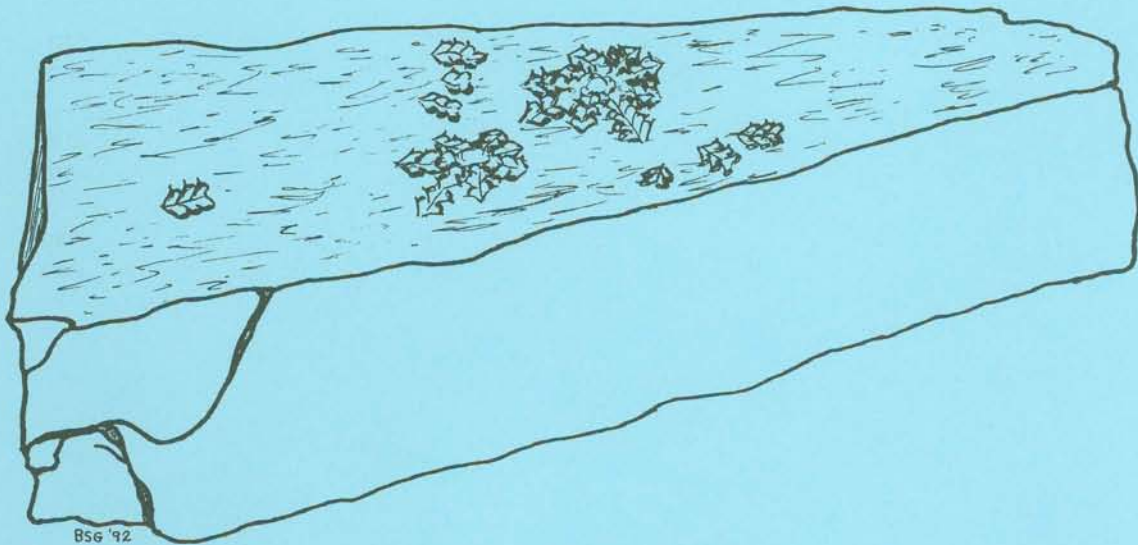




New Jersey Geological Survey
Geological Survey Report 28



**GRAPTOLITE BIOSTRATIGRAPHY OF THE
ORDOVICIAN MARTINSBURG FORMATION
IN NEW JERSEY AND CONTIGUOUS AREAS**



856 '92

STATE OF NEW JERSEY

Jim Florio, *Governor*

Department of Environmental Protection and Energy

Scott A. Weiner, *Commissioner*

Division of Science and Research

Robert K. Tucker, Ph.D., *Director*

Geological Survey

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Cover illustration: *Orthograptus ruedemanni*, a graptolite found in the Ramseyburg Member of the Martinsburg Formation. Idealized drawing by Barbara Smith Grandstaff, based on NJSM 12846 (see page 7).

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CONTENTS

	page
Abstract	1
Introduction	1
Acknowledgments	1
Collection methods	1
Previous studies	2
Martinsburg Formation	4
Geology	4
Biostratigraphy	5
Graptolite zones	5
Faunal site descriptions	5
Overview	13
Discussion	14
Conclusions	14
Bibliography	15
Glossary	inside back cover

Illustrations

Figure 1. Map of northwestern New Jersey and contiguous areas showing distribution of Martinsburg Formation and locations of fossil-collection sites	3
2. Geologic interpretations of the Lehigh River area of Pennsylvania; Martinsburg Formation and associated rocks	
A. Lithostratigraphy	6
B. Biostratigraphy (graptolite zones)	6

Tables

Table 1. Graptolite zonation of the Ordovician Martinsburg Formation	2
2. Faunal list for members of the Martinsburg Formation in the study area	13
3. Summary of graptolite correlations for members of the Martinsburg Formation	14

GRAPTOLITE BIOSTRATIGRAPHY OF THE ORDOVICIAN MARTINSBURG FORMATION IN NEW JERSEY AND CONTIGUOUS AREAS

ABSTRACT

Paleontological collections, including many new graptolite discoveries from northern New Jersey, eastern Pennsylvania, and southeastern New York, confirm that the Ordovician Martinsburg Formation consists of three members: in ascending order the Bushkill, Ramseyburg and Pen Argyl Members. The Bushkill and Pen Argyl Members are not equivalent in age as previously suggested by some authors. The Bushkill Member correlates with the *Climacograptus bicornis* to *Corynoides americanus* Zones. The Ramseyburg Member correlates with the interval represented by the *Orthograptus ruedemanni* Zone and the lowest part of the *Climacograptus spiniferus* Zone. The Pen Argyl Member correlates with the upper part of the *Climacograptus spiniferus* Zone.

INTRODUCTION

The subdivision of the Ordovician Martinsburg Formation in eastern Pennsylvania has been the subject of much debate (Drake and Epstein, 1967; Wright and others, 1979; Lash and others, 1984). A three-member division has been used by the U.S. Geological Survey in its mapping program. Some workers, however, believe that the upper member of the threefold division is the lower member repeated by folding and faulting, so that the Martinsburg contains only two members.

The objective of the present study was to obtain biostratigraphic data within the Martinsburg Formation and to evaluate its internal stratigraphy. Included in the study area are the type sections for all three members of the formation (Drake and Epstein, 1967). This paper presents biostratigraphic information from the Martinsburg Formation in New Jersey (Warren and Sussex Counties), Pennsylvania (Northampton County), and New York (Orange County). The study area has yielded fossils from all three stratigraphic units of the Martinsburg. This report also evaluates graptolite data collected by Wright and others (1979) in the area between Harrisburg and the Lehigh River in Pennsylvania.

Acknowledgments

This work was supported in part by a grant from the Eastern National Parks and Monuments Association as a project to evaluate resources of the Delaware Water Gap National Recreation Area.

The identification of graptolite specimens, especially partly deformed materials, required the efforts of a specialist. We are therefore very grateful to Dr. Stanley Finney (Oklahoma State University) for donating his services in these identifications. The advice of Dr. Jack B. Epstein was invaluable during early stages of the field work, and in a review of the manuscript. Dr. John Pojeta (U.S. Geological Survey) provided identifications of some fossil pelecypods. Dr. William B.

Gallagher (New Jersey State Museum) gave field assistance and helpful advice.

Volunteers and interns who assisted in the field and laboratory were Rachel Benton, Wayne Brewster, Gregory Chludzinski, Lawrence Conti, Fia Coscia, Cheryl Henry, Kenneth Langer, Abigail Miller, Louise Miller, Patrick Miller, and Charles Robbins. Several important sites were discovered by these volunteers and their dedicated efforts as amateur paleontologists deserve our grateful recognition.

Editorial reviews by Dr. Robert C. Ramsdell and I.G. Grossman are much appreciated. Allan Thomas, S. Donald Weeks, and Elsayed Aboyoussef, all of the New Jersey State Museum, assisted with preparation of figures and illustrations. We further acknowledge the kind cooperation of many property owners who allowed access to their lands. Their permission is, of course, a necessary prerequisite to any geological investigation, including fossil collecting.

COLLECTION METHODS

The Martinsburg Formation was searched for fossils from Plainfield Township, in Northampton County, Pennsylvania, to Greenville, in Orange County, New York. Generally, all roadcut, streamcut, and quarry exposures in New Jersey and selected exposures in Pennsylvania and New York were examined. In many promising exposures, a bulk sample was collected and searched under the binocular microscope in the laboratory. Samples of 100 kg were found to yield significant materials when thus processed, even though little or nothing was found in the field.

Collecting was hampered by the well developed slaty cleavage and the high degree of metamorphism. There is essentially no metamorphism at Harrisburg, Pennsylvania. The metamorphic grade increases to greenschist facies at the Pennsylvania-New Jersey border (Delaware

River), and reaches biotite grade at the Hudson River in New York (Drake 1970, p. 277).

Because many of the specimens are preserved as thin pyrite films, they weather easily and rarely were seen except on fresh surfaces. However, graptolites were found in beds that appear to have a higher pyrite content. In places these beds were stained and weathered differently from the rest of the outcrop.

PREVIOUS STUDIES

The Martinsburg Formation first was described by Geiger and Keith (1891), and named by Keith (1894) for exposures near Martinsburg, West Virginia (Drake and Epstein, 1967). The name was first used in New Jersey by Lewis and Kummel (1918) for the pelitic rocks lying between the Middle Ordovician Jacksonburg Formation and the Shawangunk Formation of Silurian age. The formation name is used for clastic rocks and their metamorphic equivalents of Middle and Upper Ordovician age from New York to Tennessee.

Early biostratigraphic work in the Ordovician System of New Jersey was by Stuart Weller (1903). Although Weller found little fossil material in the Martinsburg Formation, the Jutland area in Union and Clinton Townships, Hunterdon County (fig. 1) was one notable exception where well-preserved graptolites were found in abundance. The fauna of the Jutland area, (currently referred to as the Jutland Klippe) is described by Perissoratis and others (1979) and Parris and Cruikshank (1986). The youngest graptolites from the Jutland Klippe correspond to the *Nemagraptus gracilis* Zone of

Berry (1960, 1976). Rocks of the Jutland area are allochthonous, and represent an earlier phase of sedimentation prior to the deposition of the sediments called Martinsburg in more northerly areas of New Jersey (Lash and Drake, 1984; Lash and others, 1984). The rocks of the Jutland Klippe correlate with the Hamburg Klippe in central Pennsylvania and are not part of the Martinsburg Formation, although they are shown as such on the old New Jersey State Geologic map (Lewis and Kummel, 1918).

Outside the Jutland area, Weller (1903) described two other Ordovician faunas from Sussex County, New Jersey. In Sussex Boro, he reported a primarily shelly fauna, whereas he collected a graptolite fauna in Frankford Township (Weller, 1903, Locality 75B; locality 31 of this report). The fossils were sufficiently identifiable to confirm an Ordovician age. The specimens reported by Weller from Frankford Township were restudied by Ruedemann (1947), but no detailed age conclusions resulted.

Willard (1949) collected a shelly faunule in Stillwater Township, Sussex County, which he attributed to the Eden Stage (see table 1). The specimens apparently have been lost, but the exposure still exists, and has been reinvestigated as part of the present study (locality 21). Beerbower (1956) cited an occurrence of *Triarthrus beckii* Green (Lafayette College S-161-2) from a fine-grained sandstone within the Ramseyburg Member just below the unconformable contact with the overlying Shawangunk Formation, in a temporary exposure at the Delaware Water Gap. As the locality is no

Table 1. Graptolite zonation of the Ordovician Martinsburg Formation. Modified from Ross and Bergstrom (1982), Bergstrom and Mitchell (1989), and Finney (1986).

LITHOSTRATIGRAPHY (correlated to Riva zones)		BIOSTRATIGRAPHY		CHRONOSTRATIGRAPHY	
		Berry (1960, 1970, 1971)	Riva (1969, 1974)		
Martinsburg Formation	Pen Argyl Member	<i>Orthograptus quadrimicronatus</i>	<i>Climacograptus manitoulinesis</i>	<i>Climacograptus spiniferus</i>	Edenian
	Ramseyburg Member		<i>Climacograptus pygmaeus</i>		
	Bushkill Member	<i>Orthograptus amplexicaulus</i>	<i>Climacograptus spiniferus</i>	<i>Corynoides americanus</i>	Shermanian
<i>Orthograptus ruedemanni</i>			<i>Diplograptus multidentis</i>		
<i>Corynoides americanus</i>					
Jacksonburg Formation		<i>Climacograptus bicornis</i>		Kirkfieldian	

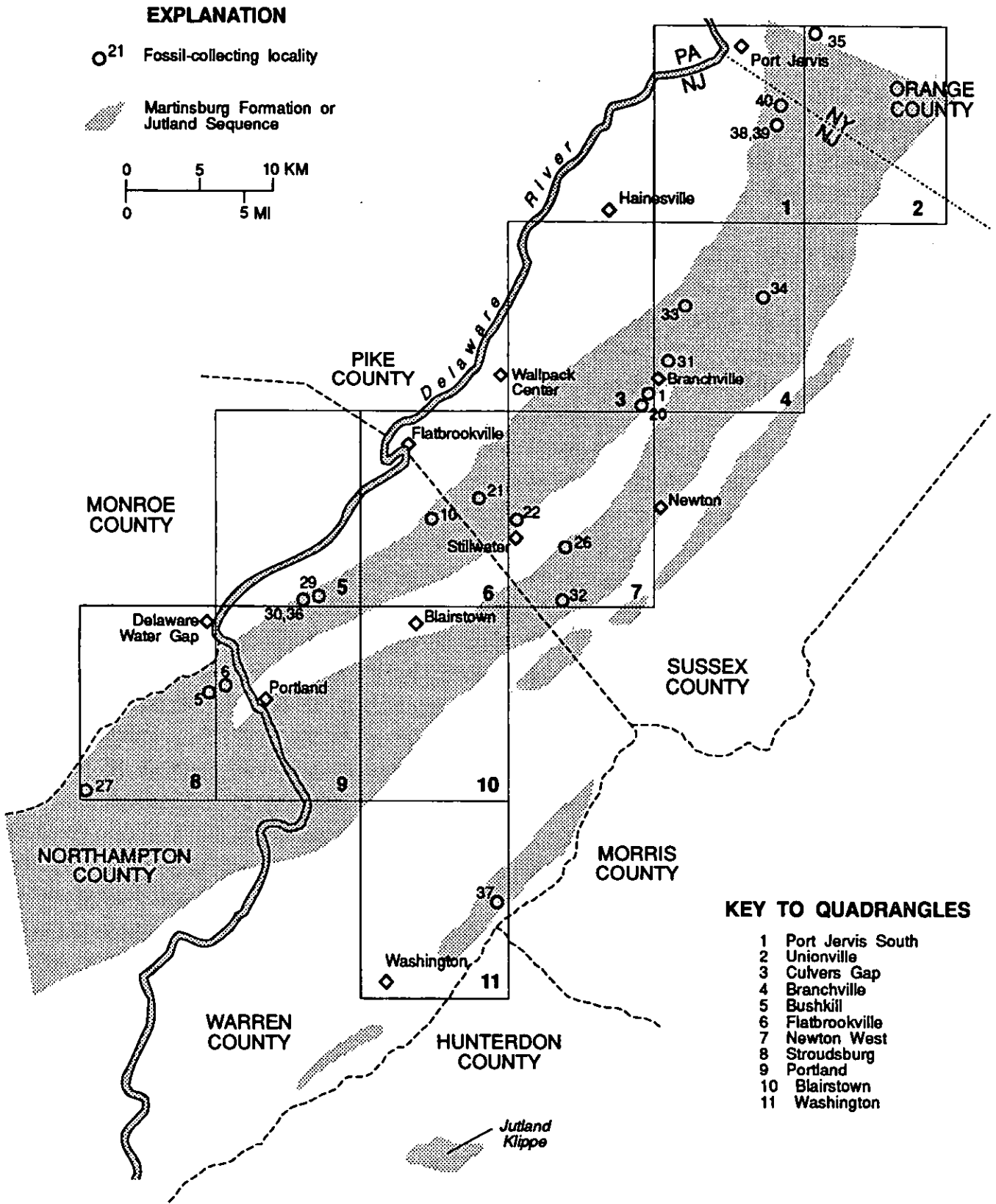


Figure 1. Map of northwestern New Jersey and contiguous areas showing distribution of Martinsburg Formation and locations of fossil-collection sites.

longer accessible, no further collecting was possible, although implications of the find were reconsidered. This is the same trilobite species that has been reported from the Martinsburg Formation at Swatara Gap in Pennsylvania (Wright and others 1977; Gerhart, 1983).

Berry (1971) described a graptolite fauna from the Martinsburg Formation in the Town of Greenville, Orange County, New York. The localities were apparently in the Ramseyburg Member (locality 35), and were as-

cribed to the *Climacograptus spiniferus* Subzone of the *Orthograptus truncatus intermedius* Zone (Berry, 1960, 1976).

Epstein and Berry (1973) collected a graptolite fauna from four localities at Lehigh Gap, Pennsylvania, in the Pen Argyl Member. The fauna from each locality contained 5 to 7 graptolite species, which correlated with the *Climacograptus spiniferus* Subzone of the *Orthograptus truncatus* var. *intermedius* Zone (Berry, 1970) (table 1).

MARTINSBURG FORMATION

GEOLOGY

Within the study area the Martinsburg Formation is currently divided into three members: the Bushkill Member, a basal shale/slate unit; the Ramseyburg Member, a middle graywacke-bearing unit; and the Pen Argyl Member, an upper shale/slate unit. A thorough description of these members, and a historical discussion of the stratigraphy, was provided by Drake and Epstein (1967). Work in progress by the U.S. Geological Survey includes description of an additional lithostratigraphic unit for the northern part of the area of investigation (Drake, in press).

Although there are good stratigraphic, petrologic and structural arguments for the current three-division Martinsburg Formation (Lash and others, 1984), some workers (Wright and others, 1979) believe that the Bushkill and Pen Argyl Members are the same unit repeated by folding and thrusting. Fossils, notably graptolites, occur in all current or proposed members of the Martinsburg Formation and provide a basis for determination of whether the members are sequential or repeated.

The two-member division was favored by Lesley (1892), Lewis and Kummel (1918), Willard (1943), Wright and Stephens (1978), Wright and others (1979), Stephens and Wright (1981), and Stephens and others (1982). The most significant recent biostratigraphic work in eastern Pennsylvania is that of Wright and others (1979).

The three-member division has been used by Behre (1933) and by Drake and Epstein (1967). All geologic mapping by the U.S. Geological Survey in eastern Pennsylvania and northwestern New Jersey since the work by Drake and Epstein (1967) has been based on the threefold division. Because of the sparse fossil record, the three-member division proposed by Drake and Epstein (1967) was the result of careful and detailed stratigraphic and structural mapping; they had few

biostratigraphic data. Where the Ramseyburg Member was seen in contact with the Pen Argyl Member, the Pen Argyl member overlies the Ramseyburg. Where the Pen Argyl appears to be overlain by the Ramseyburg Member, it can be shown that the beds are locally overturned.

Wright and others (1979) based their two-member interpretation on fossil collections made in the area west of the Lehigh River (fig. 2b). Biostratigraphic work farther to the southwest is reported in Aldrich (1965) and Stephens and Wright (1981), but is not discussed here because the three-member division of the Martinsburg Formation extends southwestward only as far as Harrisburg, Pennsylvania.

The faunal collections of Wright and others (1979) correlated the Bushkill Member with the *Diplograptus multidentis* to *Orthograptus ruedemanni* Zones of Riva (1969, 1974). Collections from the Shochary Ridge, a sandstone unit now designated the Shochary Sandstone and the New Tripoli Formation by the U.S. Geological Survey (Lyttle and others, 1986), correlated with the *Orthograptus ruedemanni* to *Climacograptus spiniferus* Zones. The Shochary Ridge sandstone was considered equivalent to the Ramseyburg Member by Wright and others (1979). Rocks which these authors interpreted to be the Pen Argyl Member (for them, synonymous with the Bushkill Member) correlated with the *Climacograptus spiniferus* Zone near the unconformable contact with the Silurian Shawangunk Formation, and with the *Orthograptus ruedemanni* Zone near Shochary Ridge. Lash and others (1984) cited studies made in New England suggesting that graptolites may be susceptible to facies control (Cisne and Chandlee, 1982), and argued that the reason the graptolite data of Wright and others (1979) did not agree with the three-member division was that, because of facies control, their correlations were unreliable. One would expect that if facies control were important, there would be little regularity to the data collected by Wright and others (1979). However their data appear to be regular, even if

their interpreted zone distributions cross lithologic boundaries (fig. 2).

With the map of localities from Wright and others (1979, fig. 2), and the lithostratigraphy from the U.S. Geological Survey mapping program (Lash 1982, 1985; Lyttle and others, 1986) as a basis, the correlations given by Wright and others (1979) agree closely with those of this study. In the area on the east side of the Lehigh River, where Wright and others reported fossils of *Orthograptus ruedemanni* age from the Pen Argyl Member (Bushkill Member of their report), there still appears to be a problem. Their data cannot be evaluated here because they gave no faunal lists for each site.

Shochary ridge is interpreted as a syncline (Wright and others, 1979; Lyttle and Drake, 1979; Lyttle and others, 1986). However Stephens and Wright (1981) and Wright and others (1979) did not recognize that the syncline is bounded on the north and south by faults (Lyttle and Drake, 1979; Lyttle and others, 1986) (fig. 2a), and interpreted the area to conform to a two-member subdivision. Wright and others (1979) did not recognize an inlier of the Bushkill Member exposed on the north side of Shochary Ridge (fig. 2). The inlier appears to be the source of the graptolites of Bushkill age in what Wright and others (1979) interpreted as the Pen Argyl Member.

Regardless of the interpretation of the structure and lithostratigraphy by Wright and others (1979), their faunal data base is excellent. Based on the structural inter-

pretation of the area by Lyttle and others (1986), the biostratigraphic data apparently agree with a three-member division of the Martinsburg formation followed in this report, with the exception of the previously noted area to the east of the Lehigh river (fig. 2).

BIOSTRATIGRAPHY

Graptolite Zones

There are two graptolite zonations currently in use for eastern North America: those of Berry (1960, 1976) and Riva (1969, 1974). These two schemes differ somewhat in theoretical approach. Preference for one or the other generally is determined by one's structural and stratigraphic interpretation of the Ordovician System in the eastern United States. The theoretical differences and debated points are well summarized by Finney (1982).

Correlations are given here (table 1) according to both zonations, following the published correlation chart of Ross and Bergstrom (1982) wherever possible.

Faunal Site Descriptions

Location and faunal lists are given below for each site at which graptolites have been collected, with a discussion on the correlation of each locality. Some localities contain only shelly fauna, others only graptolites, and several have both. Numbers for the specimens listed, unless otherwise stated, are New Jersey State Museum (NJSM) accession numbers for the geological collections. This material is available for inspection upon request.

Locality 1 Martinsburg Formation Bushkill Member

Location: West side of State Highway 206 at milepost 117, approximately 1 kilometer north of junction with County Route 519 in Branchville Boro, Sussex County, New Jersey (Culvers Gap 7 1/2' quadrangle).

Fauna:	<i>Cryptolithus tessellatus</i> Green	12554
	<i>Plectorthis</i> sp.	12555
	<i>Climacograptus</i> sp.	12678

Correlation: *Cryptolithus tessellatus*, long considered to be characteristic of the traditional Trenton faunas, is significant. It is designated as Morphotype A of Lesperance and Bertrand (1976). The species also has been recorded from the Jacksonburg Formation which underlies the Bushkill Member (NJSM 6260). Much of the Jacksonburg Formation in this area, along with the Bushkill Member of the Martinsburg Formation, also is assigned to the Shermanian Stage, but its graptolite facies equivalents cannot be determined. The *Climacograptus bicornis* Zone is the most likely equivalent for locality 1.

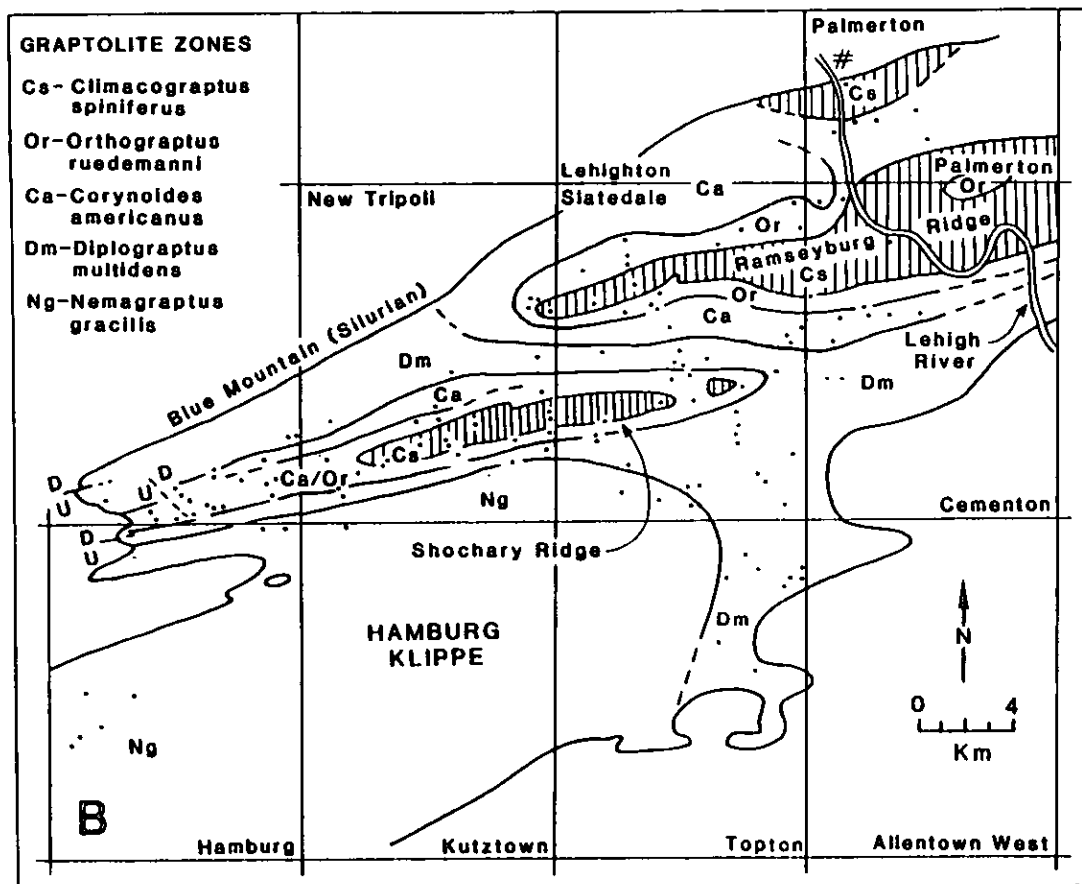
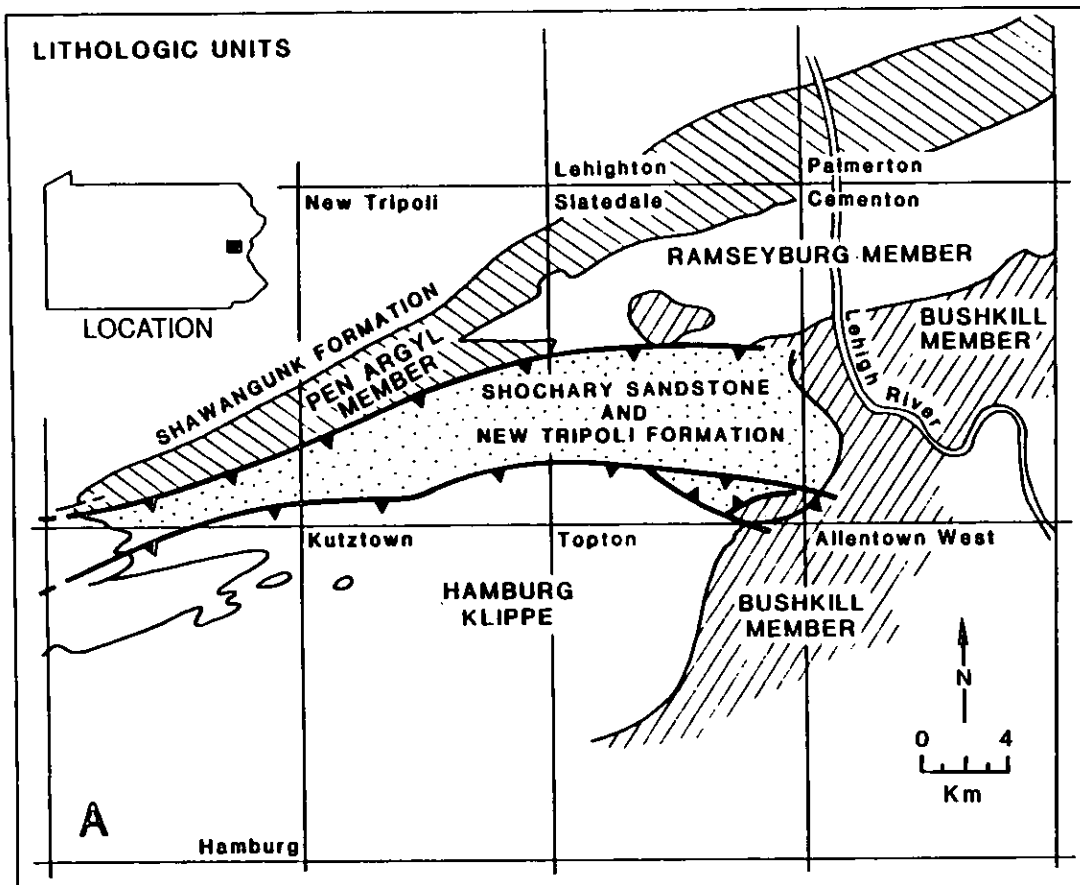


Figure 2. Geologic interpretation of the Lehigh River area of Pennsylvania; Martinsburg Formation and associated rocks. A. Lithostratigraphy (modified from Wright and others, 1979 and Lash and others, 1984). B. Biostratigraphy (graptolite zones, modified from Wright and others, 1979).

Locality 5
Martinsburg Formation
Ramseyburg Member

Location: In the bed of Slateford Creek, approximately 1 kilometer upstream from its intersection with State Highway 611, and 100 meters downstream from a small dam, Upper Mount Bethel Township, Northampton County, Pennsylvania (Stroudsburg 7 1/2' quadrangle).

Fauna:	<i>Orthograptus ruedemanni</i> (Gurley)	12846					
	<i>Orthograptus</i> cf. <i>O. ruedemanni</i>	12630	12772	12801	12802	12803	12845
		12919	12920				
	<i>Orthograptus</i> sp.	12651	12652	12653	12657		

Correlation: *Orthograptus ruedemanni* Zone.

Locality 6
Martinsburg Formation
Bushkill Member

Location: Old quarry in streambed on west side of State Highway 611, approximately 1 kilometer south of the intersection of Slateford Creek and the highway. Upper Mount Bethel Township, Northampton County, Pennsylvania. Quarry #28 of Epstein (1970) (Portland 7 1/2' quadrangle).

Fauna:	<i>Orthograptus</i> sp.	10853	12623	12624	12625 (in part)
	<i>Glyptograptus</i> sp.	12625 (in part)			

Correlation: Uncertain, perhaps within the *Corynoides americanus* Zone. Compare to locality 20.

Locality 10
Martinsburg Formation
Ramseyburg Member

Location: Old quarry on west side of the Millbrook-Blairstown Road, approximately 3.2 kilometers south of Millbrook, Hardwick Township, Warren County, New Jersey. (Flatbrookville 7 1/2' quadrangle).

Fauna:	<i>Cryptolithus lorettensis</i> Foerste	12714
	<i>Crinoidea</i> (columnals)	11257
	<i>Brachiopoda</i> , indeterminate	14472

Correlation: The *Cryptolithus* specimens, which are an assemblage within Morphotype C (Morphotype Association, III.1) of Lesperance and Bertrand (1976), are of notably small size. The correlation is similar to that of the Swatara Gap fauna (*Climacograptus spiniferus* Zone of the graptolite facies).

Locality 20
Martinsburg Formation
Bushkill Member

Location: Road exposure and small quarry on south side of Morris Avenue, approximately 1 kilometer northeast of its intersection with Sussex County Route 655 (Morris Turnpike) and 0.7 kilometer south of United States Highway 206, in Frankford Township, Sussex County, New Jersey (Culvers Gap 7 1/2' quadrangle).

Fauna:	<i>Glyptograptus</i> sp.	12581		
	<i>Climacograptus</i> sp.	12584	12585	12663
	<i>Diplograptus</i> cf. <i>D. multidentis</i>	12659	12660	
	Elles and Wood			

<i>Orthograptus</i> or <i>Glyptograptus</i> sp.	12661	12662	12665
<i>Prolobella corrugata</i> Ruedemann	12629	12664	

Correlation: Correlation with the lower part of the *Diplograptus multidentis* Zone of Riva (1969, 1974) appears likely.

Locality 21
Martinsburg Formation
Ramseyburg Member

Location: Exposure in bank above Flatbrookville-Stillwater Road, just uphill from a sharp bend in the road at the 1080 foot contour, on southeast side of Kittatinny Mountain. Locality previously published by Willard (1949). Stillwater Township, Sussex County, New Jersey. (Flatbrookville 7 1/2' quadrangle).

Fauna:	<i>Brachiopoda</i> , cf. <i>Sowerbyella</i>	14473
	<i>Brachiopoda</i> , cf. <i>Resserella</i>	14474
	<i>Crinoidea</i> (columnals)	14475

Taxa listed by Willard (1949) were cited as:

- Crinoidea* (columnals)
- Cornulites* sp.
- Dinorthis* sp.
- Sowerbyella rugosa* (Meek)
- Resserella multisecta* (Meek)
- Cryptolithus bellulus* (Ulrich)

The repository of Willard's specimens is unknown.

Correlation: Although no *Cryptolithus* specimens have been found at the site in recent years, Willard's (1949) identification may be tentatively accepted, although it is uncertain whether his specimens would be considered *C. bellulus* by current standards. The specimens from Swatara Gap, now regarded as *C. lorettensis*, were considered by some authorities to be *C. bellulus* (Whittington, 1968; Epstein and others, 1972). The fauna probably resembled that of locality 10, correlated with the Swatara Gap fauna and with the *Climacograptus spiniferus* Zone of graptolite facies.

Locality 22
Martinsburg Formation
Bushkill Member

Location: Embankment on west side of road just north of the intersections of County Routes 521 and 612 in Middleville, Stillwater Township, Sussex County, New Jersey (Newton West 7 1/2' quadrangle).

Fauna:	<i>Glyptograptus euglyphus</i> Lapworth	12586	12591	12592	12599	12604
		12612	12613	12744	12745	
	<i>Nautiloidea</i>	12590	12596	12563		
	<i>Prolobella corrugata</i> Ruedemann	12614	12753			
	<i>Murchisonia</i> sp.	12595				
	<i>Plectrothis</i> sp.	12589				
	<i>Gastropoda</i>	12684				
	cf. <i>Cornulites</i> sp.	12791				
	<i>Brachiopoda</i>	12747				
	<i>Pelecypoda</i>	12749				
	<i>Crinoidea</i>	12748				

Correlation: *Glyptograptus euglyphus* ranges from the *Glyptograptus teretiusculus* Zone up to high in the *Climacograptus bicornis* Zone, up to approximately the *Diplograptus multidentis* zone of Riva, (Stanley Finney, Oklahoma State University, written communication, 1985). The shelly forms are similar, if not completely identical, to species from the Jacksonburg Formation, which underlies the Martinsburg Formation at locality 22 by less than ten meters. It appears likely that this important fauna belongs to the *C. bicornis* Zone of Berry and is only slightly younger than the youngest of the graptolite localities of the Jutland Klippe to the south. It is probably the oldest fauna from the Martinsburg Formation in the area of study and is particularly important because it has a shelly fauna as well as abundant graptolites.

Locality 26
Martinsburg Formation
Bushkill Member

Location: Road cut on west side of Sussex County Route 610, 1 kilometer southeast of milepost 3, at junction with Verdone Road, 0.7 kilometer northwest of State Route 94, Fredon Township, Sussex County, New Jersey (Newton West 7 1/2' quadrangle).

Fauna: *Orthograptus* sp. 12628

Correlation: Uncertain, only one specimen is known from the locality. Even one graptolite is unusual, as the lower Martinsburg Formation is atypically very calcareous at this exposure.

Locality 27
Martinsburg Formation
Pen Argyl Member

Location: Gully in the northwest corner of the Bangor Fidelity Quarry, Plainfield Township, Northampton County, Pennsylvania (Stroudsburg 7 1/2' quadrangle).

Fauna: *Climacograptus spiniferus* Ruedemann 12637 12638 12848
Climacograptus cf. *C. spiniferus* 12633 12688 12697
Orthograptus sp. 12636 12686 12689 12694

Correlation: This fauna contains abundant graptolites, but deformation has rendered most of the specimens unidentifiable. It is an especially important fauna, however, since it is the only one from the Pen Argyl Member within the area considered here. It is the northeasternmost fauna ever reported from the member, occurring near the limit of exposure of the lithostratigraphic unit. It seems to correlate with the *Climacograptus spiniferus* Zone and is probably assignable to the Shermanian Stage.

Locality 29
Martinsburg Formation
Ramseyburg Member

Location: Road cut on south side of the road which ascends to the upper reservoir of the Yards Creek Pumped Storage Project, at the level of the 1180-foot contour, Blairstown Township, Warren County, New Jersey (Bushkill 7 1/2' quadrangle).

Fauna: *Trilobita*, indeterminate 12675
Crinoidea, indeterminate 12674

Correlation: Uncertain

Locality 30
Martinsburg Formation
Ramseyburg Member

Location: Outcrops on north side of pipeline of the Yards Creek Pumped Storage Project, at level of the fourth con-

crete foundation west of the picnic parking area, Blairstown Township, Warren County, New Jersey (Bushkill 7 1/2' quadrangle)

Fauna: *Orthograptus quadrimucronatus* (Hall) 12672 12779 12792 12795 12797
Orthograptus calcaratus (Lapworth) 12673
Orthograptus sp. 12669 12670 12671 12776 12777 12778

Correlation: The species are long-ranging forms which of themselves do not provide very specific age information. However, *O. quadrimucronatus* does not occur in beds as old as the youngest known occurrences of *Glyptograptus euglyphus* (Stanley Finney, Oklahoma State University, written communication, 1985) which confirms that this is a younger assemblage than that of locality 22. It may be tentatively correlated with the *Orthograptus ruedemanni* Zone on the basis of stratigraphic placement and faunal consistency with locality 5, which is also in the Ramseyburg Member.

Locality 31
Martinsburg Formation
Bushkill Member

Location: Abandoned quarry near the top of hill about 1 kilometer northeast of Branchville, New Jersey at 870-foot contour (Branchville 7 1/2' quadrangle). Access is from Fox Hill Road, in Frankford Township, Sussex County, New Jersey. Locality previously published by Weller (1903) as his locality 75B.

Fauna: *Glyptograptus* sp. 12667

The fauna cited by Weller (1903) includes the following species:

Diplograptus foliaceus (Murchison)
D. angustifolius (Hall)
Lasiograptus mucronatus (Hall)
Corynoides calicularis Nicholson
Dalmanella testudinaria Dalman

In addition, the following specimens (which probably came from Weller's original collections) are deposited at the New Jersey State Museum:

Diplograptus (Lasiograptus) cf. eucharis 10757
Dicellograptus smithi 10760

Weller's specimens were restudied by Ruedemann (1947), who had made the original identifications. The faunal list included specimens from the Jutland Klippe as well as from this locality, thus it is difficult to determine which specimens came from each area. It also is difficult to interpret the fauna as given by Weller and Ruedemann without re-examination of the original specimens. Unfortunately, the specimens cannot be located.

Here are details of this fauna:

It is unclear what Ruedemann meant by *Diplograptus foliaceus* and *D. angustifolius* (see Ruedemann, 1947). *Lasiograptus mucronatus* (Hall) would currently be considered *Hallograptus mucronatus* (Hall), said by Riva (1974) to be characteristic of his *Diplograptus multidentis* Zone. *Corynoides calicularis* (*calicularis*) ranges from the *Nemograptus gracilis* to the *Corynoides americanus* Zone; it is particularly characteristic of the *Diplograptus multidentis* and *Corynoides americanus* Zones. *Lasiograptus eucharis* was said by Ruedemann (1947) to have a wide stratigraphic range. *Dicellograptus* is not found in any sites younger than the *Diplograptus multidentis* Zone of Riva.

Correlation: The most reasonable correlation, based on all the information, is an age equivalent to the *D. multidentis* Zone of Riva. It appears that the original collections were mishandled to some extent, and confusion will result from any examination or restudy of any materials alleged to have come from this locality. New collections should be made, and no correlation is proposed until that is done.

Locality 32
Martinsburg Formation
Bushkill Member

Location: Road cut on south side of Fredon-Greendell Road (Sussex County Route 608) about 0.2 kilometer northwest of intersection with Wintermute Road (Sussex County Route 519), Fredon Township, Sussex County, New Jersey (Newton West 7 1/2' quadrangle).

Fauna: cf. *Orthograptus* sp. 12685

Correlation: Uncertain, fauna inadequate for determination.

Locality 33
Martinsburg Formation
Ramseyburg Member

Location: West side of Mattison Avenue, 0.3 kilometer south of intersection with Dennis Phillips Road (turn in Mattison Avenue roadway) and near Branchville Reservoir, Frankford Township, Sussex County, New Jersey (Branchville 7 1/2' quadrangle).

Fauna: *Orthograptus* sp. (possibly *O. amplexicaulus* or *O. calcaratus*) 12774 12918

Correlation: Uncertain, fauna insufficient for determination.

Locality 34
Martinsburg Formation
Ramseyburg Member

Location: Road cut on south side of Sussex County Route 628 about 0.3 kilometer east of the eastern end of Berry Road and west of the junction with Sussex County Route 635, Wantage Township, Sussex County, New Jersey (Branchville 7 1/2' quadrangle).

Fauna: *Brachiopoda*, indeterminate, and *Crinoidea*, indeterminate 14476

Correlation: Uncertain, fauna insufficient for determination.

Locality 35
Martinsburg Formation
Ramseyburg Member

Location: Median divider of road cut for Interstate Highway 84, about 4 kilometers east of Port Jarvis and 1 kilometer east of the rest area in westbound lanes near the Kittatinny Mountain summit in Greenville Township, Orange County, New York (Unionville 7 1/2' quadrangle). The lithologic unit informally has been designated as the "sandstone at Pine Bush" (Epstein and Lytle, 1987).

Fauna: *Brachiopoda*, indeterminate 12771
Promopaleaster sp. 12770

This fauna was found about 50 meters below the contact with the Shawangunk Formation. A previously published fauna (Berry, 1971) was from approximately 30-60 meters below the Shawangunk Formation in the same locality. The fauna reported by Berry (1971) contained the following species:

Climacograptus spiniferus Ruedemann

Climacograptus typicalis Hall

Dicranograptus ramosus Hall

Orthograptus quadrimucronatus var. *approximatus* (Ruedemann)

Correlation: The graptolites are indicative of the *Climacograptus spiniferus* Zone and the shelly fauna probably also falls within that Zone. The asteroid genus *Promopaleaster* also occurs at Swatara Gap, Pennsylvania, which also correlates with the *Climacograptus spiniferus* Zone (Wright and others, 1977).

Locality 36
Martinsburg Formation
Ramseyburg Member

Location: South side of Yards Creek Pumped Storage Project pipeline at fourth concrete foundation north of north-west corner of the picnic parking area Blairstown Township, Warren County, New Jersey (Bushkill 7 1/2' quadrangle).

Fauna: *Orthograptus cf. quadrimucronatus* (Hall) 12800
Orthograptus sp. 12799

Correlation: The bed may be identical with that at locality 30, which is on the opposite side of the pipeline. The fauna and preservation at both localities are consistent. Tentatively, it may be considered a probable correlative of the *Orthograptus ruedemanni* Zone.

Locality 37
Martinsburg Formation
Bushkill Member

Location: Old quarry just south of Washburn Road near creek crossing and railroad tracks, and along a farm road, Mansfield Township, Warren County, New Jersey (Washington 7 1/2' quadrangle)

Fauna: *Plectorthis plicatella* (Hall) 14477

Correlation: This is the only faunal locality thus far reported from one of the Martinsburg Formation outliers occurring between the main body of outcrops and the Jutland Klippe. The abundant fauna consists essentially of one species, which also is found in the underlying Jacksonburg Formation. This would be consistent with a low position in the section and a relatively early age.

Locality 38
Martinsburg Formation
Ramseyburg Member

Location: East side of Mountain Road (Sussex County Route 519), just south of Glen Road intersection, Wantage Township, Sussex County, New Jersey (Port Jervis South 7 1/2' quadrangle).

Fauna: *Brachiopoda*, indeterminate 14478
Crinoidea, indeterminate 14479

Correlation: Uncertain; fauna insufficient for determination.

Locality 39
Martinsburg Formation
Ramseyburg Member

Location: North side of Glen Road, at topographic high point about midway along the road, Wantage Township, Sussex County, New Jersey (Port Jervis South 7 1/2' quadrangle).

Fauna: *Brachiopoda*, indeterminate 14480
Crinoidea, indeterminate 14481

Correlation: Uncertain; fauna insufficient for determination.

Locality 40
Martinsburg Formation
Ramseyburg Member

Location: West side of Sussex County Route 519, (possibly a quarry) about 0.4 kilometer south of New York State border in Wantage Township, Sussex County, New Jersey (Port Jervis South 7 1/2' quadrangle).

The lithologic unit may be the "sandstone at Pine Bush", informally designated by Epstein and Lyttle (1987).

Fauna: *Orthograptus quadrimucronatus* (Hall) 13838 13839 13840

Correlation: The fauna is similar to that of locality 30 and the stratigraphic position is similar. The tentative correlation is with the *Orthograptus ruedemanni* Zone.

OVERVIEW

The new faunal collections from the Martinsburg indicate that the three Martinsburg members correlate with four graptolite zones of Riva (1969; 1974). In ascending order, these four are: *Diplograptus multidens*, *Corynoides americanus*, *Orthograptus ruedemanni*, and *Climacograptus spiniferus*. An alternative correlation is with the *Climacograptus bicornis* and *Orthograptus truncatus* var. *intermedius* Zones of Berry (1960, 1970) (table 1). The *Orthograptus truncatus* var. *intermedius* Zone is now designated the *O. amplexicaulus* Zone (Finney, 1986). This is the same age range as determined by Wright and others (1979), although, as previously indicated, the stratigraphic subdivision differs from theirs. The four zones of Riva are interpreted by him to represent a longer interval than is represented by the zones of Berry (Ross and Bergstrom, 1982).

A composite faunal list for each member of the Martinsburg Formation is given in table 2. Table 3 shows graptolite correlations for Martinsburg localities.

Table 2. Composite faunal list for members of the Martinsburg Formation in the study area. (Complete faunal lists for each locality are given in the text.)

GRAPTOLITE FAUNA		
BUSHKILL MEMBER	RAMSEYBURG MEMBER	PEN ARGYL MEMBER
<i>Diplograptus foliaceus</i>	<i>Climacograptus spiniferus</i>	<i>C. spiniferus</i>
<i>D. angustifolius</i>	<i>C. typicalis</i>	<i>Orthograptus</i> sp.
<i>D. cf. D. multidens</i>	<i>Dicranograptus ramosus</i>	
<i>Dicellograptus smithi</i>	<i>Orthograptus quadrimucronatus</i>	
<i>Glyptograptus euglyphus</i>	<i>O. quadrimucronatus</i> var. <i>approximatus</i>	
<i>Corynoides calicularis</i>	<i>O. calcaratus</i>	
<i>Climacograptus</i> sp.	<i>O. ruedemanni</i>	
<i>Glyptograptus</i> sp.	cf. <i>O. amplexicaulis</i> , <i>O. calcaratus</i>	
<i>Lasiograptus mucronatus</i>		
<i>L. cf. eucharis</i>		
<i>Orthograptus</i> sp.		
SHELLY FAUNA		
<i>Cryptolithus tessellatus</i>	<i>Cryptolithus bellulus</i>	None found
<i>Dalmanella testudinaria</i>	<i>C. lorettensis</i>	
<i>Plectorthis</i> sp.	<i>Dinorthis</i> sp.	
<i>Murchisonia</i> sp.	<i>Sowerbyella rugosa</i>	
cf. <i>Cornulites</i> sp.	<i>Resserella multisecta</i>	
<i>Prolobella corrugata</i>	<i>Promopaleaster</i> sp.	
<i>Nautiloidea</i>	<i>Crinoidea</i>	
<i>Gastropoda</i>	<i>Cornulites</i> sp.	

DISCUSSION

Structural complexity and discontinuity of outcrops are major obstacles to stratigraphic work in this area. However, although the stratigraphic position of individual exposures can rarely be established with certainty, all outcrops of the three members of the Martinsburg are faunally distinctive within the study area (table 3).

The Bushkill Member consistently correlates with the *Climacograptus bicornis* to *Corynoides americanus* Zones.

The Ramseyburg Member correlates with the *Orthograptus ruedemanni* Zone to the lowermost part of the *Climacograptus spiniferus* Zone.

The Pen Argyl Member correlates with the upper part of the *Climacograptus spiniferus* Zone.

Although resolution is inadequate to indicate that the Pen Argyl is significantly younger than the Ramseyburg member, it is demonstrably younger than the Bushkill Member. Thus, the Bushkill and Pen Argyl Members are of different ages and are not equivalent units.

The paleontologic data of Wright and others (1979) agree with the data collected for this study, except for those from some sites in the Pen Argyl Member east of

the Lehigh River (fig. 2), if the structure and stratigraphy of Lyttle and others (1986) are accepted.

Wright and others (1977) reported an extensive shelly and graptolite fauna from the Martinsburg Formation at Swatara Gap, in central Pennsylvania. The assemblage correlates with the lower *Climacograptus spiniferus* Zone of Riva (1974). Its faunal composition suggests that it correlates with the Ramseyburg Member of eastern Pennsylvania.

Age determination for the Pen Argyl Member in this study agrees with that established for a fauna collected at Lehigh Gap, Pennsylvania (Epstein and Berry, 1973). The fauna at Lehigh Gap is more extensive than that collected at Plainfield Township (27), and was determined to correlate with the upper *Climacograptus spiniferus* Subzone of the *Orthograptus truncatus* var. *intermedius* Zone of Berry (1960).

Further collecting, using the methods of bulk sampling and microscopic examinations, should yield even more faunal localities. It is planned to continue paleontological investigations in the Delaware Water Gap region and others are encouraged to do likewise.

Table 3. Summary of graptolite correlations for Martinsburg localities; faunal lists for each locality are given in the text.

Locality	Member	Graptolite Zone
27	Pen Argyl	<i>Climacograptus spiniferus</i>
5	Ramseyburg	<i>Orthograptus ruedemanni</i>
10	Ramseyburg	<i>Climacograptus spiniferus</i>
21	Ramseyburg	<i>Climacograptus spiniferus</i>
30	Ramseyburg	<i>Orthograptus ruedemanni</i>
35	Ramseyburg	<i>Climacograptus spiniferus</i>
40	Ramseyburg	<i>Orthograptus ruedemanni</i>
1	Bushkill	<i>Climacograptus bicornis</i>
6	Bushkill	<i>Corynoides americanus</i>
20	Bushkill	<i>Corynoides americanus</i>
22	Bushkill	<i>Climacograptus bicornis</i>

CONCLUSIONS

Sufficient biostratigraphic data now exist for evaluation of the three-member division of the Martinsburg Formation currently followed by the U.S. Geological Survey (Drake and Epstein, 1967). The data demonstrate that the three-member division is valid. They also show that both the Pen Argyl (upper *Climacograptus spiniferus* Zone) and the Ramseyburg Member (*Orthograptus ruedemanni* to lower *C. spiniferus* Zone) are younger than the Bushkill (*Climacograptus bicornis* to *Diplograptus multidentis* Zone) Member (table 2). The

data are inadequate to enable placement of an upper age limit on the Pen Argyl Member.

The results from this investigation agree well with published works of Epstein and Berry (1973) and Wright and others (1977). The new age data agree with those of Wright and others (1979) although the resulting stratigraphic interpretation does not. The structural and stratigraphic interpretations agree with those of Lyttle and others (1986).

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GLOSSARY

Allochthonous - Transported from position and area of origin; lying outside the area of original deposition.

Biostratigraphy - stratigraphy based on ranges and assemblages of fossils (Units: zone, subzone).

Chronostratigraphy - stratigraphy based on time and sequence (Units: system, series, stage).

Cf. (confer) - compare, as to a named taxon.

Faunule - a minor assemblage of associated fossil taxa, especially if characteristic of a locality.

Graywacke - coarse-grained sandstone with a predomi-

nantly detrital matrix (no chemical cement) and significant feldspar and/or lithic fragments.

Klippe - isolated remnant of allochthonous rocks.

Lithostratigraphy - stratigraphy based on rock units correlated by composition and texture (units: group, formation, member)

Pelitic - composed of metamorphosed fine-grained sediments.

Taxon (plural, taxa) - A category of biological classification, such as a species, genus, family, order, or class.

**GRAPTOLITE BIOSTRATIGRAPHY OF THE ORDOVICIAN MARTINSBURG FORMATION IN NEW JERSEY AND CONTIGUOUS AREAS
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