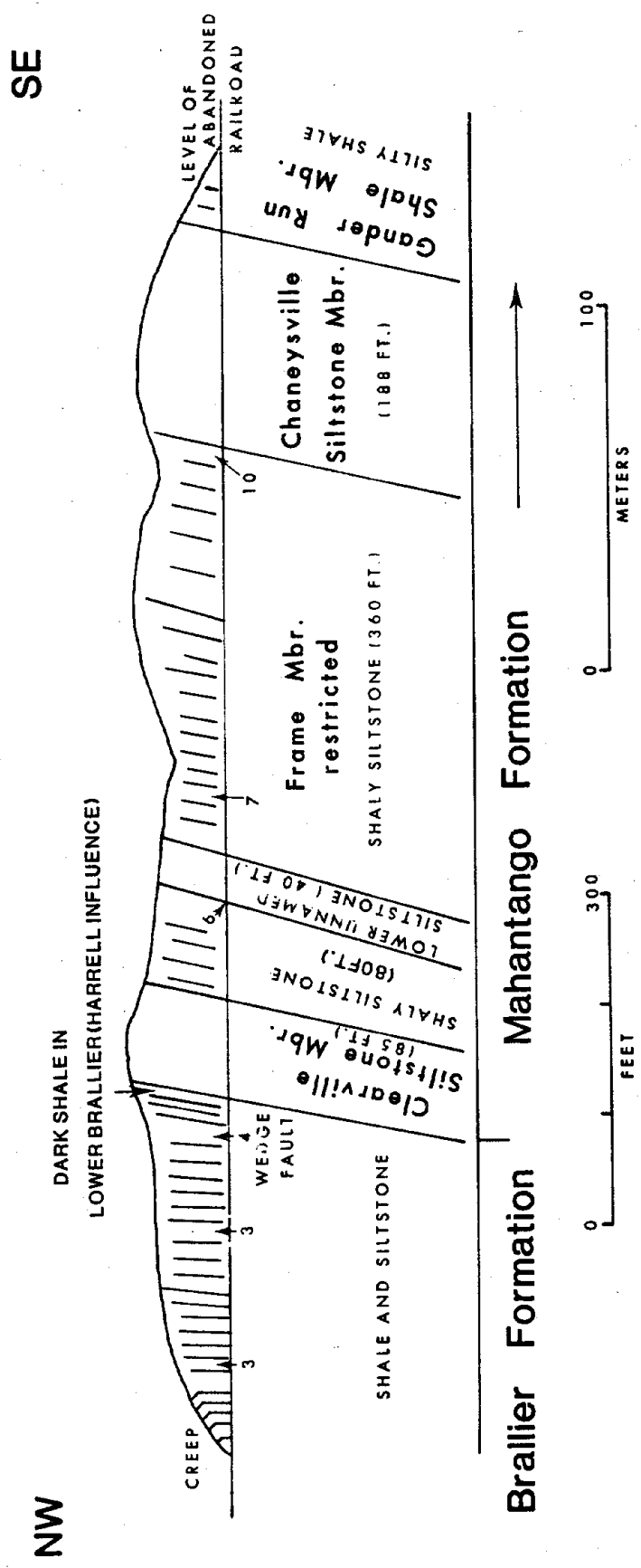


Figure 42. Sketch of exposures at Woodmont Station, Washington County, Maryland. (Cross section prepared by John Dennison and Lee Avary.) Arrows correspond to yellow paint marks.

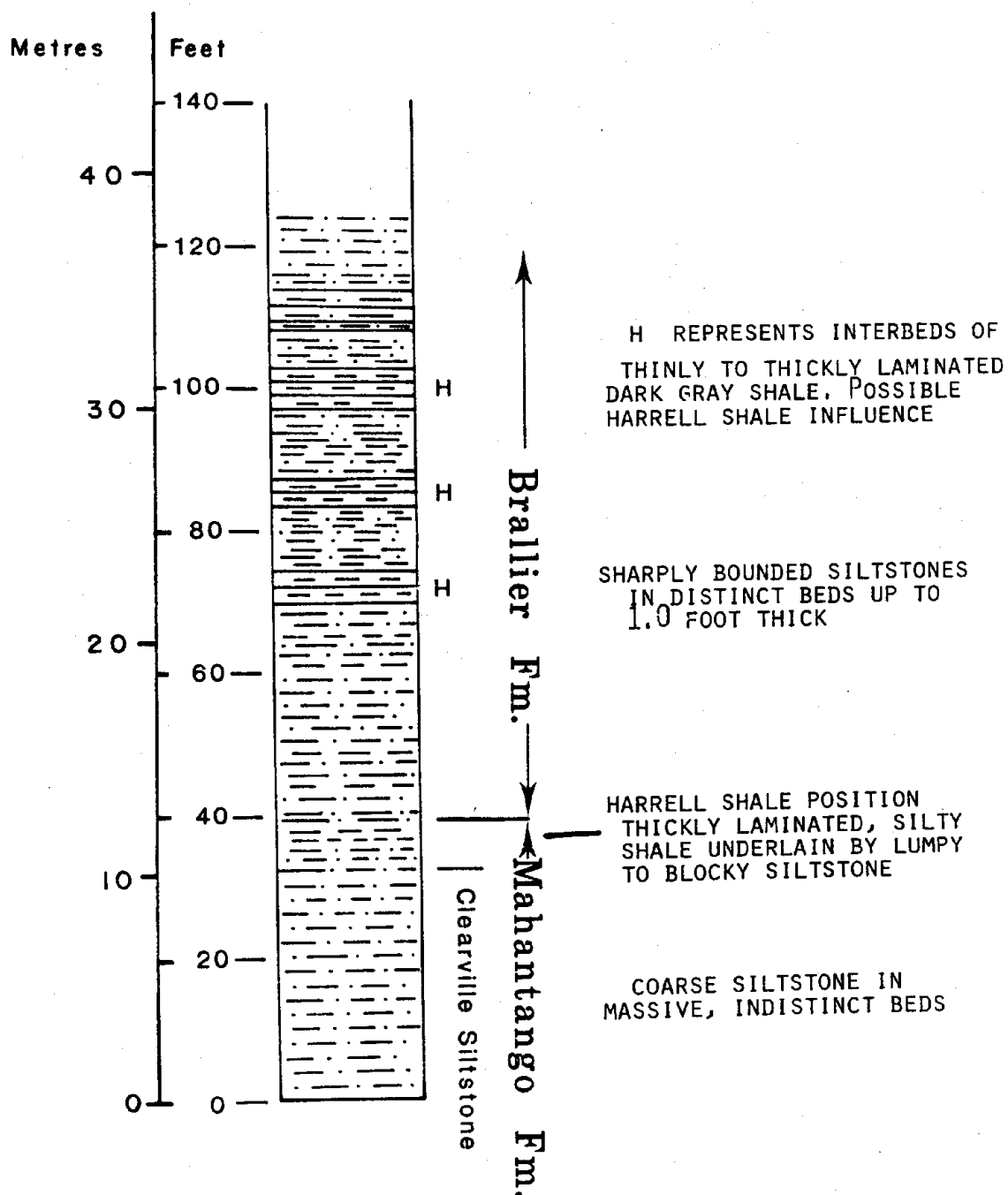


Figure 43. Details of Brallier-Mahantango Formation contact at Woodmont Station, Washington County, Maryland. (Section measured by Kenneth Hasson and John Dennison.)

The Brallier-Mahantango contact along the eastbound lane projects to road level 6 feet west of end of metal guard rail. Exposure is even better on opposite side of Interstate 70, where field work can be safely done on terrace above west-bound lane.

No strata even remotely resembling Harrell dark shale lithology are present this far east on the Fulton Lobe. The eustatic sea level rise which produced the Taghanic overlap during the Taghanic Age, here caused an abrupt shift from shallow-water Mahantango sedimentation to deep-water Brallier turbidites. Regional facies relationships indicate that the base of the Brallier here is at the approximate position of the Tully Limestone farther west. (The Taghanic Stage includes the Tully Limestone in New York.)

- |     |       |   |
|-----|-------|---|
| 2.5 | 93.3  | EXIT FROM LEFT LANE of I-70 onto Maryland Route 615. TURN LEFT and then right heading up the hill on Route 615. (DO NOT reenter I-70 westbound.)  |
| 0.9 | 94.2  | Proceed northeast along crest of Timber Ridge, formed by the lower part of the Hampshire Formation. (The name Hampshire Formation is used in Maryland, West Virginia, and Virginia for the approximate equivalent of the Catskill Formation of Pennsylvania.)   |
| 1.6 | 95.8  | The mountain straight ahead is Dickey's Mountain, a southward plunging anticlinal ridge formed by Tuscarora Sandstone, which is overlain by Rose Hill Formation. The Rose Hill is overlain by Keefer Sandstone, which here is a white, quartz arenite named from Keefer Mountain which extends at lower elevations southward from the plunging Dickey's Mountain. |
| 0.3 | 96.1  | T-intersection at Pennsylvania-Maryland border. CONTINUE STRAIGHT AHEAD into Fulton County, Pennsylvania.   |
| 1.0 | 97.1  | Catskill Formation redbeds.   |
| 1.9 | 99.0  | T-intersection at Damascus Christian Church. TURN RIGHT onto Route 928.   |
| 0.3 | 99.3  | TURN RIGHT onto paved road.   |
| 0.5 | 99.8  | Y-intersection. BEAR LEFT.  |
| 0.4 | 100.2 | Bridge across Licking Creek, from whence comes the name Licking Creek Limestone Formation of Helderberg Group. The type section is located 3 miles to the south.  |
| 0.1 | 100.3 | Y-intersection. TURN RIGHT.<br>Prominent siltstone exposed on left 100 feet to right of intersection in first road cut is Clearville siltstone member (informal name) of Mahantango Formation.  |
| 0.3 | 100.6 | LUNCH STOP.   |

Turn buses around in Marcellus Shale quarry on left.

STOP 10. Dickeys Mountain.

Discussants: John Dennison  
Jon Inners  
Richard Jolley  
Kenneth Hasson

See Figure 44 for sketch map of outcrops along county road.

Salient features here are the faulted repetition of Tioga Bentonite (with western exposure repeated in reversed stratigraphic sequence), the most eastern exposures of the Purcell Member of the Marcellus Shale, and a prominent development of siltstones in the Mahantango Formation. The Purcell is less limy than to west, and the shale of the Marcellus is definitely siltier, more thickly laminated, and not so dark as the Marcellus Shale farther west; these traits both reflect the closer proximity to the Appalachia eastern detrital source for the Fulton Lobe of the Catskill delta complex. The shales within the Mahantango are actually much siltier than to the west, and tend to weather lumpy rather than chippy. Not only are the Clearville siltstone, the unnamed siltstone below the Clearville, and the Chaneyville Siltstone developed within the Mahantango, but consistent with general eastward coarsening of the facies, there is a pre-Chaneyville feeble development of siltstone within the Gander Run Member of the Mahantango Formation. The top of the Mahantango is concealed here, but regional evidence indicates that the Brallier Formation this far east should rest directly on the Mahantango Formation, with no intervening Harrell Shale, and with little or no Mahantango silty shale above the Clearville siltstone.

After lunch the buses will return to the Y-intersection near the bridge across Licking Creek, and await the geologists arriving on foot as they examine the outcrops.

- |     |       |  |
|-----|-------|--|
| 0.3 | 100.9 | Reboard buses, then TURN LEFT across bridge.   |
| 0.1 | 101.0 | Bridge across Licking Creek (11 ton load limit).   |
| 0.4 | 101.4 | Y-intersection. CONTINUE STRAIGHT AHEAD.   |
| 0.4 | 101.8 | STOP SIGN at T-intersection. TURN RIGHT onto Pennsylvania Route 928 northbound.  |
| 0.6 | 102.4 | Road proceeds along crest of homoclinal ridge formed by Catskill Formation redbeds.                                      |
| 0.5 | 102.9 | Red corn fields are not a result of lateritic weathering. That's Hampshire Formation soil, which seems quite productive. |
| 0.7 | 103.6 | Village of Dickeys Mountain.   |
| 0.6 | 104.2 | Mahantango Formation on left.  |
| 0.1 | 104.3 | STOP SIGN. TURN LEFT at T-intersection.  |
| 3.1 | 107.4 | T-intersection at bridge. CONTINUE STRAIGHT AHEAD.   |

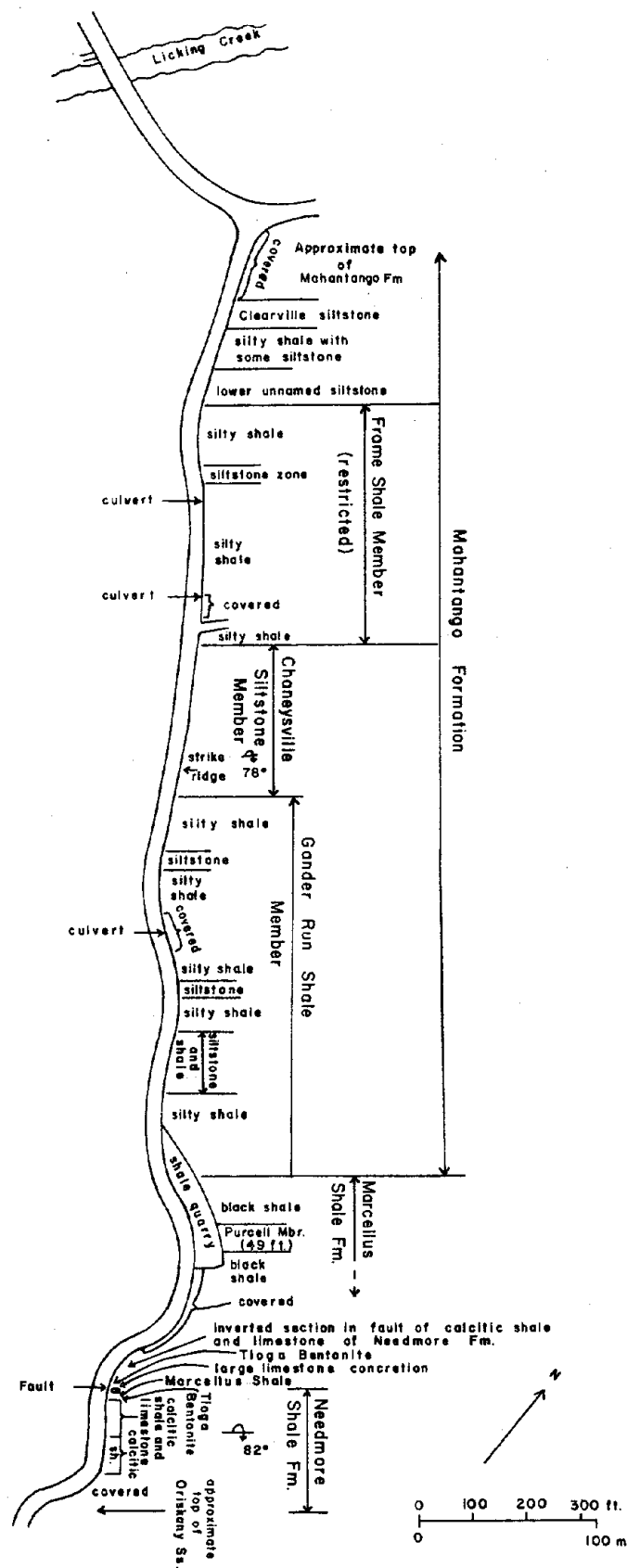


Figure 44. Sketch map of strata cropping out along road a Dickey's Mountain, Fulton County, Pennsylvania. (Prepared by John Dennison and Richard Jolley.) Strike of beds is about N190E, and stratigraphic zonation is position of strata along northeast bank of road.

Fossiliferous upper Helderberg limestone occurs in cliff to right of road.

- 1.1 108.5 Village of Big Cove Tannery.
- 0.8 109.3 Intersection of Pennsylvania Route 928 and U. S. Route 522.  
TURN RIGHT onto U. S. Route 522 northbound.
- 0.7 110.0 Pull off on right side of road and unload buses. USE CAUTION  
walking across highway.

#### STOP 11. Websters Mill.

Discussants: John Dennison  
Richard Jolley  
Kenneth Hasson

The Clearville member of the Mahantango Formation is not a siltstone this far east, but instead is a sandstone, in part quartz conglomeratic. There is no dark Harrell Shale so far east on the Fulton Lobe.

The following section is reproduced from Ellison (1965, Pennsylvania Topog. and Geol. Survey General Geology Rept. G 48, p. 223-229). Hasson and Dennison interpret unit 1 of this section to be Brallier Formation rather than Harrell Shale. It should be noted that Ellison used the Frame Member for all Mahantango strata above the Chaneyville, not in the restricted sense advocated by Hasson and Dennison.

### SECTIONS IN BEDFORD AND FULTON COUNTIES

#### SECTION 10.—SECTION AT WEBSTERS MILLS

This section is exposed in a roadcut along the northwestern side of Route 522, 0.1 to 0.5 mile south of Websters Mills, and is part of a faulted sequence between Dickeys Mountain to the south and Little Scrub Ridge to the north. The strata here are dipping very steeply to the west-northwest and are almost continuously exposed from the lower part of the Gander Run Member of the Mahantango Formation into the lower shales of the Harrell Formation.

On the Needmore, Pennsylvania Quadrangle the base of the described section is 8,400 feet north of latitude 39°50' N., and 11,100 feet east of longitude 78°05' W.

At Websters Mills, nearly all of the Gander Run, Chaneyville, and Frame Members is exposed. However, in this section the members are not well defined; generally the formation here is composed of silty shale or claystone, and siltstone, with the siltstone being somewhat more prominent in the middle of the formation. The upper contact of the Mahantango Formation with the Harrell Formation is placed just above the *Sulcoretepora* Zone (1,230 feet) of the Frame Member. Neither the Burket black shale nor the Tully Member of the Harrell Formation is present in this section. The lower contact with the Marcellus Formation was not observed. However, north of the base of the described section, adjacent to a limestone wall, a few feet of badly contorted Marcellus black shale is exposed. This has not been included in the description of the section.



Units 1 through 5, and the upper 170 feet of unit 6 are exposed along the highway; the lower part of unit 6, the concealed interval of unit 7, and about 50 feet of unit 8 are in a brush-covered roadcut along an abandoned road above and back 30 to 100 feet from the highway. The lower part of the section, units 8, 9, and 10 are poorly exposed in the bank along the highway.

The *Sulcoretepora* Zone is represented in this section by the fossiliferous horizon at 1,230 feet, and although the fauna here is relatively diminished, typical species such as *Pustulatia pustulosa*, *Actinopteria decussata*, and *Hibbardia lacrimosa* are present. At 1,199 feet, in unit 2, very abundant specimens of "*Spirifer*" *tullius* are interpreted as representing the "*Spirifer*" *tullius* zonule of the *Tropidoleptus carinatus* Zone of other sections.

Unit	Unit Thickness	Cumulative Thickness	Unit	Unit Thickness	Cumulative Thickness
Harrell Formation					
Unit					
1. Shale, slightly silty, weathered olive gray (5Y4/1) and dark yellowish brown (10YR4/2). Siltstone, weathered olive gray, in 1- to 6-inch beds forms 25 percent of unit. Stop sign and concrete storm drain are about position of base of this unit.	200	200	unit and comprises basal 9 feet of unit. Abundant <i>Taonurus</i> sp. Fossiliferous 33 feet below top (1156 feet)—Brachiopoda: <i>Tropidoleptus carinatus</i> (C), <i>Devonochonetes scitulus</i> (P), " <i>Spirifer</i> " <i>tullius</i> (C); Pelecypoda: <i>Nucula bellistriata</i> (P).	51	1189
Hamilton Group					
Mahantango Formation					
Frame Member					
Unit					
1. Shale, slightly silty, weathered olive gray (5Y4/1) and dark yellowish brown (10YR4/2). Siltstone, weathered olive gray, in 1- to 6-inch beds forms 25 percent of unit. Position of upper contact uncertain. Fossiliferous zone and manganese? oolites 16 to 17 feet above base (1,230 feet)—Bryozoa: <i>Fenestella</i> cf. <i>F. emaciata</i> (C), <i>F. cf. F. sinuosa</i> (C), <i>Sulcoretepora</i> cf. <i>S. incisurata</i> (VA), fistuliporoid sp. (A); Brachiopoda: <i>Stropheodonta demissa</i> ? (P), <i>Douvillina inaequistriata</i> (C), <i>Atrypa reticularis</i> (C), <i>Pustulatia pustulosa</i> (C), <i>Delthyris sculptilis</i> (A), <i>Elytha fimbriata</i> (A), <i>Cyrtina hamiltonensis</i> (P); Pelecypoda: <i>Nucula bellistriata</i> (C), <i>Actinopteria decussata</i> (P); Pteropoda?: <i>Styliolina</i> sp. (C); Ostracoda: <i>Hibbardia lacrimosa</i> (C), Echinodermata: crinoid columnals (A).	20	1234	4. Sandstone, fine-grained, medium-greenish-gray, weathering olive gray to brownish gray, in 3- to 18-inch beds in upper half and 2- to 8-inch beds in lower half of unit. Conglomerate, dark-greenish-gray, weathering light olive gray, in 1½-inch bed 45 feet above base. Conglomerate and very coarse-grained sandstone, in 1- to 10-inch beds with shaly interbeds forming 5 percent of 15-inch sequence 50 above base. Fault separates units 3 and 4, so thicknesses are minimum. Storm drain is 6 feet above base.	46	1138
2. Sandstone, fine-grained, medium-greenish-gray (5GY5/1) weathering olive gray, in 2-inch to 2-foot, commonly 1-foot beds, partly laminated, well cemented. Interbeds of shale form 5 percent of unit and increase in proportion toward top. Fossiliferous 15 feet below top (1199 feet)—Brachiopoda: " <i>Spirifer</i> " <i>tullius</i> (VA); Echinodermata: crinoid columnals (C).	25	1214	5. Shale, silty, medium-light-gray (N6) to olive gray, weathering olive gray (5Y4/1), in 1- to 3-mm beds. Siltstone, light-olive-gray, weathering olive gray, in ½-inch lenses forms 5 percent of unit. Fossiliferous zones as noted: 7 to 11 feet below top (1085 to 1081 feet)—Brachiopoda: <i>Tropidoleptus carinatus</i> (A), <i>Camarotoechia sappho</i> (P), <i>Mucrospirifer mucronatus</i> (C), <i>Delthyris sculptilis</i> (P); Pelecypoda: <i>Grammysia</i> ? sp. (P), <i>Leiopteria</i> sp. (P). 48 feet below top (1044 feet)—Anthozoa: 2 indeterminate spp. horn corals (C); Bryozoa: indeterminate sp. (P); Brachiopoda: <i>Rhipidomella vanuxemi</i> (P), <i>Tropidoleptus carinatus</i> (C), <i>Stropheodonta demissa</i> ? (P), <i>Protoleptostrophia perplana</i> (C), <i>Retichonetes vicinus</i> (P), <i>Mucrospirifer mucronatus</i> (A), <i>Mediospirifer belliplicata</i> (C); Pelecypoda: <i>Grammysia</i> ? sp. (P), <i>Modiomorpha concentrica</i> (P), <i>Actinopteria decussata</i> (C), <i>Cypricardella bellastrata</i> (P); Trilobita: <i>Phacops rana</i> (P), Echinodermata: crinoid columnals (A). 45 to 33 feet		
3. Siltstone, argillaceous and micaceous, and sandstone, fine-grained, medium-greenish-gray (5GY5/1) and medium-gray, weathering olive gray, in 1- to 7-inch beds. Shale, weathered olive gray forms 20 percent of					

below top (1041 to 1029 feet)—Bryozoa: indeterminate sp. (P); Brachiopoda: *Tropidoleptus carinatus* (A), *Douvillina inaequistriata* (P), *Devonochonetes scitulus* (A), *Atrypa reticularis* (P), *Spinocyrtia granulosa* (C), *Mucrospirifer mucronatus* (C), *Mediospirifer* sp. (C), *Ambocoelia umbonata* (A); Pelecypoda: *Cornellites flabella* (C), *Pterinopecten princeps* (P), *Modiomorpha concentrica* (P); Gastropoda: bellerophonitid sp. (P); Echinodermata: crinoid columnals (A). 68 feet below top (1024 feet)—Brachiopoda: *Tropidoleptus carinatus* (A), *Devonochonetes scitulus* (C), *Mucrospirifer mucronatus* (P).

# Chaneysville Member

82 1092

6. Siltstone, argillaceous, medium-dark-gray (N4), weathering dark yellowish brown (10YR4/2), in 12- to 20-inch beds. Top of unit marked by sandstone, fine-grained, calcareous, medium-light-greenish-gray (5Y6/1), weathering light gray to medium brown, in 2-foot bed. Road marker 9/50 opposite top of unit. Thickness 9 feet.

Claystone, shale, very silty, medium-gray (N5), weathering olive gray (5Y4/1), generally in indistinct beds but some 1- to 2-inch beds. Siltstone and sandstone, fine-grained, medium-dark-gray (N4), in 1- to 4-inch beds form 5 to 10 percent of unit and increase in number and thickness in upper half of unit, forming 20 percent of upper 100 feet of unit. Partially concealed. Thickness 335 feet.

Fossiliferous zones as noted: Top of unit (1010 feet)—Bryozoa: indeterminate sp. (P); Brachiopoda: *Rhipidomella leucosia* (P), *Tropidoleptus carinatus* (C), *Devonochonetes scitulus* (A), *Protolaptostrophia perplana* (P); Trilobita: *Phacops rana* (P). 6 feet below top (1004 feet)—Bryozoa: *Sulcoretepora* sp. (A); Brachiopoda: *Tropidoleptus carinatus* (C), *Devonochonetes coronatus* (A), *D. scitulus* (P), *D. syrtalis* (C), *Pholidostrophia pennsylvanica* (P), *Delthyris sculptilis* (C), *Mucrospirifer mucronatus* (VA); Gastropoda: *Bembexia sulcomarginata* (C); Echinodermata: crinoid columnals (A). 74 feet below top (936 feet)—Brachiopoda: *Mucrospirifer mucronatus* (C); Pelecypoda: *Nucula bellistriata* (P); Gastropoda: *Bembexia capillaria* (P). 114 feet below top (896 feet)—Bryozoa: *Sulcoretepora* cf. *S. incisurata* (C); Brachiopoda: *Devonochonetes scitulus* (A), *Retichonetes vicinus* (P), *Longispina mucronatus* (C), "*Spirifer*" *tullius* (P), *Mucrospirifer mucronatus* (A), *Athyris spiriferoides* (A), *Ambocoelia umbonata* (C); Pelecypoda: *Actinopteria decussata* (C), *Nucula bellistriata* (P), *Nuculites oblongatus* (P), *Modiomorpha concentrica* (C), *Goniophora hamiltoniae* (P). 134 feet below top (876

feet)—Bryozoa: fistuliporoid bryozoan (P); Brachiopoda: *Schuchertella variabilis* (P), *Tropidoleptus carinatus* (VA), "*Chonetes*" sp. (P), *Devonochonetes scitulus* (C), *Mucrospirifer mucronatus* (C); Gastropoda: bellerophonitid gastropod sp. (C), *Platystrophia patulus* (P); Echinodermata: crinoid columnals (A). 158 feet below top (852 feet)—Bryozoa: *Sulcoretepora* cf. *S. incisurata* (C); Brachiopoda: *Protolaptostrophia perplana* (A), *Mucrospirifer mucronatus* (A); Pelecypoda: *Paracyclas lirata* (P); Gastropoda: *Naticonema lineata* (P). 161 feet below top (849 feet)—Bryozoa: *Sulcoretepora* cf. *S. incisurata* (C); Brachiopoda: *Tropidoleptus carinatus* (A); Echinodermata: crinoid columnals (A). 164 feet below top (846 feet)—Brachiopoda: *Mucrospirifer mucronatus* (A); Gastropoda: *Bembexia laevis* (P); Echinodermata: crinoid columnals (P). 166 feet below top (844 feet)—Brachiopoda: *Devonochonetes coronatus* (C), *D. scitulus* (C), *Mucrospirifer mucronatus* (VA); Gastropoda: *Bembexia sulcomarginata* (A). 169 feet below top (841 feet)—Brachiopoda: *Longispina mucronatus* (P), *Mucrospirifer mucronatus* (VA). 172 feet below top (838 feet)—Brachiopoda: *Mucrospirifer mucronatus* (C). 185 feet below top (825 feet)—Brachiopoda: *Devonochonetes scitulus* (C), *Mucrospirifer mucronatus* (A). 200 feet below top (810 feet)—Brachiopoda: *Mucrospirifer mucronatus* (A); Gastropoda: *Bembexia sulcomarginata* (C); Pteropoda: *Tentaculites attenuatus* (A). 204 feet below top (806 feet)—Brachiopoda: *Devonochonetes syrtalis* (P), *D. scitulus* (A), "*Spirifer*" sp. (C); Pteropoda: *Tentaculites attenuatus* (P). 239 feet below top (771 feet)—Brachiopoda: *Mucrospirifer mucronatus* (C); Gastropoda: *Bembexia sulcomarginata* (P); Cephalopoda: *Striacoceras typum* (P); Pteropoda: *Tentaculites attenuatus* (P). 254 feet below top (756 feet)—Brachiopoda: *Tropidoleptus carinatus* (C), *Devonochonetes syrtalis* (A), *Mucrospirifer mucronatus* (A), Gastropoda: *Bembexia sulcomarginata* (P); Trilobita: *Trimerus (Dipleura) dekayi* (P); Echinodermata: crinoid columnals (C). 281 feet below top (729 feet)—Brachiopoda: *Tropidoleptus carinatus* (VA), *Devonochonetes coronatus* (A), "*Spirifer*" sp. (P); Gastropoda: indet. gastropod sp. (A); Pteropoda: *Tentaculites attenuatus* (C); Echinodermata: crinoid columnals (VA). 309 feet below top (701 feet)—Brachiopoda: *Devonochonetes scitulus* (VA), *Retichonetes marylandicus* (A), *Longispina mucronatus* (C), *Mediospirifer audaculus* (C); Pelecypoda: *Cornellites flabella* (P), *Glyptodesma erectum* (P). 311 feet below top (699 feet)—Brachiopoda:

	Unit Thickness	Cumulative Thickness
<i>Devonochonetes scitulus</i> (C), <i>Longispina mucronatus</i> (VA), " <i>Spirifer</i> " <i>tullius</i> (C). 320 feet below top (690 feet)—Brachiopoda: <i>Tropidoleptus carinatus</i> (A), <i>Longispina mucronatus</i> (C), " <i>Spirifer</i> " sp. (P); Gastropoda: <i>Bembexia sulcomarginata</i> (P); Trilobita: <i>Trimerus (Dipleura) dekayi</i> (P); Echinodermata: crinoid columnals (P). 331 feet below top (679 feet)—Brachiopoda: <i>Tropidoleptus carinatus</i> (A), " <i>Chonetes</i> " sp. (C), <i>Delthyris sculptilis</i> (P); Pelecypoda: <i>Cornellites flabella</i> (P); Echinodermata: crinoid columnals (C).	344	1010
Gander Run Member		
7. Concealed. Argillaceous siltstone partially exposed near intersection with road leading into bush.	121	666
8. Shale, silty, weathered light olive gray (5Y5/2), in 1-mm to 1-inch beds. Siltstone, argillaceous, in poorly defined beds forms 20 percent of unit, more prominent		

	Unit Thickness	Cumulative Thickness
in upper 250 feet of unit. Partially concealed. At top of unit (545 feet)—Brachiopoda: <i>Devonochonetes scitulus</i> (A); Pelecypoda: <i>Leiopteria laevis</i> (P), <i>Orthonota undulata</i> (C), <i>Paracyclas lirata</i> (P), <i>Leptodesma rogersi</i> (P), <i>Grammysioidea alveata</i> (P). Gastropoda: bellerophonoid gastropod sp. (P), <i>Crenistriella crenistria?</i> (P) <i>Bembexia sulcomarginata?</i> (C).	376	545
9. Shale, deeply weathered to medium light gray.	142	169
10. Shale, silty, weathered olive gray. Siltstone, argillaceous, medium-gray, weathering olive gray, forms 20 percent of unit.	27	27

#### SUMMARY

Harrell Formation	200' exposed
Mahantango Formation	1,230' exposed
Frame Member	220'
Chaneyville Member	335'
Gander Run Member	666' exposed

After examining the outcrop, reboard the buses and proceed ahead.

- 0.4 110.4 Mellotts Grocery. TURN AROUND buses and HEAD SOUTH on U. S. Route 522.
- 0.7 111.1 Cross Big Cove Creek.
- 0.4 111.5 Intersection of U. S. Route 522 and Pennsylvania Route 928. PROCEED AHEAD on Route 522 southbound. (This is same site as cumulative mileage 109.3 on road log.)
- 2.5 114.0 Crossing Scrub Ridge, a synclinal ridge capped by Pocono Group.
- 3.9 117.9 Enter village of Needmore.
- 0.3 118.2 Needmore Post Office. Needmore is the source of the name Needmore Shale, although there is no good measured section available near this village.
- 3.3 121.5 Enter village of Dott.
- 0.6 122.1 Intersection of U. S. Route 522 and Pennsylvania Route 643. TURN RIGHT onto Route 643 toward Town Hill.
- 3.6 125.7 Cross summit of Sideling Hill, a synclinal ridge capped by Pocono Group.
- 0.5 126.2 DANGEROUS hairpin turn in highway.
- 1.9 128.1 STOP SIGN. PROCEED to RIGHT on Route 643.
- 1.3 129.4 Summit of Town Hill. TURN LEFT onto Route I-70 westbound.

- 0.3 129.7 Pocono Group sandstone.
- 1.1 130.8 Rest area.
- 1.6 132.4 Mauch Chunk Formation redbeds.
- 1.4 133.8 Mauch Chunk Formation redbeds.
- 0.8 134.6 Leave Fulton County, and enter Bedford County near village of Crystal Spring.

Park buses at county boundary.

## STOP 12. Crystal Spring.

Discussant: William Sevon

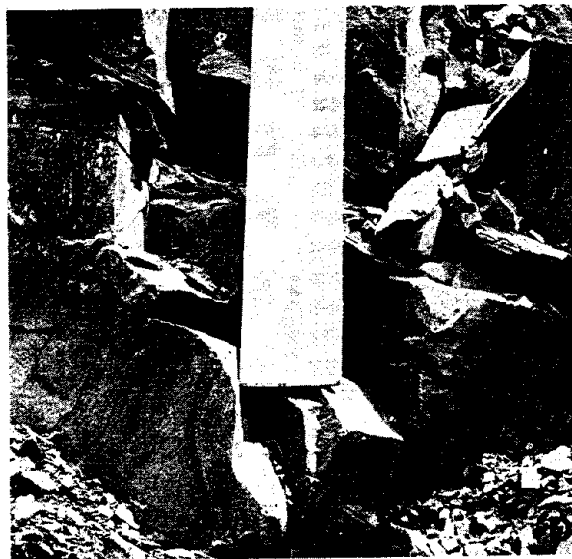
This stop is located along the north side of the west-bound lane of Interstate 70 immediately west of the Bedford County line. The uppermost part of the Catskill Formation, all of the Rockwell Formation and much of the Burgoon Formation are exposed in the roadcut. The purpose of the stop is to examine the Rockwell Formation, particularly the polymictite diamictites within the unit. The main part of the Rockwell Formation is described in the Described Section, and some details are shown in Figure 45. Regional aspects of the Rockwell-Spechty Kopf diamictite problem are discussed elsewhere in this guidebook.

Only the uppermost part of the Catskill Formation is exposed here, but two complete fining upward cycles occur, and several subcycles occur within the finer-grained redbed sequences. These cycles are typical of the upper part of the Catskill Formation, and represent meandering river deposits. Those interested in structure may appreciate the Z-fold and 2 faults which separate a thin (6 cm  $\pm$ ) sandstone bed in the upper 2 m of the unit.

The Rockwell Formation here comprises several different rock types which presumably represent an integrated sedimentological sequence quite different from that of the underlying Catskill Formation. The sequence is outlined in the Described Section. Note in particular the nature of the contacts, the character of the polymictic diamictite, the varied sizes and lithologies of the clasts within the diamictite, and the succession of rock types.

The matrix of the diamictite is a turbid brown clay with floating grains of quartz, chlorite, platy micaceous minerals, hematite, and chert (Seaman, 1979). Metamorphic, sedimentary, and igneous clasts of various size occur. The variety of clasts and the extreme size of some should generate some conclusions about the nature of the source area and its original distance from the deposit.

The four planar-bedded units overlying the diamictite (Units 7, 8, 10, 11; Described Section) would seem to require deposition in a subaqueous environment. Their intimate relationship to the diamictites thus suggests a subaqueous environment of deposition for the diamictite. If most or all of the Rockwell Formation was deposited in a subaqueous environment here, and the underlying Catskill was deposited by meandering streams on an alluvial



plain, what happened at the base of the Rockwell? Does the answer lie in Units 2-5 (Described Section)? Consider also the fact that this sequence is unlike the Rockwell exposed along the Pennsylvania Turnpike 1 km to the north (see STOP 13).

<u>Unit</u>	<u>Description</u>	<u>Thick- ness (m)</u>
Rockwell Formation		
11.	Sandstone and siltstone interbedded (Figure 45f): Sandstone, fine-grained, medium light gray, weathers olive gray, quartzitic; planar beds up to 40 cm thick, but generally less than 10 cm thick; no internal laminae obvious; some beds rippled. Siltstone, medium dark gray, weathers olive gray, thinly laminated, occasional sand grains and pebbles--largest pebble noted, 8x6x4 cm. Several meters thick, overlain by conglomeratic sandstone which might be picked as base of Burgoon Formation.	5+
10.	Siltstone, olive gray, thinly laminated, almost varve-like at base, grades upward into olive gray sandstone with load casts and scattered clasts, in turn grades up into grayish red shaly claystone with occasional clasts up to 1 cm diameter, sharp upper contact.	4
9.	Diamictite, polymictic, grayish red, exfoliation weathering, large clast (27x12x? cm) of gray sandstone about 1 m above road level 2 m above base of unit (Figure 45e), lateral relationships and upper contact not clear because of cover.	5
8.	Sandstone, very fine-grained, medium gray, weathers olive gray, massive beds up to a meter thick become thinner in upper half (generally less than 20 cm) and are separated by thin (1 cm or less) beds of olive gray siltstone (Figure 45d). Beds appear structureless, but weathering-etched surfaces indicate thin, planar and cross-bedded laminae. Uppermost 1 m confused and probably load-casted. Sharp upper contact.	8
7.	Siltstone, olive gray, planar-bedded, lower beds generally 0.5-1 cm thick (Figure 45c), beds thicken upwards to 5-10 cm thick, weathering disintegration in irregular platy pieces. Very uniform lithology. Sharp upper contact.	4

Figure 45. Parts of the Rockwell Formation exposed along the west-bound lane of Interstate 70 just west of the Bedford County line. A. Polymictic diamictite showing exfoliation weathering (Unit 6, Described Section 1). Scale divided into inches and cm. B. Large clast (20x27x36 + cm) of sandstone in polymictic diamictite (Unit 6, Described Section 1). Scale is 31 cm long. C. Planar-bedded siltstone above the polymictic diamictite (Unit 7, Described Section 1). Scale is divided into inches and cm. D. Very fine-grained sandstone beds interbedded with thin siltstone beds (Unit 8, Described Section 1). Scale is 27 cm long. E. Polymictic diamictite showing disintegration sub-normal to bedding and a large clast (27x12x? cm)(Unit 9, Described Section 1). Scale is divided into inches and cm. F. Planar-bedded sandstone and siltstone interbeds with some rippled surfaces (Unit 11, Described Section 1). Scale is divided into inches and cm.

6. Diamictite, polymictic, unsorted mixture of clay to large clasts, olive gray to grayish red with brown weathered color. Unstratified and homogeneous, exfoliation weathering either concentrically (Figure 45a) or sub-normal to bedding. Some zones appear rolled, loaded or slumped, but may be only exfoliation appearance. Most clasts quartz and smaller than 1 cm, but granite, schist, red and white quartzite, and sandstone clasts occur. Largest clast (20x27x36 cm) occurs 2 m above road 1 m below top of unit (Figure 45b). Sharp upper contact. 4.2
5. Sandstone, fine- to medium-grained, olive gray, massive with suggestion of contorted planar beds, load-casted appearance, scattered clasts up to 1 cm, gradational upper contact. 1
4. Sandstone, fine- to medium-grained, medium light gray weathers olive gray, quartzitic, well sorted, may have been locally calcareous (note deeply leached dark brown area), may be laterally discontinuous, sharp upper contact. 0.85
3. Sandstone, conglomeratic, fine- to medium-grained matrix with scattered quartz and ironstone pebbles, largest clast noted is quartz (4x2.5x? cm), massive at base becomes planar bedded in upper part, weathers more readily than adjacent units, sharp upper contact. 1.24
2. Sandstone, very fine- to fine-grained, olive gray, micaceous, planar bedded with beds 5-30 cm thick generally, some thicker units, beds become more massive in apparent bedding upward, at least one slump mass, numerous joint surfaces sub-normal to bedding have apparent slickensides parallel to laminae. Sharp upper contact may become gradational laterally. Basal contact sharp, scoured with 0.5-1 m relief, basal beds have local vague appearance of load casting. 9

#### Catskill Formation

1. Sandstone, siltstones, and claystones in fining upward cycles starting with gray, fine- to medium-grained sandstones with sharp base, grading upward into grayish red siltstones and claystones. Sub-cycles of siltstone and claystone occur in the finer redbed sequences. Uppermost 2.5 m has thin (6 cm +) sandstone bed involved in 2 faults and a Z-fold.

#### Base

- 1.2 135.8 Catskill Formation redbeds.
- 2.3 138.1 TRAFFIC LIGHT at end of Route I-70. TURN RIGHT onto U. S. Route 30 eastbound.
- 0.3 138.4 CONTINUE STRAIGHT AHEAD past entrance to Pennsylvania Turnpike and PROCEED EASTWARD on U. S. Route 30.
- 2.2 140.6 Summit of Rays Hill at Bedford-Fulton County boundary. Reenter Fulton County toward the east.
- 0.3 140.9 TURN AROUND buses and HEAD WEST along U. S. Route 30. On south side of highway at turnaround point is exposure of base of Burgoon Sandstone.

0.3 141.2 Park buses on pulloff near summit of Rays Hill, and unload passengers for explanation of structural relations.

STOP 13. Rays Hill Summit (Breezewood Fault).

Discussant: Donald Hoskins.

The Pennsylvania Turnpike cut at Rays Hill Summit was excavated along the surface trace of the Breezewood fault and is one of the few rock exposures of this and its companion fault to the north, the Sideling Hill fault. The Breezewood and Sideling Hill faults were discovered during reconnaissance mapping for the 1980 version of the Geologic Map of Pennsylvania. Brief descriptions of the faults were given in Hoskins and Root (1977), and Root and Hoskins (1977).

Evidence for both faults can be observed from the vantage point of Rays Hill Summit. While examination of the rocks within the lower part of the Turnpike cut is impossible because of steep slopes and Turnpike traffic, essential features of the Breezewood fault can be observed from this vantage point. Anomalous bedding attitudes resulting from fault movement are visible in rock exposures in the upper part of the Turnpike cut adjacent to the scenic overlook.

Apparent lateral displacement along the Breezewood fault is shown most clearly by the offset (Figure 46) of the basal conglomeratic part of the Burgoon Formation, which is here displaced approximately 2000 feet (600 meters). The exposure of the basal Burgoon on the south side of the Breezewood fault was seen along the south side of U. S. Route 30 at mileage 140.9. North of the fault and the Turnpike, the basal Burgoon is present on the crest of Rays Hill and nearly forms a dip slope down to the level of the Turnpike pavement.

The regional strike of strata along Rays Hill south of the fault, is N45E and dips range from 35-40°S (Figure 47). At the top of the north face of the Turnpike cut, the bedding of the rocks is N73W, 47°N. At the road level in the cut, attitudes vary from N45W to N75W with dips ranging from 60°N to vertical. At the top of the south face of the cut, near the vantage point, attitudes measured near some red shales range from N56W to N81W with dips from 72°N to vertical. Eastward from these attitudes, the same layers swing within a few tens of feet to N84E and vertical dip.

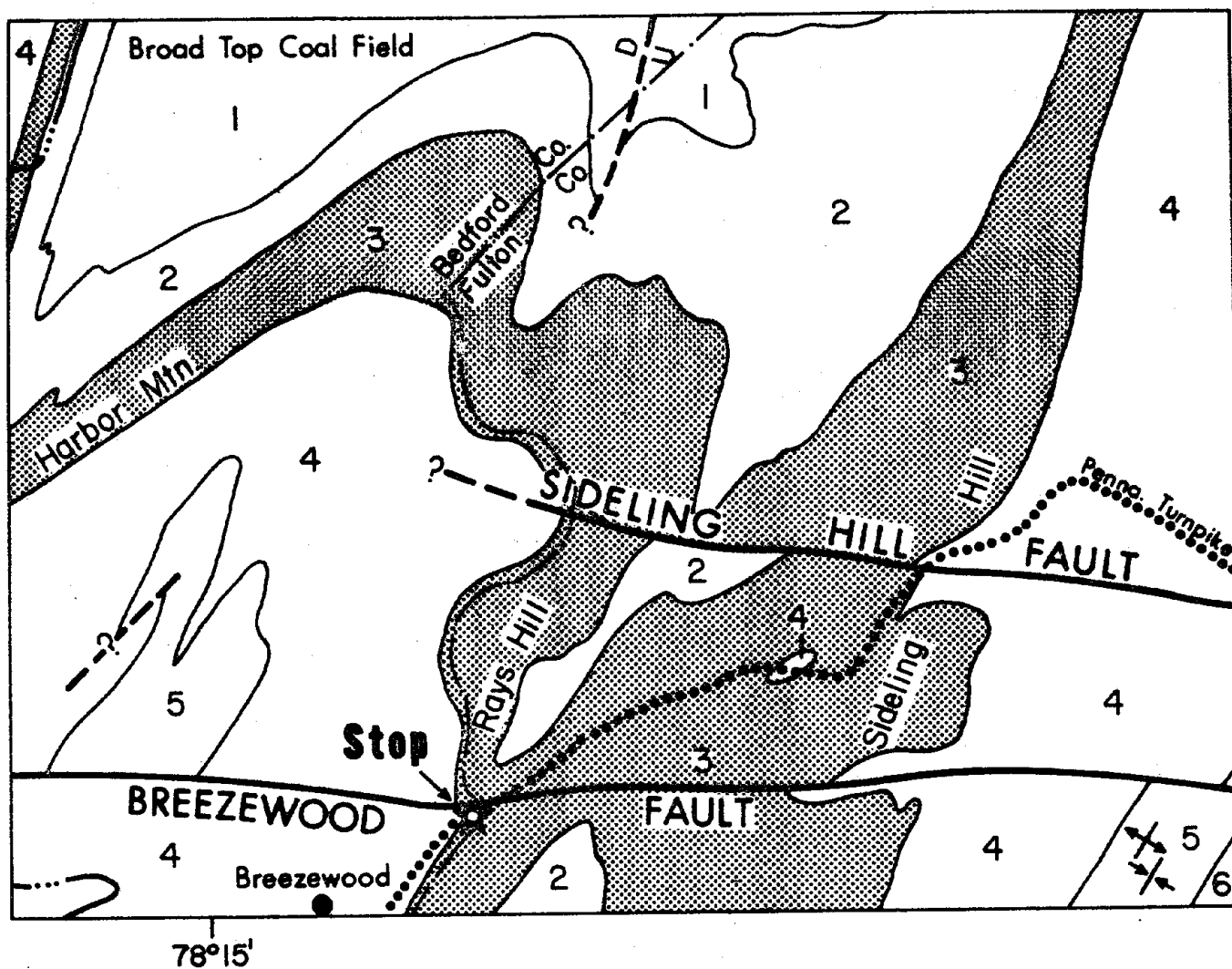
Anomalous bedding attitudes near the fault trace are the most common structural features observed in the few exposures seen along both the Breezewood and the Sideling Hill faults that are direct evidence of movement along the faults. Similar rotations of attitude from the regional strike and dip as seen at the Turnpike cut, have been measured in four other localities west of Rays Hill along the trace of the Breezewood fault.

Additional evidence of the offset at the Rays Hill Summit Turnpike cut is the lack of lateral continuity of similar lithologies across the cut. The rocks exposed here are all included in the Rockwell Formation but differ considerably from the previous stop in that none of the pebbly mudstone is present, while red beds and carbonaceous ("coaly") shales are more common. Present here also is a very clayey layer reminiscent of an underclay.

On the north side of the cut, only one thin red bed is present while the south side has several. No representatives of the "coaly" layers occur on the north face.

Some of the lithologic discontinuities between the north and south faces may be due to primary lateral discontinuity of Rockwell lithologies, often observed in Upper Devonian-Mississippian rocks in Pennsylvania, but some





Geologic Map of Sideling Hill and Breezewood Faults

1	Pennsylvanian	4	Upper Devonian (A)
2	Upper Mississippian	5	Upper Devonian (B)
3	Lower Mississippian	6	Middle Devonian

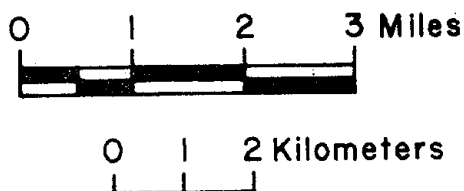
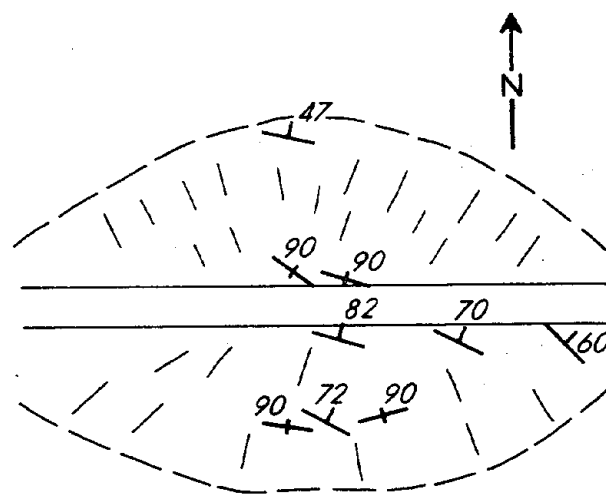


Figure 46. Geologic map of the Breezewood area.



38 - Regional attitude

Figure 47. Schematic sketch of Turnpike cut with representative bedding attitudes.

discontinuity must also be due to the offset here on the Breezewood fault.

The trace of the Sideling Hill fault is also visible 3.2 miles (5.5 kilometers) northeast from the vantage point. Refer to the photograph and sketch of the view to the northeast (Figures 48 and 49).

Apparent offset of Rays Hill, due to the Sideling Hill fault, is right lateral; eastward, the apparent offset on Sideling Hill is left lateral. Still farther east apparent offset is again right lateral. Eastward, the apparent offset on the Breezewood fault at the Turnpike cut is left lateral. Near Hustontown, the apparent offset is reversed to right lateral.

The variation in apparent offsets plus the depression of the syncline between Rays Hill and Sideling Hill, south of the Sideling Hill fault, and the elevation of the anticline of lower Upper Devonian rocks (northwest of Breezewood) north of the Breezewood fault, imply that considerable vertical movement was involved with the faulting.

Disruption in rocks along the Sideling Hill fault was shown uniquely in the construction for the South Penn Railroad tunnel through Sideling Hill (later to become the Sideling Hill Tunnel of the Pennsylvania Turnpike, now abandoned). Cleaves (1949, page 24, reproduced here as Figure 50) shows that many reversals of dip and faulting were encountered during tunnel construction and remodeling. Regionally, one would expect that rocks in this part of Sideling Hill would show a consistent low angle, northwest dip, perhaps modified by a broad syncline-anticline reversal. Nothing in the previously known geology of Sideling Hill would have suggested the complexity exposed during tunnel construction.

The traces of the Breezewood and Sideling Hill faults bifurcate two major topographic reentrants on the east side of Sideling Hill. The reentrants show on the geologic map (Figure 46), outlined by the contact between unit 3 and 4. These topographic lows are probably the result of easier erodibility of fractured rocks along the traces of the faults. It was logical for the South Penn Railroad construction engineers to select this part of Sideling Hill to penetrate since, there, they would have to tunnel the least distance. It is serendipitous that the least construction distance was exactly along the

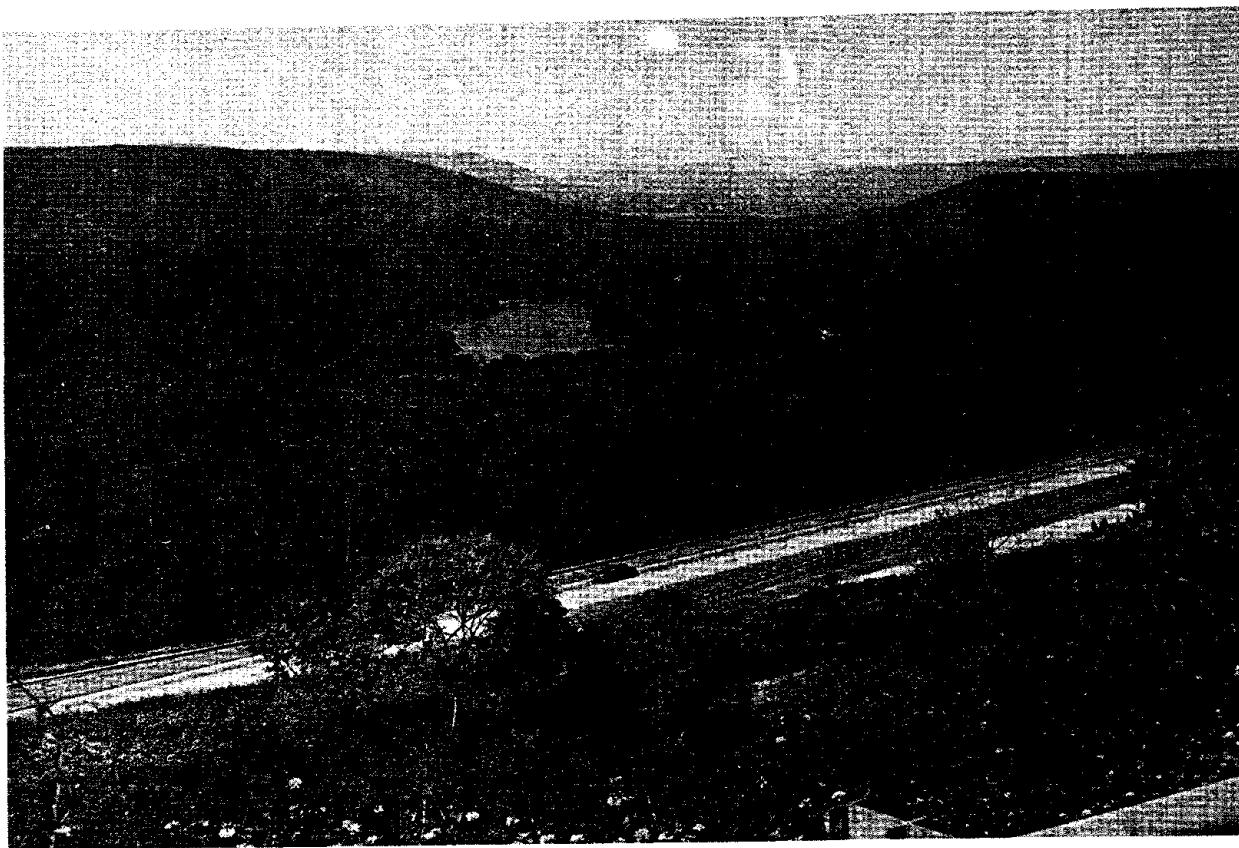


Figure 48. View northeast from Rays Hill Summit.

trace of the fault, thus revealing to us the true structural geology in Sideling Hill.

It was also serendipitous that, in abandoning the Sideling Hill tunnel and the Rays Hill tunnel--and the stretch of Turnpike in between--to avoid reconstruction of the tunnels to four lanes, the new construction followed the trace of the Breezewood fault in creating a new cut. The same construction logic was used because the trace of the Breezewood fault through Rays Hill occurs at the lowest topographic position on Rays Hill, which again is probably due to the easier erodibility of the fractured rocks along the fault trace.

The Breezewood and Sideling Hill faults have been examined only in a reconnaissance fashion. Additional work needs to be done to determine, if possible, the actual movement on the faults. The western end of the Sideling Hill fault needs additional work to determine if it stops as shown on the sketch map. Or, does it turn southward into a thrust fault, as it does on the east end and, if so, does that affect the Breezewood fault?

The Breezewood and Sideling Hill faults, among other mapped faults east and west of this area, are considered surface evidence of a "fundamental fault" which crosses much of Pennsylvania near the N40° latitude (Root and Hoskins, 1977).

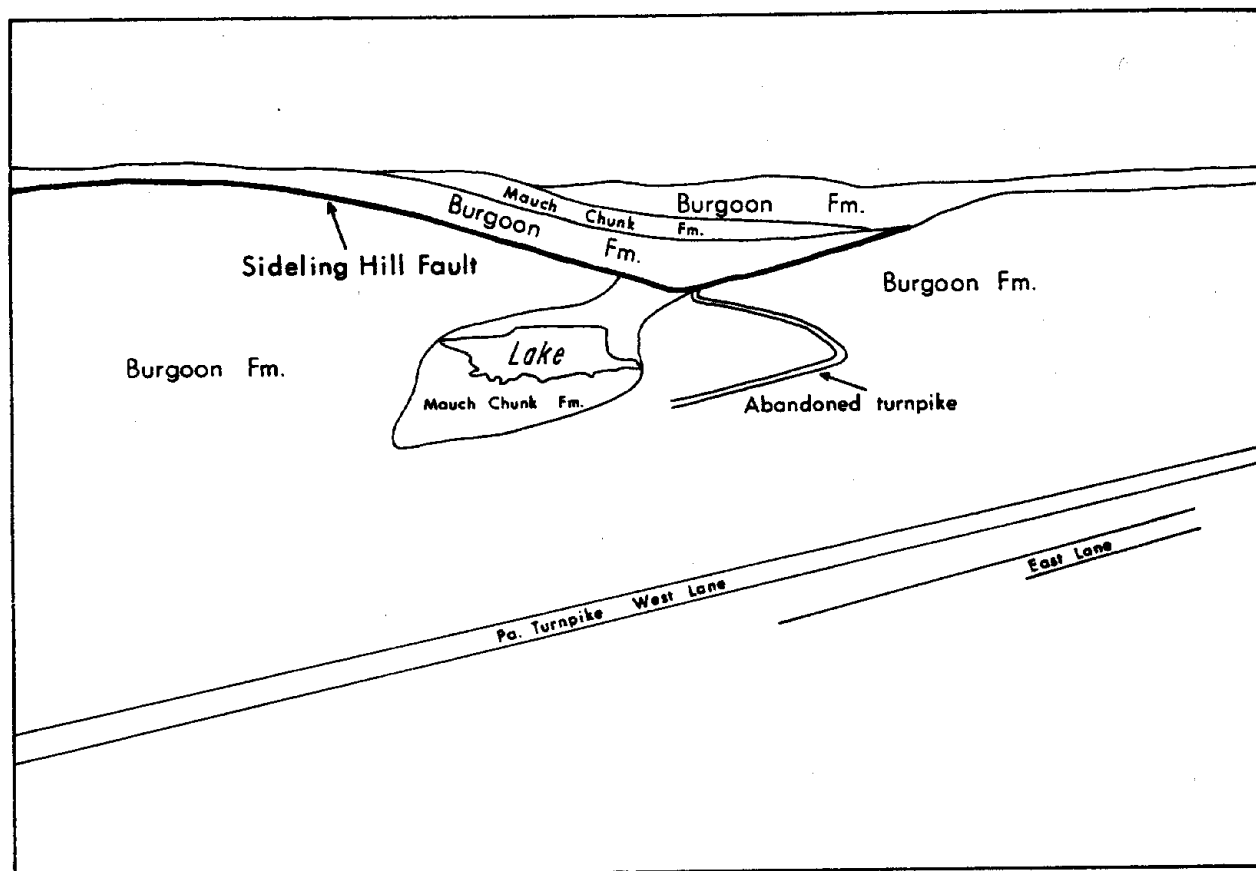


Figure 49. Sketch showing geologic features in Figure 48.

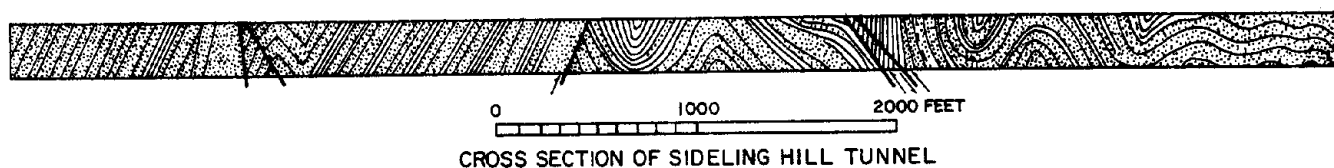


Figure 50. Cross section of geology in Sideling Hill tunnel of Pennsylvania Turnpike.

- |     |       |  |
|-----|-------|--|
| 2.2 | 143.4 | Proceed through town of Breezewood and U. S. Route 30 westbound.   |
| 1.7 | 145.1 | Deep cut in Catskill Formation.  |
| 6.9 | 152.0 | Traffic light in downtown Everett at junction of U. S. Route 30 and Pennsylvania Route 126 southbound. Continue ahead on Route 30 straight through town. |

- 0.2 152.2 Traffic light at junction of U. S. Route 30 and Pennsylvania Route 126 northbound. Continue ahead on Route 30. (This is same site as cumulative mileage 133.1 and 158.1 in this road log.)
- 0.4 152.6 Cliff on right is Helderberg Limestone. Continue straight ahead toward Bedford on U. S. Route 30. (This is same site as cumulative mileage 110.5 and 132.6 on this road log.)
- 5.8 158.4 Juniata Formation redbeds overlain by white Tuscarora Sandstone at The Narrows of Raystown Branch of Juniata River through Evitts Mountain.
- 0.1 158.5 Turn right onto U. S. Route 30 Bypass leading through north edge of Bedford.
- 1.9 160.4 Turn right from U. S. Route 30 Bypass onto U. S. Route 220 Bypass northbound toward Altoona.
- 2.2 162.6 Exit from U. S. Route 220 Bypass onto road leading toward Pennsylvania Turnpike and State Police.
- 0.5 163.1 Stop sign at T-intersection. Turn left.
- 0.1 163.2 Turn left into parking lot of Bedford Holiday Inn.

END OF FIELD TRIP