The Accotink Schist, Lake Barcroft Metasandstone, and Popes Head Formation— Keys to an Understanding of the Tectonic Evolution of the Northern Virginia Piedmont

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By AVERY ALA DRAKE, JR., *and* PETER T. LYTTLE

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A stratigraphic, sedimentologic, and tectonic study of a crystalline terrane in the northern Virginia Piedmont

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THE ACCOTINK SCHIST, LAKE BARCROFT METASANDSTONE, AND POPES HEAD FORMATION—KEYS TO AN UNDERSTANDING OF THE TECTONIC EVOLUTION OF THE NORTHERN VIRGINIA PIEDMONT

By AVERY ALA DRAKE, JR., and PETER T. LYTTLE

ABSTRACT

The newly named Accotink Schist and Lake Barcroft Metasandstone of the Eastern Fairfax sequence are the structurally lowest metamorphic rocks in the northernmost Piedmont of Virginia. The Accotink consists of beds of pelitic schist that have thin basal intervals containing graded, very fine grained metasiltstone, as well as interbeds of metasandstone like that in the overlying Lake Barcroft Metasandstone. The unit is characterized by the Bouma turbidite sequences Te and Tde and can be assigned to turbidite facies D and E. The thickness of the Accotink is not known because its base is not exposed.

The Accotink Schist grades up into the Lake Barcroft Metasandstone, which consists of two types of metasandstone. Type I meta-arenite is quartzofeldspathic granofels which forms thick sequences of amalgamated beds that can best be described as belonging to the Bouma turbidite sequence Ta and to turbidite facies B_2. Type II metagraywacke of the Lake Barcroft Metasandstone consists of micaceous metagraywacke in thin to medium beds, which can be described as belonging to the Buoma turbidite sequences Tabe and (or) Tae and to turbidite facies C. The Lake Barcroft Metasandstone appears to be about 400 m thick. It and the Accotink Schist are thought to represent a coarsening-upward sequence of an outer submarine-fan association of rocks.

The Eastern Fairfax sequence is overlain by the Sykesville Formation. We believe that this contact is a movement surface upon which the Sykesville was emplaced by subaqueous sliding. The Sykesville contains isoclinally folded fragments, thought to be rip-ups, of Accotink and Lake Barcroft rocks. The Eastern Fairfax sequence is intruded by rocks of the Occoquan Granite batholith, which contains pendants of isoclinally folded schist and metagraywacke. After intrusion, the metasedimentary and plutonic rocks were folded together. Garnet and chlorite porphyroblasts within the Eastern Fairfax sequence appear to be related to the emplacement of the batholith. The minimum age of the Eastern Fairfax sequence is that of the Occoquan Granite batholith, currently thought to be about 560 m.y. The sequence, then, is considered to be of Early Cambrian age or older. The Accotink Schist and Lake Barcroft Metasandstone have some lithic similarity to the Loch Raven Schist and Oella Formation of Crowley (1976) of the Baltimore area, but a correlation is very uncertain at this time.

The newly named Popes Head Formation overlies all other metasedimentary and transported meta-igneous rocks in northernmost Virginia west of the Occoquan Granite batholith and is intruded by the batholith. The Popes Head consists of a lower Old Mill Branch Metasiltstone Member and an upper Station Hills Phyllite Member. The Old Mill Branch consists largely of alternating coarser and finer grained strata that are mostly fine- to very fine grained, mineralogically quite mature graded metasiltstone, which can be described as belonging to Bouma turbidite sequence Tbde and (or) Tde, more rarely Tcde. The metasiltstone contains interbedded intervals in which both felsic and mafic metatuff contain pristine euhedral crystals of igneous minerals. We believe that the metatuff represents ash-fall deposits. The Old Mill Branch appears to be about 730 m thick.

The Old Mill Branch grades up into the Station Hills Phyllite Member, which consists of thin- to medium-bedded pelitic phyllite and smaller amounts of very fine grained metasiltstone. The metasiltstone beds are graded, and many phyllite beds appear to have basal intervals containing graded, very fine grained metasiltstone. These beds can be described as belonging to Bouma turbidite sequence Tde. The Station Hills has intervals containing chlorite-rich phyllite, which probably represents mafic metatuff. No felsic metatuff has been recognized. The top of the Station Hills is not known, neither therefore, is its thickness. This unit appears to have a maximum thickness of about 300 m in northernmost Virginia.

The metasedimentary rocks of the Popes Head Formation probably belong to turbidite facies D and were probably deposited by weak turbidity flows. The interbedded volcanic material suggests that the Popes Head was deposited by the bilateral filling of a basin, perhaps a back-arc basin.

The minimum age of the Popes Head depends on the age of the Occoquan Granite batholith. The unit, therefore, is considered to be of Proterozoic Z and (or) Early Cambrian age. The unit has some similarity to the Chopawamsic Formation of the Quantico fold sequence south and east of the Occoquan Granite batholith, but that unit is thought to be older than the Sykesville Formation; whereas the Popes Head is younger. Metasiltstone like that of the Popes Head Formation is interbedded with purple and green pelitic phyllite characteristic of the Ijamsville Phyllite in southern Frederick County, Md. These two units may have a lateral facies relationship.

INTRODUCTION

The names Accotink Schist and Lake Barcroft Metasandstone, which refer to rocks constituting the Eastern Fairfax sequence, and Popes Head Formation are introduced here for two sequences of metamorphic rocks in the Piedmont of northern Virginia. These sequences are part of a terrane of matamorphosed sedimentary and less common volcaniclastic rocks, now pelitic phyllite and schist, metasiltstone, metagraywacke, and psammitic-matrix sedimentary mélange that crops out between the Culpeper Triassic and Jurassic basin and the Atlantic Coastal Plain. At the turn of the century, all the rocks of this terrane were mapped as Carolina Gneiss (Darton and Keith, 1901). Since that time, most geologists (Fisher, 1970; Hopson, 1964; Johnston 1962, 1964); Mixon and others, 1972; Reed and Jolly, 1963; Seiders and Mixon, in press; Seiders and others, 1975; Southwick and others, 1971; and Stose, 1928) have mapped these rocks as Wissahickon Formation, although some have considered the complicated psammitic-matrix sedimentary mèlange to be a separate Sykesville Formation. This stratigraphic assignment is not surprising, as the rocks are on strike with a metamorphic terrane in the Maryland Piedmont that has largely been called Wissahickon and, in fact, is considered one giant formation by Higgins and Fisher (1971). More recently, Drake and Morgan (in press) have suggested that the Wissahickon Formation could better be visualized as a Wissahickon terrane because of severe stratigraphic uncertainties and the presence of allochthonous rocks.

Bennison and Milton (unpub. data, 1950), in their mapping of the Fairfax and Seneca 15-minute quadrangles, did not follow the conventional Wissahickon terminology. They recognized a sequence of flyschoid schist and metagraywacke that they correlated with the Peters Creek Schist (Stose and Jonas, 1939) of Maryland and Pennsylvania and they thought that the psammitic-matrix sedimentary mélange was granitized schist. More important, they mapped a separate sequence of metasiltstone and phyllite that they named the Clifton Phyllite. This unit is renamed Popes Head Formation in this paper because the stratigraphic name Clifton is pre-empted.

More recent detailed mapping in Fairfax County (U.S. Geol. Survey, 1977, p. 54-55; Drake and Froelich, 1977; Drake and others, 1979) has shown that there are five sequences of metamorphic rocks in northernmost Virginia: (1) A flyschoid sequence of pelitic schist or phyllite and metagraywacke; (2) psammitic-matrix sedimentary mélange; (3) a sequence of metasiltstone and phyllite named herein the Popes Head Formation; (4) a previously unrecognized sequence of schist and metasandstone in the eastern part of the county named herein the Accotink Schist and Lake Barcroft Metasandstone; and (5) allochthons consisting of the Piney Branch Complex, a mixture of about subequal parts of ultramafic and mafic rocks, and its discontinuous sole of mélange, the Yorkshire Formation (Drake and Morgan, in press). Drake and others (1979) and Drake and Morgan (in press) recognize the psammitic-matrix sedimentary mélange as the Sykesville Formation and agree with Bennison and Milton (unpub. data, 1950) that the flyschoid sequence of rocks that crops out west of the Sykesville Formation along the Potomac River can best be correlated with the Peters Creek Schist. As the northern Virginia exposures of these last two units have recently been described by Drake and Morgan (in press), they will be discussed further herein only as they relate to other rocks.

Since the pioneering work of Hopson (1964), most of the rocks called Wissahickon have been recognized as turbidites that were deposited in a deep marine basin. The new stratigraphic units defined in this paper are also turbidites and are described using Bouma's (1962) concept of an ideal sequence of structures (fig. 1). This ideal sequence is rare, if present, in the rocks described herein. Hence, they are described on the basis of the

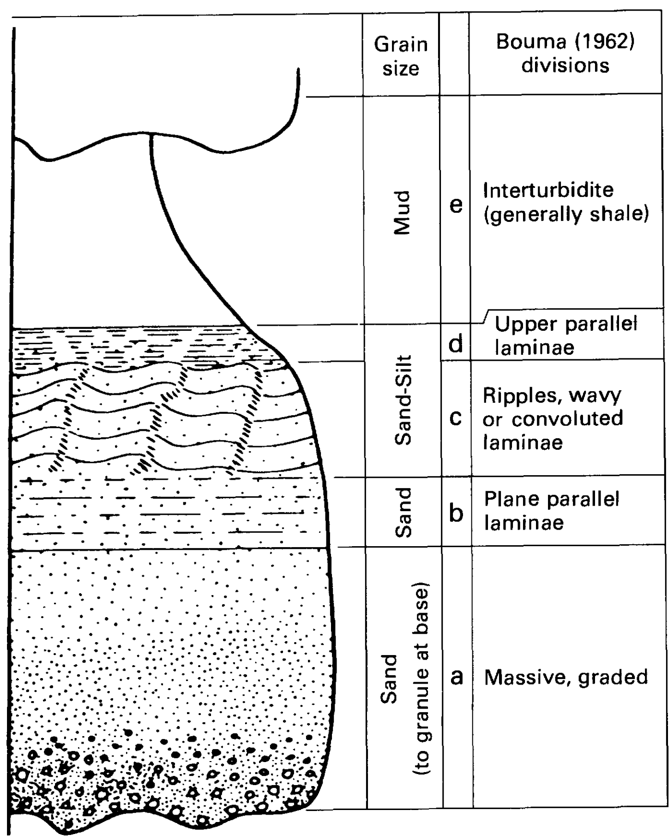

FIGURE 1.—Ideal sequence (the Bouma sequence) of structures in a turbidite bed modified (from Middleton and Hampton, 1973).

Bouma divisions recognized in a sedimentation sequence. A sequence beginning with massive graded rock passing up into pelite is described as a Tae turbidite, whereas one beginning with an interval containing rippled, cross-laminated rock that passes up into an interval containing parallel laminated rock and finally into pelite is described as a Tcde turbidite. This shorthand notation is convenient and is common usage in the modern literature.

In recent work, particularly in Italy, concepts to analyze and subdivide turbidite facies have been devised (see particularly Walker and Mutti, 1973; Mutti and Ricci Lucchi, 1978). These concepts are purely descriptive and are used to indicate the primary characteristics of a body of rock that differentiate it from adjacent rock bodies, both laterally and vertically. The most important criteria used in facies subdivision are: grain size, bed thickness and sand/shale ratios, bed regularity, sole mark assemblages, and internal structures and textures such as presence or absence of grading, massive bedding in sandstones, and variations in the Bouma sequence. The concept of facies subdivision is of utmost importance in determining sedimentary environments, and we have attempted to apply that concept to the poorly exposed metamorphosed turbidites of Fairfax County. Table 1 presents the classification used for the rocks described herein.

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We are indebted to our colleagues A. E. Nelson for some of the geologic mapping that went into this study and for many hours of discussion of the complex geology of northern Virginia; J. M. Aaron for early guidance in interpreting the sedimentology of the Popes Head Formation; and Louis Pavlides for many hours of discussion of the Virginia Piedmont, which has been of utmost importance to our understanding of the stratigraphy of the northern part of this enigmatic terrane.

EASTERN FAIRFAX SEQUENCE

Rocks here called the Eastern Fairfax sequence crop out in the eastern part of Fairfax County in the Fairfax, Annandale, and Falls Church 7½-minute quadrangles (pl. 1). These rocks are not known north of this outcrop area, but south of the area they form inclusions and medium- to large-sized roof pendants in tonalite plutons and the Occoquan Granite batholith (pl. 1). In addition, we have seen identical rocks within the terrane mapped as Wissahickon Formation by Seiders and Mixon (in press) in the southwestern part of the Occoquan 7½-minute quadrangle.

The Eastern Fairfax sequence appears to be beneath the Sykesville Formation. It consists of a lower Accotink Schist and an upper Lake Barcroft Metasandstone. Both units in the sequence contain beds of the other rock type.

TABLE 1.—*Classification of turbidite and other resedimented facies*
[Modified from Walker and Mutti, 1973]

Facies	Description
A	Coarse-grained sandstones and conglomerates.
A_1	Disorganized conglomerates.
A_2	Organized conglomerates.
A_3	Disorganized pebbly sandstones.
A_4	Organized pebbly sandstones.
B	Medium-fine- to coarse-grained sandstones.
B_1	Massive sandstones having "dish" structure.
B_2	Massive sandstones not having "dish" structure. Most beds lack alternating parallel lamination but may contain crude, subparallel, faint stratification. Beds have a very high (>10:1) sand/shale ratio, indicating that sandstone are amalgamated; that is, beds are welded together without interbedded shales. Beds range from tens of centimeters to about 2 m thick, have scoured bases, and most are lenticular.
C	Medium- to fine-grained sandstones—classic "proximal" turbidites beginning with Bouma division a. Strata typically are sharp, flat based, regularly bedded, and have good lateral continuity. Sandstones range from about 10 cm to 1 m in thickness and have sand/shale ratios of about 5:1. Amalgamation is uncommon, and most sandstone beds grade up into shale (Bouma division e). Most beds in a sequence begin with Bouma division a. Parallel (Bouma divisions b and d) and ripple cross-lamination (Bouma division c) is uncommon, and rock can typically be described as a Tae turbidite. Facies C is not sharply separated from Facies B_2, and there is a spectrum of beds between B_2 and C.
D	Fine- to very fine grained sandstones and siltstones—classic "distal" turbidites beginning with Bouma division b or c. Sandstone beds have sharp flat bases, are prominently graded, and are about 1–10 cm thick. The sand/shale ratio is low, 1:1 or less. Most sequences start with the Bouma division b or c and can be described as Tbcde, Tbde, or Tcde turbidites, the Tcde being the model sequence. There is a gradation between turbidites of Facies C and D.
E	Similar to Facies D, but has higher sand/shale ratios, thinner, more irregular beds, and more discontinuous beds in wedges and lenses. The tops of most sandstone beds are not graded but are in sharp contact with overlying shales. Facies is characterized by Tae turbidites.
F	Chaotic deposits formed by downslope mass movements.
G	Hemipelagic and pelagic shales and marl—silty or calcareous deposits having indistinct and poorly developed lamination or distinct parallel bedding and resulting from very dilute suspensions.

ACCOTINK SCHIST

The Accotink Schist is herein named for exposures at its type locality along Accotink Creek west of the Capital Beltway (Interstate Route 495), just north of the Little River Turnpike exchange in the Annandale 7½-minute quadrangle, Fairfax County, Va. (pl. 1). Other exposures in this general area are in the small streams tributary to

Accotink Creek. Good outcrops are sparse in this deeply weathered, highly urbanized area, but the unit is well exposed along the upper reaches of Accotink creek at New Hope and in a small stream tributary to Lake Barcroft south of J.E.B. Stuart High school in the Annandale 7½-minute quadrangle. Many of the exposures of the unit are saprolite.

If fresh, the Accotink Schist is light gray, but in most exposures the rock is weathered to yellowish gray, moderate brown, or very pale orange. In outcrop it can be characterized as a quartz-muscovite-biotite-chlorite-plagioclase schist. The total mineral assemblage seen in thin section for the Accotink Schist is quartz-muscovite-biotite-chlorite-plagiolase (garnet-magnetite-epidote-apatite-zircon-pyrite). Here, and throughout this paper, hyphenated mineral-assemblage lists are arranged in order of decreasing modal percentages. Accessory minerals that are not present in all specimens are listed in parentheses. A typical texture consists of an interlocking network of angular, recrystallized, more rarely subrounded and equigranular quartz and subordinate plagioclase and laths of muscovite, biotite, and chlorite. Quartz is more abundant than the phyllosilicates and the relative proportions of the phyllosilicates stay fairly constant throughout a given specimen. In a few samples, phyllosilicates are more abundant than quartz. In no sample are the quartz and phyllosilicates segregated into rhythmic sedimentation units, a feature so typical of the Peters Creek Schist of the Potomac River gorge (Drake and others, 1979; Drake and Morgan, in press; compare fig. 2 with fig. 3).

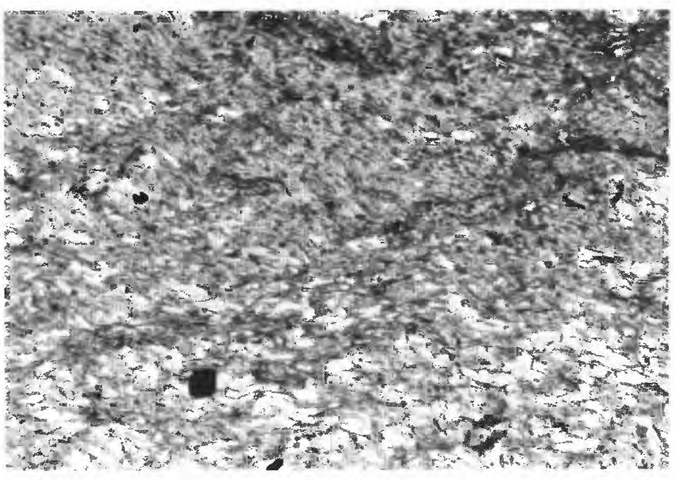

FIGURE 2.—Accotink Schist from Accotink Creek about 800 m northwest of New Hope, Annandale quadrangle. Texture to be noted is the intimate intergrowth of quartz, micas, and chlorite. This contrasts sharply with cleanly segregated layers of micas and quartz in the Peters Creek Schist (fig. 3). Mineralogy in order of decreasing abundance is muscovite, quartz, chlorite, garnet, magnetite, and minor plagioclase. Plain light; 1 cm in photo equals 0.5 cm.

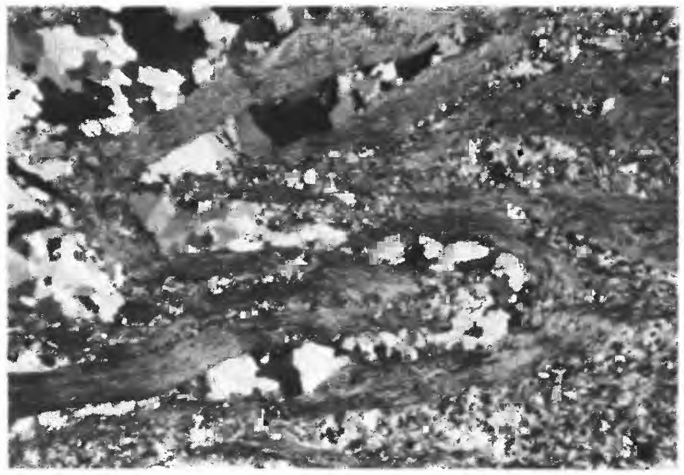

FIGURE 3.—Peters Creek Schist, from Potomac River gorge about opposite the center of Bear Island, Falls Church quadrangle, showing segregation of quartz and mica-rich layers, probably a result of both original compositional layering and later metamorphic differentiation. Early cleavage is tightly folded. Quartz layers show recrystallization and shearing that produce long, very thin attenuated lenses. Incipient formation of late-spaced cleavage also evident. Crossed polarizers; 1 cm on photo equals 0.5 cm.

The schist is interbedded with two types of metasandstone that are characteristic of the overlying Lake Barcroft Metasandstone (see below). Most of the interbedded metasandstones are well-foliated, regularly bedded, micaceous metagraywacke. Where present, this metagraywacke appears to be a more quartzofeldspathic element of a pelitic sedimentary sequence. The other type of metasandstone is a poorly foliated, quartzofeldspathic granofels that typically forms randomly scattered, discontinuous beds. Some of these beds form lenses having a maximum thickness of about 2 m in a stream exposure. Both types of metasandstone are discussed in the section on the Lake Barcroft Metasandstone.

Muscovite, biotite, and tiny chlorite laths have grown in the first cleavage. These phyllosilicates are transposed into the second cleavage, and it looks as if a second generation of muscovite also crystallized in the second cleavage. Large porphyroblasts of chlorite and garnet, which contain numerous inclusions, grow at nearly any angle to the second cleavage and in outcrop appear to have grown under static conditions. Thin-section study, however, shows that some of the garnet porphyroblasts have been slightly rotated and that the second cleavage bends around the ends of some of the seemingly random-oriented chlorite porphyroblasts suggesting that the chlorites have also been rotated to varying degrees (fig. 4). The ends of a few large chlorites are splayed and rotated approximately parallel to the second schistosity. These relations suggest that porphyroblast growth was, in part, syntectonic with the second-cleavage formation.

FIGURE 4.—Accotink Schist from west bank of Accotink Creek about 500 m northwest of the intersection of the Capital Beltway (I-495) and the Little River Turnpike, Annandale quadrangle. Well-developed late second cleavage (roughly horizontal in photograph) has almost totally transposed early cleavage. Large poikioblastic chlorites (c) containing numerous quartz inclusions and small euhedral pseudomorphs after garnet formed after development of early schistosity were rotated to varying degrees during development of late transposition cleavage, and probably formed during an intervening contact metamorphism related to the intrusion of the Occoquan Granite batholith. Relict cores of garnet (G) rimmed by chlorite and (or) biotite (center of photograph) are occasionally seen. Plain light; 1 cm on photo equals 0.5 cm.

A poorly developed third cleavage transposes the second cleavage, but there is no evidence of new mineral growth.

In most exposures, bedding is transposed, and cleavage is the dominant planar element. This cleavage is folded (fig. 5), and a later strain-slip cleavage formed axial planar to these folds as shown by mica alignment (fig. 4). In a few exposures, a third cleavage can be seen, but its common manifestation is a crenulation of the second cleavage (fig. 6).

Bedding characteristics are difficult to determine because of the extreme deformation and poor exposure, but within the unit most intervals that contain pelitic rocks are 20–210 cm thick. These intervals do not contain single beds but are the intervals between metagraywacke layers. Determination of the number of sedimentation units within such an interval is very difficult, but in one well-exposed fold hinge, we can see that individual sedimentation units have a maximum postdeformational thickness of about 1.5 cm and average about 1 cm. In this good exposure, the pelite has a few intervals less than 0.5 cm thick that contain very fine grained, graded silt. This suggests that these intervals of the Accotink contain turbidites belonging to the Tde sequence of Bouma (1962). The intervals containing fine pelite are probably T_e sequences. The Accotink then, can be assigned to turbidite facies D and E of Mutti and Ricci Lucchi (1978) and Walker and Mutti (1973).

FIGURE 5.—Accotink Schist, from Accotink Creek at New Hope, Annandale quadrangle, showing steep-plunging folds (to the left of knife) in first schistosity. Outcrop face is about vertical.

The thickness of the Accotink Schist is unknown because the base is not exposed in Fairfax County, nor is it known elsewhere. The schist appears to grade up into the Lake Barcroft Metasandstone. In mapping, the contact is arbitrarily placed stratigraphically below outcrops where the eastern Fairfax sequence consists of as much as 50 percent metasandstone.

LAKE BARCROFT METASANDSTONE

The Lake Barcroft Metasandstone is herein named for exposures at its type locality at the confluence of and along the Holmes Run and Tripps Run arms of Lake Barcroft, Annandale 7½-minute quadrangle, Fairfax County (pl. 1). The unit is also well exposed in a large

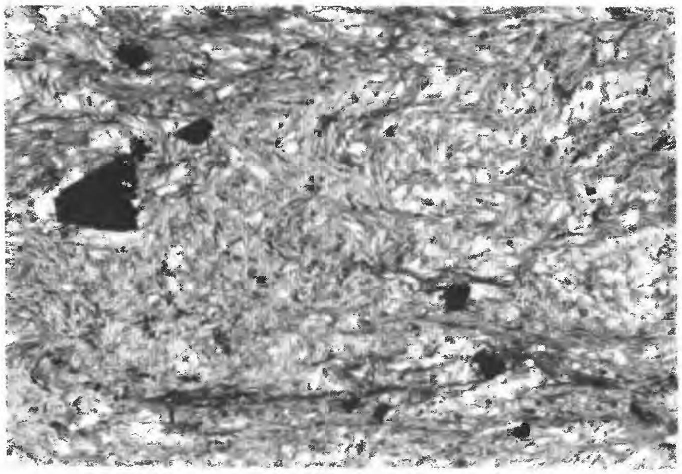

FIGURE 6.—Accotink Schist, from Accotink Creek about 800 m northwest of New Hope, Annandale quadrangle, showing rotation of mica flakes that define early recrystallization schistosity and incipient later spaced strain-slip cleavage (roughly horizontal in photograph). Minerals in order of decreasing abundance are muscovite, quartz, chlorite, minor biotite, pyrite, and magnetite. Plain light; 1 cm on photo equals 0.2 cm.

pendant in the Occoquan Granite batholith along a 1,200-m reach of Pohick Creek from a point about 400 m south of Old Keene Mill Road and along Accotink Creek and its tributaries between Old Keene Mill and Hooes Roads, Annandale 7½-minute quadrangle, Fairfax County (pl. 1). The unit consists of two types of metasandstone. Type I meta-arenite is thick-bedded quartzofeldspathic granofels, without interbedded pelite; whereas, Type II is thin- to medium-bedded micaceous metagraywacke containing pelitic layers.

TYPE I META-ARENITE

Type I meta-arenite of the Lake Barcroft Metasandstone is typically a light-greenish-gray to light-gray to bluish-white granofels that weathers grayish orange pink or yellowish gray. Some of the rock can properly be called metagraywacke, although most exposures are meta-arenite. In fresh outcrop, the rock seems much more quartzose than it is, but abundant chalky-weathering feldspar is apparent in saprolite.

The typical mineral assemblage of Type I meta-arenite is quartz-epidote-plagioclase-chlorite (-muscovite-magnetite). Thin-section study shows that the rock consists of an equigranular mass of very closely packed and interlocking recrystallized quartz, plagioclase, and clumps of epidote, sericite, and chlorite after plagioclase (fig. 7). Muscovite, where present, generally forms small laths, but some are larger and contain quartz inclusions. Muscovite orientation suggests that some rocks have a second cleavage, but this could not be measured in the field.

Individual beds are as much as 2 m thick, but the massive nature of much of the rock probably results from the sedimentary amalgamation of beds; that is, successive sand beds are welded together without interbedded shales. The continuity of individual beds of Type I meta-arenite cannot be determined within the Lake Barcroft terrane, but beds of this type of rock within the Accotink Schist are lenticular. A vague distribution grading was noticed in a few exposures as was a faint lamination in others. Cross-lamination was not seen. Only a very few bed bottoms were seen; these are marked by what appear to be deep bulbous flute casts. No other sedimentary structures were seen. The massive granofels shows a faint foliation marked by flattened quartz and, in exposures that contain it, orientated muscovite.

The thick sands, no intervening pelite, high sand/shale ratio, and few internal structures of the Type I meta-arenite suggest that it is probably a sequence of Ta turbidites as defined by Bouma (1962). These features also suggest that this rock type can be assigned to turbidite facies B_2 of Walker and Mutti (1973).

TYPE II METAGRAYWACKE

Type II metagraywacke of the Lake Barcroft Metasandstone is typically a very light gray to light-gray, yellowish-gray-weathering, fine- to medium-

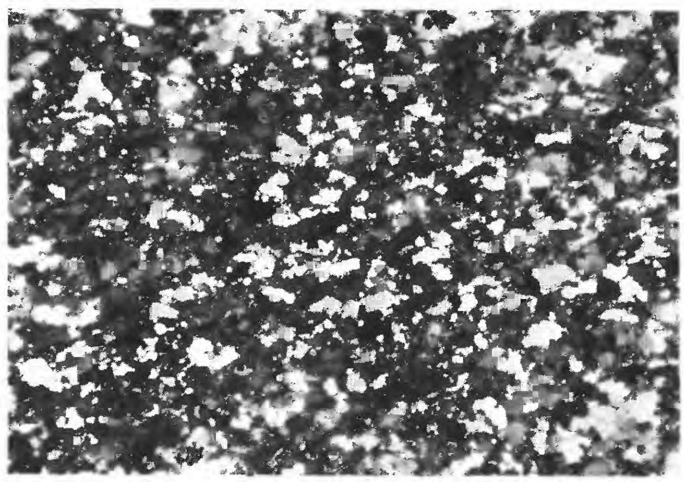

FIGURE 7.—Type I meta-arenite of the Lake Barcroft Metasandstone from Indian Run about 900 m southeast of Little River Turnpike, Annandale quadrangle. Quartz-rich meta-arenite containing minor amounts of fresh plagioclase and clumps of intergrown sericite, epidote, and chlorite. These clumps probably represent both alteration products of plagioclase and an original minor clay component. crossed nicols; 1 cm on photo equals 0.5 cm.

grained rock. Much of it can be characterized as a graywacke that has well-developed cleavage but little segregation of individual minerals into metamorphically differentiated layers. Isoclinal folds having long limbs and tight hinges are common (fig. 8).

The typical mineral assemblage of Type II metagraywacke of the Lake Barcroft Metasandstone is quartz-biotite-muscovite-plagioclase (-garnet-epidote-magnetite). Biotite and muscovite parallel the first cleavage and have been partly transposed into a later strain-slip cleavage. Garnet porphyroblasts have grown across the first schistosity and typically are partly altered to chlorite on crystal margins (fig. 8). The general presence of garnet in the Type II metagraywacke suggests that it is fairly aluminous and points up the difference in composition between these rocks and the metagraywackes of the Peters Creek Schist, which are not known to contain garnet at the same grade of metamorphism. Epidote forms well-developed euhedral grains and is never seen as an obvious alteration product of plagioclase. The amount of calcium in both the plagioclase and epidote suggests that the original sediment was fairly rich in calcium and perhaps contained carbonate.

Beds are generally regular, sharp, flat based, and 10-15 cm thick, although in some exposures they reach a maximum thickness of about 30 cm. In many exposures, individual sedimentation sequences begin with a graded interval and terminate with pelitic material. Some beds appear to have parallel laminations, but this is not certain because of the well-developed schistosity that generally parallels bedding on the limbs of early isoclinal folds. In other exposures, no sedimentary structures other than bedding can be seen, but sedimentation sequences begin with graywacke and grade up into pelite. We have not seen cross-lamination in the metagraywacke.

FIGURE 8.—Type II metagraywacke of the Lake Barcroft Metasandstone from Holmes Run about 200 m northwest of Annandale road (TI on pl. 1), Annandale quadrangle, showing an early isoclinal fold (above and to the right of the hand lens) and garnet porphyroblasts that have chlorite rims.

Classically, a sequence consisting of Type II metagraywacke of the Lake Barcroft would be considered a distal turbidite unit (facies D of Walker and Mutti, 1973) because of the relatively fine grain size of sediments and the thin bedding. However, the unit should probably be assigned to turbidite facies C (Mutti and Ricci Lucchi, 1978, Walker and Mutti, 1973), as many beds appear to have the Bouma (1962) sequence T_{abe} or perhaps sequence T_{ae} in which there is little bed amalgamation. The apparent large number of beds starting with Bouma (1962) division a and the apparent lack of division c seems particularly important. The turbidite facies C interpretation is strengthened by the fact that the Type II metagraywacke is found in the same sedimentation package as the turbidite facies B_2 rocks of the Type I metaarenite. Some exposures of the Lake Barcroft, in fact, contain beds that appear to be transitional between Types I and II metasandstones.

The Lake Barcroft Type II metagraywacke is physically overlain by the Sykesville Formation. Most authors have made the interpretation that the Sykesville has a gradational relation to both underlying and overlying rocks Hopson, 1964, Fisher, 1970, Crowley, 1976). In eastern Fairfax County, however, no evidence exists for a gradational boundary between the Lake Barcroft Metasandstone and Sykesville Formation. In fact, if a modification of the terminology of Hsü (1968) is used, there are chips (15 cm), fragments (15 cm to 1.5 m), small blocks (1.5-15 m), large blocks (15-150 m), and small slabs (150-1,500 m) of rocks identical with Lake Barcroft metagraywacke as well as Accotink Schist within the Sykesville. These exotic clasts were foliated and some were isoclinically folded before they were incorporated into the Sykesville. Exotic Lake Barcroft Metasandstone and Accotink Schist, and also ultramafic, mafic, and other strange rocks, can best be seen along Indian Run in the Annandale 7½-minute quadrangle (pl. 1). The contact between the Lake Barcroft and the Sykesville has been interpreted as the movement surface upon which the Sykesville was emplaced by subaqueous sliding (U.S. Geological Survey, 1977, p. 54–55.) This interpretation was made because the Sykesville everywhere appears to be physically above the Lake Barcroft, and there is no direct evidence that the units grade into one another. All modern authors have believed that the Sykesville was emplaced by subaqueous sliding. For this to be true, it had to slide on something. We believe that in Fairfax

County, the surface of movement is the top of the Lake Barcroft Metasandstone. If the above interpretation is correct, the exotic Lake Barcroft Metasandstone and Accotink Schist are small to very large rip-ups related to the sliding of the Sykesville. However, we cannot completely rule out the possibility that the entire Eastern Fairfax sequence constitutes a large slab within the Sykesville.

The thickness of the Lake Barcroft Metasandstone cannot really be determined because of the relations described above. Where the most data are available, just northwest of Annandale and along the east part of Lake Barcroft (pl. 1), the unit appears to be about 400 m thick.

ENVIRONMENT OF DEPOSITION

The poorly exposed, strongly deformed Eastern Fairfax sequence yields too few data to allow a detailed discussion of its depositional environment. Some generalizations, however, can be made from the observations cited above. The very fine grained, graded silt turbidite facies D (Mutti and Ricci Lucchi, 1978, Walker and Mutti, 1973) and pelite turbidite facies G (Mutti and Ricci Lucchi, 1978, Walker and Mutti, 1973) rocks of the Accotink Schist suggest low-density turbidity-current deposition combined with normal pelagic "rain". These fine-grained rocks are overlain by the coarser Types I and II Lake Barcroft Metasandstone. Type I meta-arenite has been assigned to turbidite facies B_2 (Walker and Mutti, 1973) and probably was deposited from dense rapid currents that were in disequilibrium with the bottom. The possible deep bulbous flute casts described above suggest that current flow was turbulent and capable of minor erosion and that deposition had to follow erosion rapidly to ensure preservation. The turbidite facies C beds (Mutti and Ricci Lucchi, 1978, Walker and Mutti, 1973) of the type II metagraywacke are quite typical of classical proximal turbidites, though they lack the abundant sedimentary structures of the metagraywackes of the Peter Creek Schist. The Types I and II metasandstones can be linked by rocks transitional between turbidite facies B_2 and C.

The Eastern Fairfax sequence, then, appears to be a coarsening-upward sequence, which we suggest belongs to the outer submarine-fan association of Walker and Mutti (1973). The facies G beds of the Accotink grade up into progressively thicker facies D beds. These rocks in turn grade up into Type II metagraywacke of the Lake Barcroft which would herald the progradation of the suprafan represented by the B_2 facies rocks of Type I meta-arenite. The lenticular beds of Type I meta-arenite within the Accotink Schist probably represent channels filled when the suprafan was at a different position.

AGE AND CORRELATION

The age of the Eastern Fairfax sequence cannot be determined directly. It is clearly older than the Sykesville Formation, which contains large and small clasts of rock identical with both Accotink Schist and Lake Barcroft Metasandstone. The sequence is also older than the Occoquan Granite batholith and the several tonalite plutons in eastern Fairfax County, as proved by direct outcrop observations. Particularly good intrusive relations with tonalite can be seen in the Annandale 7½-minute quadrangle along Holmes Run about 300 m northwest of Annandale Road (11 on pl. 1) and good intrusive relations with rocks of the Occoquan can be seen on the west bank of Holmes Run about on the Fairfax County-Alexandria City line, about 650 m north of Beauregard Street (01 on pl. 1). The minimum age of the Eastern Fairfax sequence, then, ultimately depends on the age of the rocks of the Occoquan. Seiders and others (1975) obtained both concordant and discordant U–Th–Pb ages of about 560 m.y. from zircon from this granite. Higgins and others (1977) have questioned these dates and have suggested that the zircons may have inherited a component of older radiogenic lead in seed crystals derived from Proterozoic basement rocks. The age of the Occoquan is a significant problem for which a final resolution has not been reached. However, we know of no direct geologic evidence that prevents the Occoquan from being as old as Early Cambrian.

We have shown that rocks of the Eastern Fairfax sequence were isoclinally folded before the intrusion of the tonalite plutons and the Occoquan Granite batholith. Actually, the isoclinal fold shown in figure 8 is in a pendant. Textural evidence described above and shown in figure 6 shows that garnet and large chlorite porphroblasts had largely grown before the formation of the second cleavage. Possibly the heat necessary for porphyroblast growth was supplied by the plutonic rocks. The Occoquan and smaller satellite bodies crop out over a much larger area than the entire Eastern Fairfax sequence and are commonly in contact with these rocks. What appears to be regional metamorphism could be, and most likely is, a large-scale contact metamorphism. That the Eastern Fairfax sequence and the plutonic rocks were deformed together after pluton emplacement is clearly shown by a comparison of the attitudes of axes of folds in schistosity and joints in the schist and metagraywacke with the attitudes of lineations and joints in the plutonic rocks (fig. 9). Until additional isotopic work is completed and proves the contrary, we are forced to conclude that the Eastern Fairfax sequence has a minimum age of Early Cambrian and may actually be Proterozoic Z. We, therefore, consider the Eastern Fairfax sequence to be Proterozoic Z and (or) Early Cambrian in age.

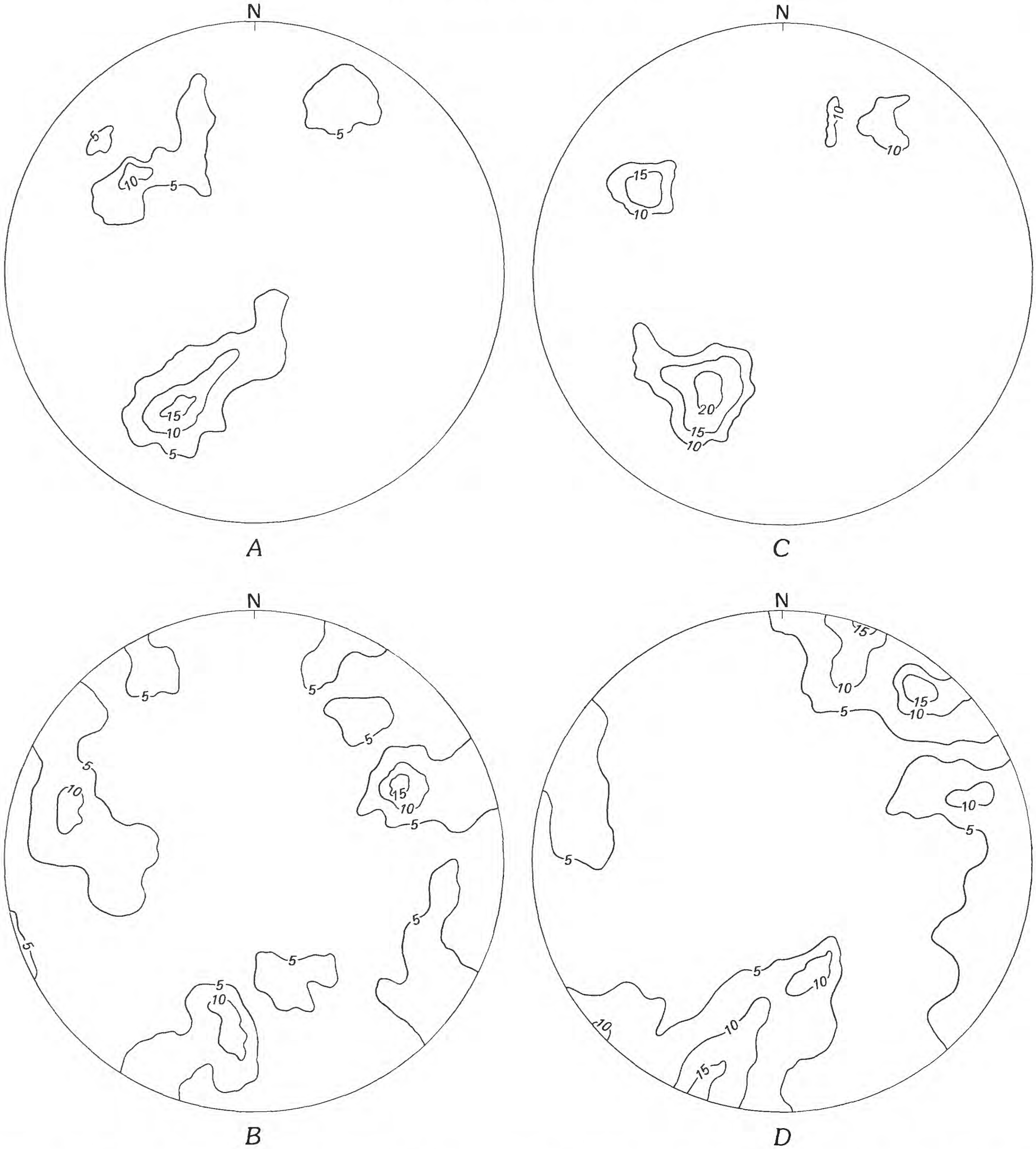

FIGURE 9.—Stereographic projections comparing structural elements in rocks of the Eastern Fairfax sequence with those in rocks of tonalite plutons and the northern part of the Occoquan Granite batholith. *A*. Equal-area plot (lower hemisphere) of 50 axes of small folds in schistosity in rocks of Eastern Fairfax sequence. Contours at 15,10, and 5 percent per 1-percent area. *B*. Equal-area plot (upper hemisphere) of 100 poles to joints in rocks of Eastern Fairfax sequence. *C*. Equal-area plot (lower hemisphere) of 40 mineral and rodding lineations in rocks of tonalite plutons and northern part of Occoquan Granite batholith. *D*. Equal-area plot (upper hemisphere) of 160 poles to joints in rocks of tonalite plutons and northern part of Occoquan Granite batholith.

Correlation of the Eastern Fairfax sequence with other rocks in the central Appalachian Piedmont is difficult, if not impossible. The position of the sequence beneath the Sykesville Formation suggests that the sequence may possibly correlate with rocks called Wissahickon Formation, eastern sequence, by Hopson (1964) or Loch Raven Schist and Oella Formation by Crowley (1976). Hopson (1964) considered these rocks to be Proterozoic Z, an interpretation that would fit the tentative age of the Eastern Fairfax sequence, but most recent authors (for example, Crowley, 1976) have considered them to be the upper part of a sequence of probable Cambrian and Ordovician age. Crowley (1979) stated that his Loch Raven Schist and Oella Formation near Baltimore are allochthonous and therefore could be older than was previously thought. If so, they could correlate with the Eastern Fairfax sequence.

POPES HEAD FORMATION

The Popes Head Formation is herein named for exposures at its type locality along Popes Head Creek and the adjacent tracks of the Southern Railroad between Station Hills, Fairfax 7½-minute quadrangle, and the confluence of the creek with Bull Run, Manassas 7½-minute quadrangle, Fairfax County (pl. 1). The unit can be seen in many exposures in streams tributary to Bull Run and Popes Head Creek in the Manassas and Fairfax 7½-minute quadrangles in saprolite exposures in streams, and in road, railroad, and construction-site cuts in the Fairfax, Annandale, Vienna, and Falls Church 7½-minute quadrangles. The unit is not known north of the outlying Coastal Plain deposits near Tysons Corner (pl. 1), but it continues to the southern limit of our mapping in the Independent Hill quadrangle, Prince William County.

The Popes Head Formation is divided into a lower Old Mill Branch Metasiltstone Member and an upper Station Hills Phyllite Member. The lower member is composed largely of metasiltstone but contains subordinate phyllite, felsic metatuff, and mafic metatuff. The upper member is composed largely of pelitic phyllite and contains subordinate very fine-grained metasiltstone and only minor amounts of mafic metatuff.

The bulk of the Popes Head is within a complexly refolded synform above various rocks of the Wissahickon terrane, Peters Creek Schist of our usage (pl. 1). The unit also is found in two small subsidiary synforms west of this major structure (pl. 1). In the southern part of the map area, the formation is intruded by the Occoquan Granite batholith.

OLD MILL BRANCH METASILTSTONE MEMBER

The Old Mill Branch Metasiltstone Member is herein named for exposures at its type locality along Old Mill Branch between Clifton Road and the Occoquan Reservoir, Manassas 7½-minute quadrangle, Fairfax County, Va. (pl. 1). Other good exposures are along the two unnamed streams between Old Mill Branch and Bull Run in the Manassas 7½-minute quadrangle; in the type section of the formation, along Piney Branch between Robeys Mill and its confluence with Popes Head Creek, Fairfax 7½-minute quadrangle; along Popes Head Road between Popes Head Creek and Ox Road, Fairfax 7½-minute quadrangle; and along Long Branch north of Arlington Boulevard in the Falls Church and Annandale 7½-minute quadrangles (pl. 1).

Where fresh, the Old Mill Branch Metasiltstone Member is light greenish gray, but in most exposures it weathers to pale greenish yellow or yellowish gray. Saprolite exposures are typically dusky yellow. The unit consists of alternating coarser and finer grained strata. Most of the coarser grained beds are medium- to fine-grained micaceous metasiltstone, but a few are fine-grained micaceous metasandstone. Some of the coarser beds, however, are extremely rich in quartz and have only wispy seams of phyllosilicates (fig. 10). The finer grained beds are metapelite and extremely fine-grained micaceous metasiltstone. The unit is isoclinally folded, and in most exposures, phyllitic cleavage is subparallel to bedding. Both bedding and cleavage have been

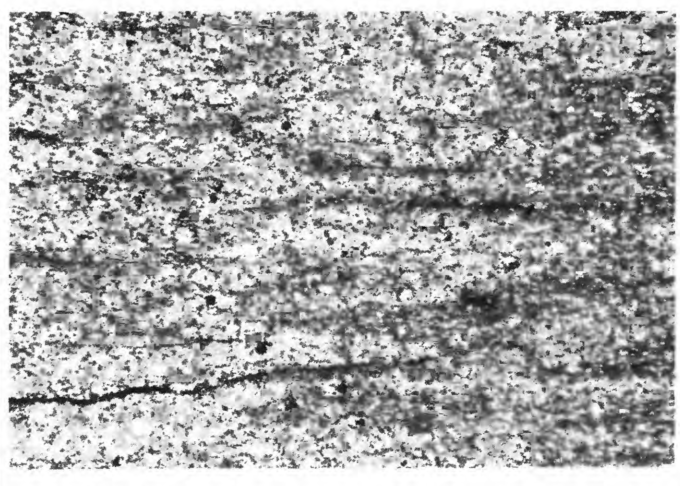

FIGURE 10.—Typical Old Mill Branch Metasiltstone Member of the Popes Head Formation from east bank of Bull Run about 150 m south of north border of Independent Hill quadrangle. Quartz-rich metasiltstone containing plagioclase, wispy seams of biotite (sometimes chlorite) parallel to a faint foliation, and scattered magnetite. Plain light; 1 cm on photo equals 0.5 cm.

deformed by a later fold phase, but a second cleavage is seen in only a few exposures. In spite of this deformation, certain sedimentologic observations can be made. The beds are 2–24 cm thick, averaging about 15 cm. They have sharp bases, appear to be regular, and show no evidence of wedging or lensing. In many exposures, metasiltstone clearly grades up into metapelite. Other beds, however, appear to be laminated, and the grading is obscure. Penetrative phyllitic cleavage makes such observations difficult. We have searched for but have found only a few cross-laminated sedimentation intervals and no sole marks. These data suggest that the Old Mill Branch consists of turbidites that can be described by the Bouma (1962) sequence T_{bde} and (or) T_{de}, and, more rarely, T_{cde}.

The typical mineral assemblage of the metasiltstone is quartz-muscovite-biotite-plagioclase (-chlorite-magnetite-epidote). Mineral assemblages in the metapelite are the same except that they contain more total phyllosilicates than quartz. Thin-section study shows that the long dimensions of all minerals, including flattened quartz, parallel the phyllitic cleavage. Bedding is largely obscured by transposition in the more pelitic rocks, but remnants suggest that the outcrop determination of lamination is correct.

FELSIC METATUFF

The Old Mill Branch Metasiltstone Member contains fairly abundant felsic metatuff. To determine the amount is impossible because of poor exposure and deep weathering and because the saprolite formed from metasiltstone closely resembles that formed from felsic metatuff. Where fresh, the metatuff is greenish gray. It weathers light gray to yellowish gray. The rock is fine grained, but euhedral plagioclase can easily be seen with a hand lens. The metatuff forms beds as thick as 60 cm within normal sedimentary sequences of Old Mill Branch rocks. Strata both above and below metatuff beds seem to contain about subequal parts of terrigenous and volcanigenic material.

Thin-section study shows that the metatuff consists of quartz, plagioclase, epidote (probably after plagioclase), muscovite, biotite (altering to, and interleaved with chlorite), chlorite, tiny green pleochroic amphibole, and magnetite. The plagioclase forms large euhedral zoned crystals in which the more calcic interiors are altered to epidote (fig. 11). The biotite and chlorite form wispy seams parallel to the phyllitic cleavage.

Thin-section study of rocks thought to have both terrigenous and volcanigenic components shows the typical well-foliated quartz-muscovite-biotite-magnetite metasiltstone that also contains tiny epidote grains and tiny needles of green pleochroic hornblende. There is no recognizable zoned or twinned plagioclase, but the rock most probably contained some, because epidote, a common alteration product of plagioclase in these rocks, is abundant. The textures suggest that this rock contains a volcanigenic component.

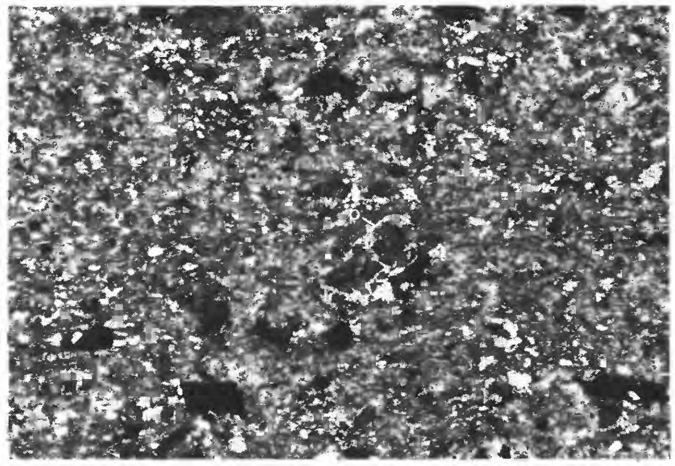

FIGURE 11.—Felsic metatuff from the Old Mill Branch Metasiltstone Member of the Popes Head Formation from a small stream tributary to Bull Run about 1,900 m west of Bull Run Marina, Independent Hill quadrangle. Large euhedral plagioclase crystals (p, near center of photograph) have more calcic cores that have altered to epidote in a fine-grained matrix of quartz, chlorite, epidote, biotite, muscovite and opaque minerals. Biotite and chlorite form wispy seams parallel to foliation. Crossed nicols; 1 cm on photo equals 0.2 cm.

The felsic metatuff must have resulted from an ash fall. The perfectly preserved zoned euhedral plagioclase crystals would never have survived the abrasion and disintegration accompanying a normal sedimentation process.

MAFIC METATUFF

Mafic metatuff does not appear to be as abundant in the Old Mill Branch Metasiltstone Member as felsic metatuff. Where best exposed, the mafic metatuff is fairly crystalline; probably a fair amount of more finely crystalline tuff was not recognized because of its similarity to greenish-gray, very fine grained metasiltstone or phyllite. The mafic metatuff weathers grayish olive green, and many outcrops are characterized by abundant oxidized pyrite. The metatuff forms layers as thick as about 60 cm and series of layers as much as 180 cm interbedded with the metasiltstone and phyllite of the Old Mill Branch. Euhedral grains of amphibole and plagioclase can be seen with a hand lens in most exposures.

Thin-section study shows that the rock has a high ratio of euhedral well-preserved blue-green amphibole, zoned plagioclase, and sphene, to mature granular terrigenous quartz and minor fine-grained plagioclase. Most rocks are extremely altered, but some retain remarkably pristine igneous textures (fig. 12). The euhedral nature of these igneous minerals suggests that the mafic metatuff layers, like the felsic metatuff, resulted from ash falls. If the original igneous protolith had been a flow or hypabyssal rock, it is unlikely that individual euhedral minerals could have been incorporated in the fine-grained matrix without greater destruction.

CONTACT RELATIONS

The Old Mill Branch Metasiltstone Member physically overlies all the other rocks of the Wissahickon terrane in Fairfax County (Drake and others, 1979). On the east, it is strongly discordant on rocks of the Peters Creek Schist, Sykesville Formation, Lake Barcroft Metasandstone, and Accotink Schist which are more deformed and at a higher metamorphic grade (pl. 1; Drake and others, 1979). On the west, it is discordant on rocks of the Peters Creek Schist, Sykesville Formation, Yorkshire Formation, and Piney Branch Complex (pl. 1; Drake and others, 1979). All these rocks are polydeformed and polymetamorphosed, and much of the Peters Creek Schist constitutes a zone of severely retrograded phyllonites and other pervasively sheared rocks. These sheared rocks had been at high metamorphic grade, and many are sheared migmatites. The contact of the Old Mill Branch is particularly difficult to map where it overlies the zone of phyllonized and pervasively sheared Peters Creek Schist (Drake and others, 1979; Drake and Morgan, in press). Both rocks are similar in fine-grain size, closely spaced foliation, and color, although the zone of mylonites and phyllonites has been multiply deformed and metamorphosed; whereas the Old Mill Branch is much less deformed and metamorphosed. Detailed mapping shows that the metasiltstone is in a large synform overturned toward the east and two much smaller outlying synforms. Both sides of the outcrop belt show abundant

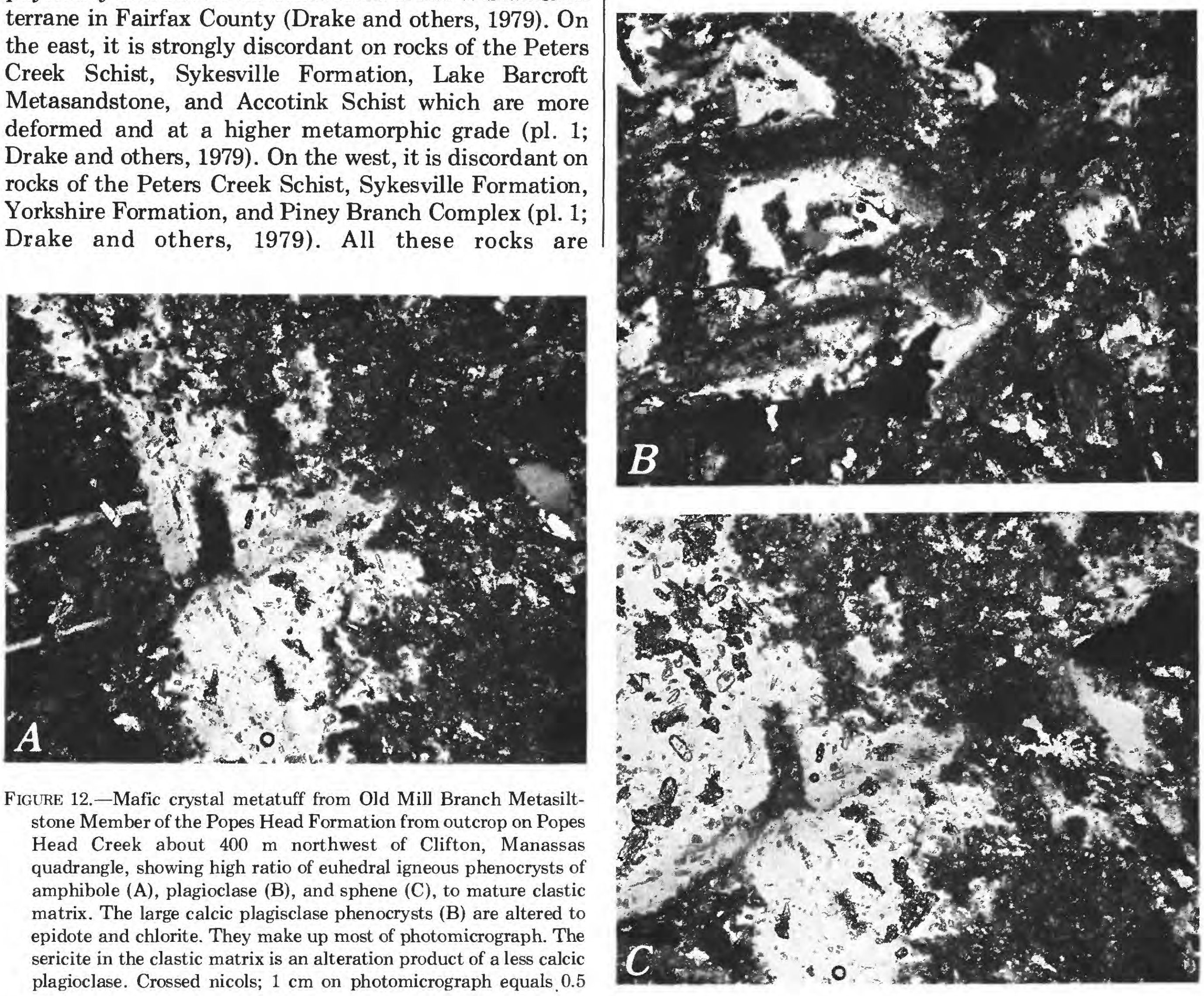

FIGURE 12.—Mafic crystal metatuff from Old Mill Branch Metasiltstone Member of the Popes Head Formation from outcrop on Popes Head Creek about 400 m northwest of Clifton, Manassas quadrangle, showing high ratio of euhedral igneous phenocrysts of amphibole (A), plagioclase (B), and sphene (C), to mature clastic matrix. The large calcic plagisclase phenocrysts (B) are altered to epidote and chlorite. They make up most of photomicrograph. The sericite in the clastic matrix is an alteration product of a less calcic plagioclase. Crossed nicols; 1 cm on photomicrograph equals 0.5 cm.

younging directions, on the basis of primary sedimentary structures, which indicate that these folds are synclines. The Old Mill Branch then is less deformed, is at a lower metamorphic grade, and is stratigraphically above the older rocks. In addition, bedding in the Old Mill Branch parallels the contact that cuts across structural markers in the older rocks. All the available evidence, therefore, strongly suggests that the contact with the older rocks is an unconformity. The contact theoretically might be a décollement, but no direct data support such an interpretation.

On the basis of map width and constructed geologic cross sections, the Old Mill Branch is about 730 m thick in southern Fairfax County. This figure is almost certainly a maximum because of the problems of mapping in poorly exposed terrane and probably unrecognized deformation.

STATION HILLS PHYLLITE MEMBER

The Station Hills Phyllite Member is herein named for typical exposures at its type locality along the tracks of the Southern Railroad from a point about 350 m west of Station Hills, Fairfax 7½-minute quadrangle, Fairfax County, to a point about 900 m east of that village (pl. 1). The unit crops out in the core of the synform defined by the Popes Head Formation and can be traced from the northern exposure of that unit south of the Tysons Corner Coastal Plain outlier to the southwestern corner of the Fairfax 7½-minute quadrangle where it plunges out (pl. 1).

The phyllite is not nearly as well exposed as the metasiltstone of the Old Mill Branch , because most of its outcrop belt is on a drainage divide in an urbanized area. The unit is relatively well exposed, chiefly as saprolite, in and around the village of Fairfax Station, Fairfax 7½-minute quadrangle, in the type section of the formation, along Braddock Road between Ox and Roberts Roads, Fairfax 7½-minute quadrangle, and in an unnamed tributary to Accotink Creek north of Arlington Boulevard in the extreme northeast corner of the Fairfax 7½-minute quadrangle (pl. 1).

The unit consists of light-greenish-gray, dusky-yellow-weathering phyllite and lesser very fine grained metasiltstone. Locally, it is interbedded with fine-grained metasiltstone. Some chlorite-rich phyllite within the unit is possibly highly altered mafic metatuff. No felsic metatuff was recognized. The member is isoclinally folded and has a strong penetrative phyllitic cleavage subparallel to bedding. Both bedding and cleavage have been deformed by a later fold phase, but a second cleavage is seen only in a few exposures. This deformation makes the recognition of sedimentary features in this incompetent unit difficult. Pelitic beds are 2-12 cm thick. Many beds appear to have thin basal intervals that contain vaguely graded, very fine grained metasiltstone. There is some suggestion that the basal metasiltstone beds are laminated, but the strong subparallel cleavage makes this determination difficult. On the basis of these rather tenuous data, the Station Hills may be described as a turbidite showing the Bouma (1962) sequence T_{de}.

The typical mineral assemblage for the phyllite is muscovite-quartz-biotite-chlorite (-plagioclase-magnetite-epidote). Metasiltstone beds are identical with the underlying Old Mill Branch. Thin-section study shows that the long dimensions of all minerals, including recrystallized quartz, parallel the phyllitic cleavage.

The Station Hills Phyllite Member conformably overlies the Old Mill Branch Metasiltstone Member. The contact is gradational and is arbitrarily placed where more than 75 percent of the beds are pelitic phyllite. The top of the Station Hills is not exposed in Fairfax County; therefore, the unit's thickness is unknown. The unit appears to have a maximum thickness of about 300 m in Fairfax County.

ENVIRONMENT OF DEPOSITION

In a terrane like this, interpretation of a depositional environment for the Popes Head Formation is difficult. Some generalizations, however, can be made. The metasiltstone and phyllite are turbidites composed of mostly fine- to very fine grained quartz, a very mature terrigenous sediment, and appear to have been deposited in a large-scale fining-upward sequence. The Bouma (1962) sequences T_{bde} and T_{de} and very rare T_{cde} suggest that these rocks can be assigned to turbidite facies D (Mutti and Ricci Lucchi, 1978; Walker and Mutti, 1973) and that they are quite distal. The rocks were probably deposited from weak turbidity flows as evidenced by lack of current-produced flow marks, the apparent absence of Bouma a divisions and sparsity of Bouma c divisions, and the fine grain size.

Interbedded with these distal turbidites are felsic and mafic metatuff, both of which contain pristine euhedral igneous minerals that show no evidence of being water worn. These metatuffs probably are ash-fall deposits. The Popes Head, then, results from simultaneous sedimentation from two sources areas. The quartzose beds probably result from a longitudinal fill from a cratonal source, although our only direct evidence is the maturity and composition of the sediment. The metatuff probably was supplied by volcanoes, and this long, fairly narrow strike belt of rocks containing the volcanigenic material suggests the possibility of an island arc. We would like to suggest, then, that the Popes Head Formation resulted from the bilateral filling of a back-arc basin, as it seems to fulfill the criteria of Winn and Dott (1978). Petrochemistry has not been completed, so that aspect of the problem must be held in abeyance.

AGE AND CORRELATION

Like the Eastern Fairfax sequence, the age of the Popes Head Formation cannot be directly determined. It is younger than all the rock units in Fairfax County north and west of the Occoquan Granite batholith and is intruded by rocks of that batholith. The best and most easily reached exposure where the intrusive relations may be seen is on the north bank of a small stream tributary to Bull Run about 275 m north of Bull Run marina, Independent Hill 7½-minute quadrangle, Fairfax County (BR on pl. 1). The phyllitic cleavage in the Popes Head in this and other exposures is roughly parallel to foliation in the batholithic rocks, suggesting that they were deformed together, a suggestion supported by the map pattern of the contact (pl. 1). The minimum age of the Popes Head, then, is the age of the Occoquan Granite batholith, which has been determined radiometrically as Early Cambrian. The controversy as to the correctness of this age has been discussed in the treatment of the Eastern Fairfax sequence. Like that sequence of rocks, we will consider the Popes Head Formation to be Proterozoic Z and (or) Early Cambrian until such time that additional isotopic work proves otherwise.

It is as difficult to find correlatives of the Popes Head Formation as it is for the Eastern Fairfax sequence. One possible correlative is the Chopawamsic Formation, which crops out south and east of the Occoquan Granite batholith in the Quantico fold sequence (Drake and others, 1979). The Chopawamsic consists mainly of volcanic and volcaniclastic rocks but contains admixed and interbedded quartzose rocks of terrigenous origin and is, therefore, more or less an analogue of the Popes Head. Seiders and others (1975) consider it to be of Early Cambrian or Proterozoic Z age. Perhaps these two units have a lateral equivalency.

One problem with this speculation is that the Popes Head appears to be younger than the Sykesville Formation in field relations. Another problem is that we have never recognized an exotic fragment of Popes Head within the Sykesville. We have seen abundant exotic fragments identical with rocks of the Chopawamsic Formation within the Sykesville; therefore, the Chopawamsic must be older than at least part of the Sykesville. Southwick and others (1971) consider that the Sykesville and Chopawamsic are partial equivalents and grade laterally into one another, and Seiders and others (1975) have described Sykesville-like material interbedded with the Chopawamsic. Both are interpretations made to explain the distribution of rock types in a poorly exposed terrane. We believe that the data presented by the earlier workers can be explained as well, if not better, as a result of the presence of fragments, blocks, and slabs of Chopawamsic within Sykesville matrix. This interpretation is supported by the direct observation of Chopawamsic-like clasts in other outcrops. The relation of the Popes Head to the Chopawamsic awaits direct study somewhere in the area south of the Occoquan Granite batholith.

North of the Potomac River in Maryland, the Wissahickon terrane (Peters Creek Schist of our usage, Wissahickon Formation, or western sequence of Hopson (1964), is bounded on the west by the Ijamsville Phyllite (Hopson, 1964, Cleaves and others, 1968). The Ijamsville is an alumina-soda-iron-rich rock characterized by purple and green muscovite-paragonite-chloritoid phyllite. It closely resembles many of the rocks of the Taconic sequence of New York and New England (Zen, 1967) and probably results from starved sedimentation on the abyssal plain.

The Ijamsville is succeeded on the west by a sequence of lightly metamorphosed, immature sandstone, siltstone, quartzite, impure marble, and basalt. These rocks, the Urbana Phyllite of Cleaves and others (1968) or Harpers Phyllite of Hopson (1964) have all the features of shallow-water deposits and are thought, by Hopson (1964) at least, to be related to the Chilhowee Group of the Blue Ridge anticlinorium.

While doing a hurried reconnaissance in Montgomery and southern Frederick Counties, Md., to prepare a tectonic lithofacies map of the central Appalachians published in Williams (1978), we found rocks that closely resemble the Popes Head in the Urbana 7½-minute quadrangle along Interstate Route 270 about 2.9 km south of its intersection with Maryland Route 80. These outcrops are found within a terrane compiled as Urbana by Cleaves and others (1968), but the rocks do not resemble other exposures of Urbana that we have seen, nor do they resemble Hopson's (1964) description of this unit (his Harpers). About 1,600 m N. 35° E. from these exposures, in outcrops along Maryland Route 355, similar metasiltstone is interbedded with purple and green phyllite typical of the Ijamsville. Hopson (1964) mentioned laminated, even-bedded metasiltstone within the terrane he considers Ijamsville but did not describe them as turbidites.

If we might speculate on these sparse data, we would like to suggest that the Ijamsville and Popes Head are related. If this speculation is correct, the interbedded Popes Head-like siltstone and Ijamsville Phyllite would have been deposited at the margin of the longitudinally filled turbidite basin where mature quartzose sediment became intermingled with the starved sedimentary sequence of the abyssal plain.[1] This discussion shows that the far western Piedmont of Montgomery and immediately adjacent Frederick Counties is the critical area in which to determine the relation of these rocks.

RESULTS AND CONCLUSIONS

In this paper we have named and described three new stratigraphic units in the enigmatic Wissahickon terrane of the central Appalachian Piedmont and have speculated on their possible environments of deposition. Even if we are completely wrong in our speculations, we present data that clearly show that rocks of the Eastern Fairfax sequence differ greatly from those of the Popes Head Formation and that both units differ from the Peters Creek Schist in sedimentologic as well as in structural and metamorphic character (Drake and others, 1979; Drake and Morgan, in press). For these reasons, we believe that it is folly to continue using the concept of a Wissahickon Formation. In discussions of a regional nature, however, the term Wissahickon is useful because of its historical usage. We strongly suggest that the name Wissahickon be used to define a terrane rather than a stratigraphic unit except in the Philadelphia area.

One other important result has come from this work. The Popes Head Formation is unconformable above a terrane of polydeformed and polymetamorphosed rocks that includes a stack of at least three allochthons: the Sykesville Formation (if one considers, as we do, that a rock body emplaced by subaqueous sliding is an allochthon), the Potomac River allochthon (pl. 1; Drake and others, 1979; Drake and Morgan, in press), and the metamorphosed ophiolite fragment called the Piney Branch allochthon (Drake and others 1979; Drake and Morgan, in press). If the Popes Head is of Proterozoic Z and (or) Early Cambrian age, then a great deal of Proterozoic deformation and metamorphism probably took place before the formation of the turbidite basin in which it was deposited. Even if the Popes Head is younger and the pre-Popes Head deformation and metamorphism can be ascribed to an early Paleozoic orogeny, the rocks beneath the Popes Head had a complex and varied structural and metamorphic history before its deposition. This history suggests that the model for the tectonic development of the central Appalachian Piedmont as first cast by Hopson (1964) and refined by Fisher (1976) is greatly oversimplified.

[1]Since this was written, the Maryland outcrops described in the paragraph above were restudied. This restudy casts some doubt on the correlation of the metasiltstones in Maryland with the Popes Head Formation and, thereby, on this sedimentalogic interpretation.

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