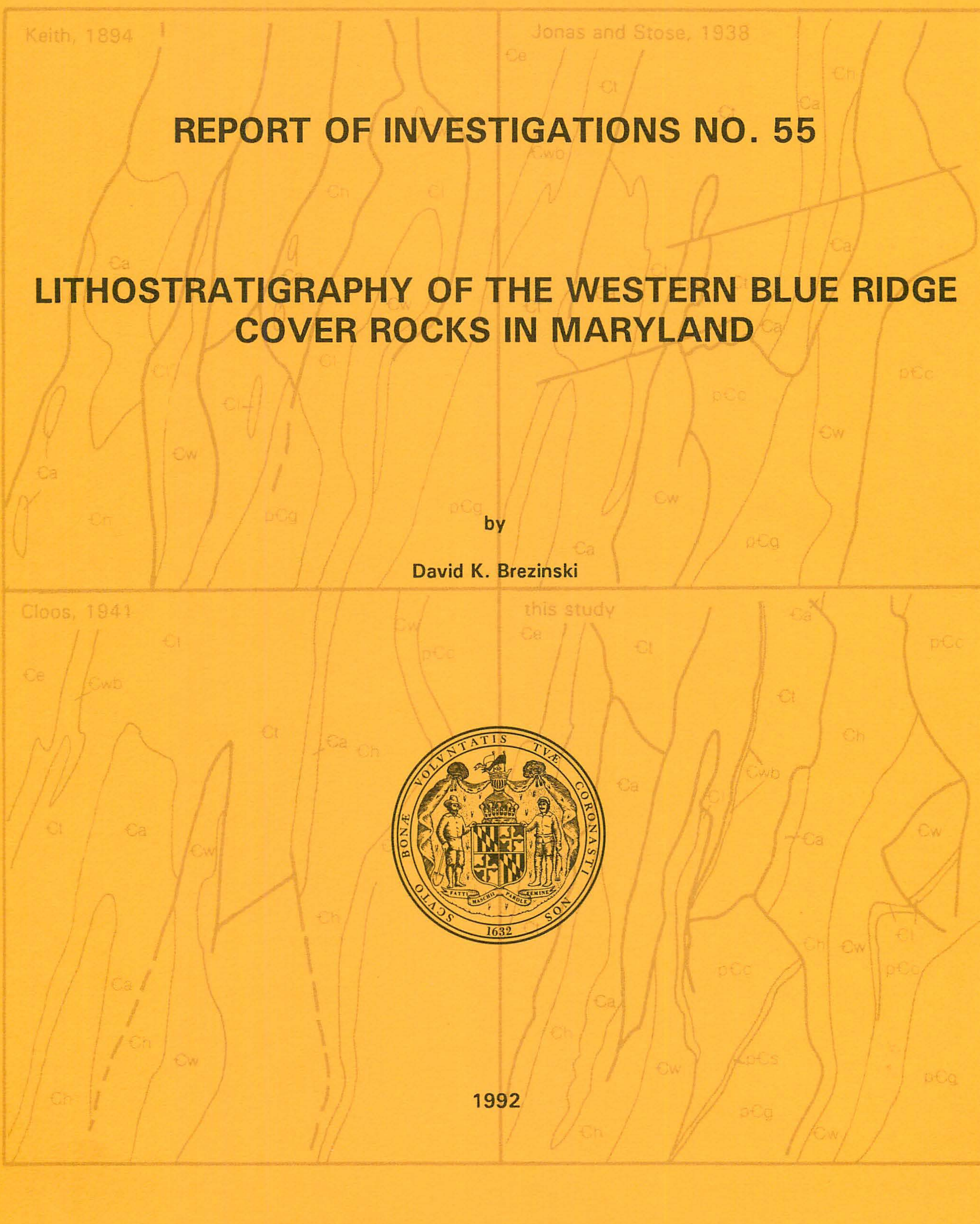
Department of Natural Resources
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

REPORT OF INVESTIGATIONS NO. 55

LITHOSTRATIGRAPHY OF THE WESTERN BLUE RIDGE COVER ROCKS IN MARYLAND



by

David K. Brezinski

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LITHOSTRATIGRAPHY OF THE WESTERN BLUE RIDGE COVER ROCKS IN MARYLAND

by

David K. Brezinski

ABSTRACT

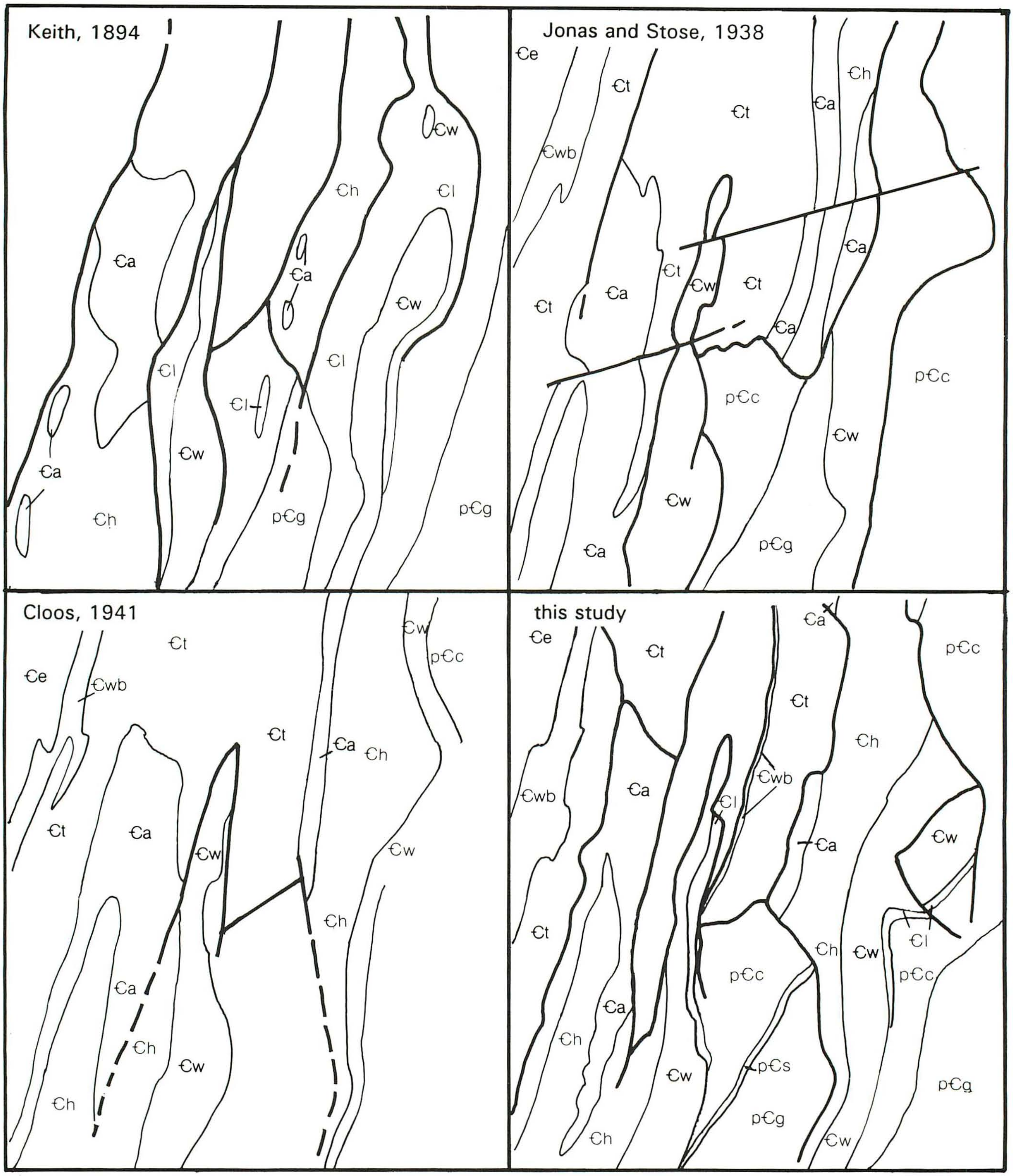
Lower Cambrian Blue Ridge cover rocks of Maryland have traditionally been considered to be in stratigraphic continuation with rocks of the Blue Ridge core. Geologic field mapping at scales of 1:24,000 and larger, as well as detailed stratigraphic studies of the cover rocks, allows subdivision into members of several formations in the Chilhowee Group and overlying carbonate rocks.

Three members are named and described within the Weverton Formation. These Members, from base to top, are: Buzzard Knob, medium-bedded, light-gray, moderately well-sorted quartzite, which is the major ridge-forming unit of the Maryland Blue Ridge; Maryland Heights Member, the medial interval consisting of interbedded, gray quartzite, graywacke, and olive siltstone; and the Owens Creek, consisting of medium- to dark-gray quartzite, conglomerate, and graywacke.

The overlying Harpers Formation is not formally divided, yet numerous ferruginous sandstone units may be locally traced. In northern Washington and Frederick Counties numerous coarse-grained sandstone and quartzite tongues are present in the lower and middle parts of the Harpers. These sandstone and quartzite tongues are interpreted to extend from the much thicker Montalto Member of the Harpers Formation of Pennsylvania. Overlying the Harpers Formation is white to very light-gray, medium-bedded, blanket sandstone known as the Antietam Formation. The Antietam Formation is gradational with the underlying Harpers Formation and grades upward into a well-sorted, *Skolithos*-burrowed, quartzarenite at the top. Above the Antietam Formation is the lowest carbonate unit of the Maryland Great Valley, the Tomstown Formation. Four new members are identified and named within Tomstown Formation. The lowest member, named Bolivar Heights, consists of basal, tan, sandy dolomite, and laminated marble, informally called the Keedysville marble, with the remainder composed of burrowed, dark-gray limestone. Overlying the Bolivar Heights Member is a sequence of thick-bedded, dark-gray, burrow-mottled dolomite, herein named the Fort Duncan Member. Massive, very light-gray, saccharoidal dolomite, named the Benevola Member, overlies the Fort Duncan Member. The uppermost part of the Tomstown consists of interbedded, dark-gray, bioturbated and algal laminated dolomite and limestone and is named the Dargan Member.

Stratigraphically overlying the Tomstown Formation is the Waynesboro Formation. Three members are recognized and named. The basal member, named Red Run, consists of interbedded, tan, fine-grained sandstone, olive shale, and tan, shaly dolomite. The middle member, named Cavetown, is composed of thick-bedded, bioturbated dolomite, laminated limestone, and a few thin shale and sandstone layers. The uppermost member of the Waynesboro, named Chewsville, consists of interbedded, red-brown shale and siltstone, light-gray and brown sandstone, and tan, sandy dolomite. Overlying the Waynesboro Formation is a thick sequence of interbedded, gray limestone, tan dolomite and olive, dolomitic shale, known as the Elbrook Formation. The Elbrook has not been subdivided.

Utilizing the above-described stratigraphic nomenclature, several discontinuities, attributable to faulting, are recognized. The Chilhowee units of South Mountain are disrupted by the High Rock, the Black Rock, and the Monument Knob faults. Along the western base of South Mountain, discontinuities suggest the existence of a major fault system, called South Mountain fault. Truncation of the members of the Waynesboro Formation distinguish the Beaver Creek fault, which has been subsequently folded.



(On the cover) Evolution of thought regarding the geology of the area near the northern terminus of Elk Ridge, Washington County, Maryland.

INTRODUCTION

GENERAL

The area of transition between the Blue Ridge and Great Valley in Maryland has been the location for classic geologic studies for more than a century. Keith (1894), in his study of the Harpers Ferry Quadrangle, made the first of numerous hypotheses on the relationship between the Blue Ridge and Great Valley. The current prevailing theory concerning the Blue Ridge-Great Valley relationship was postulated by Cloos (1951; 1971), who proposed that the relationship between the Blue Ridge, South Mountain anticlinorium, and the Great Valley or Massanutten synclinorium is "normal." That is, the stratigraphic packages within the transition are complete and there are no significant omissions. This interpretation stands in contrast to those workers (for example, Allen, 1967; Radar and Biggs, 1975; and Bartholomew, 1987) who studied the Blue Ridge and Shenandoah Valley relationship of central and southern Virginia where significant stratigraphic discontinuities attributable to thrust faulting may be shown. Consequently, a dichotomy exists relative to the perceived Blue Ridge-Great Valley relationship between central Virginia and the northern terminus of the Blue Ridge in Maryland and Pennsylvania.

In Maryland this area has not been remapped since the work of Cloos (1941). In light of a 50-year hiatus in published geologic mapping, this current study was undertaken to remap the western Blue Ridge and adjacent Great Valley in an attempt to recognize additional stratigraphic subdivisions below the formational level. It was readily apparent that several of the Blue Ridge and Great Valley formations possess lithologies that can be traced laterally and, consequently, be mapped at a 1:24,000 scale. Geologic mapping of the newly recognized subdivisions reveals numerous stratigraphic discontinuities which are interpreted as recording fault zones.

The purpose of this report is to describe the stratigraphic units of the western Blue Ridge of Maryland and thereby outline a revised stratigraphic nomenclature, and discuss new stratigraphic terms. A by-product of this work is that it reveals several significant discontinuities.

SETTING

The area studied is in eastern Washington and western Frederick Counties, Maryland (Figure 1). The geographic boundary between these two counties is the crest of South Mountain, the westernmost of the two main ridges in the Blue Ridge of Maryland (Figures 2, 3). The eastern ridge is named Catoctin Mountain. The ridge that comprises South Mountain extends from Loudoun County, Virginia, where it is called Short Hill, northeastward through Maryland into southeastern Franklin County, Pennsylvania, where it is truncated by a fault. Cloos (1951) has shown that Catoctin and South Mountain are the limbs of a large, overturned, north-plunging anticline, which he named the South Mountain anticlinorium. The mountain ridges are underlain by Lower Cambrian Weverton Quartzite, and the core of the anticline is made up of Proterozoic gneiss and volcanic rocks. According to Cloos, Catoctin Mountain is the normal limb of the fold with dips relatively gently to the southeast. South Mountain is overturned and also dips to the southeast. The nose of the South Mountain anticlinorium is broken by Triassic faults so that Catoctin Mountain does not smoothly join with South Mountain around the nose of the fold. It should be noted that the South Mountain fold of Maryland is a separate structure from that in Pennsylvania, as described by Root (1970).

The Great Valley (also known as the Cumberland or Hagerstown Valley) is underlain mainly by shale and carbonate folded into a structure known as the Massanutten synclinorium. This structure involves Cambrian through Middle Ordovician carbonate rocks and contains Upper Ordovician shale of the Martinsburg Formation in its trough. The eastern limb of this synclinorium, which is congruous with the overturned limb of the South Mountain anticline, is overturned and commonly dips to the southeast. Rocks of the eastern margin of the Hagerstown Valley range from earliest Cambrian to Early Ordovician. Only the Early Cambrian strata will be discussed in detail in this report.

HISTORY OF INVESTIGATION

The stratigraphy of the Blue Ridge and Great Valley transition area has been discussed only as an ancillary topic in conjunction with geologic mapping (Stose and Stose, 1946; Cloos, 1951; Nickelsen, 1956; Root, 1968). Many of these studies have only in a cursory manner dealt with the Lower Cambrian strata, because they are commonly poorly exposed. Sparse outcrop and lack of detailed study have led to a misrepresentation of the thicknesses, lithologic characters, and distribution of the various formations.

Keith (1893, 1894) presented the first study of the Blue Ridge and adjacent Great Valley. In his report on the Harpers Ferry Quadrangle, Keith (1894) described the Loudoun, Weverton, Harpers, and Antietam Formations. Bassler (1919) gave an overview of the stratigraphy of the Cambrian and Ordovician rocks of Maryland, but both of these reports lack detail about the Lower Cambrian units.

The stratigraphy of the Upper Cambrian through Ordovician carbonate rocks of the Hagerstown area has been described by Sando (1957), Demicco and Mitchell (1982), and Demicco (1985). Carbonate rocks of the Frederick Valley were described by Reinhardt (1974), and the Weverton Formation of Catoctin Mountain by Whitaker

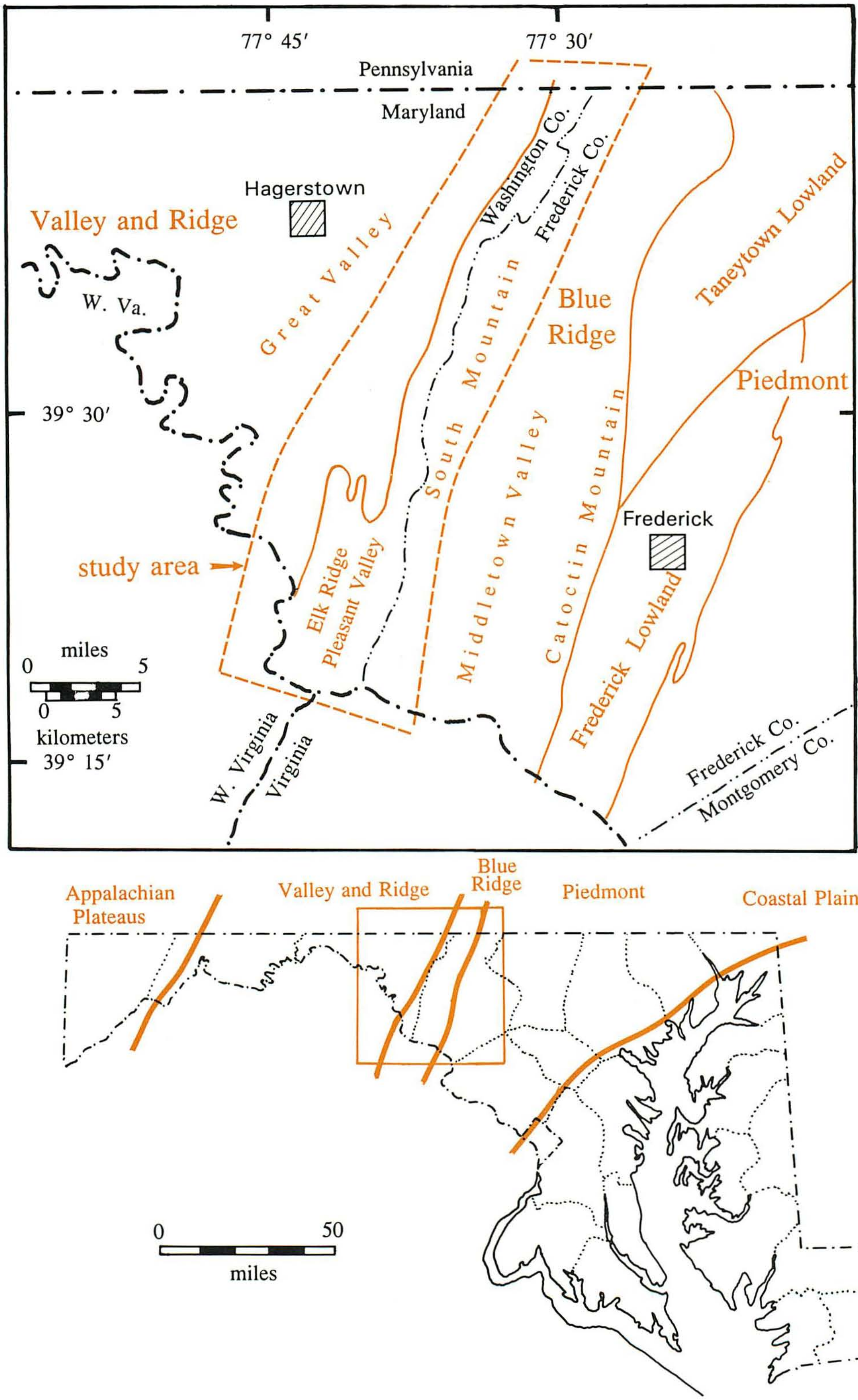
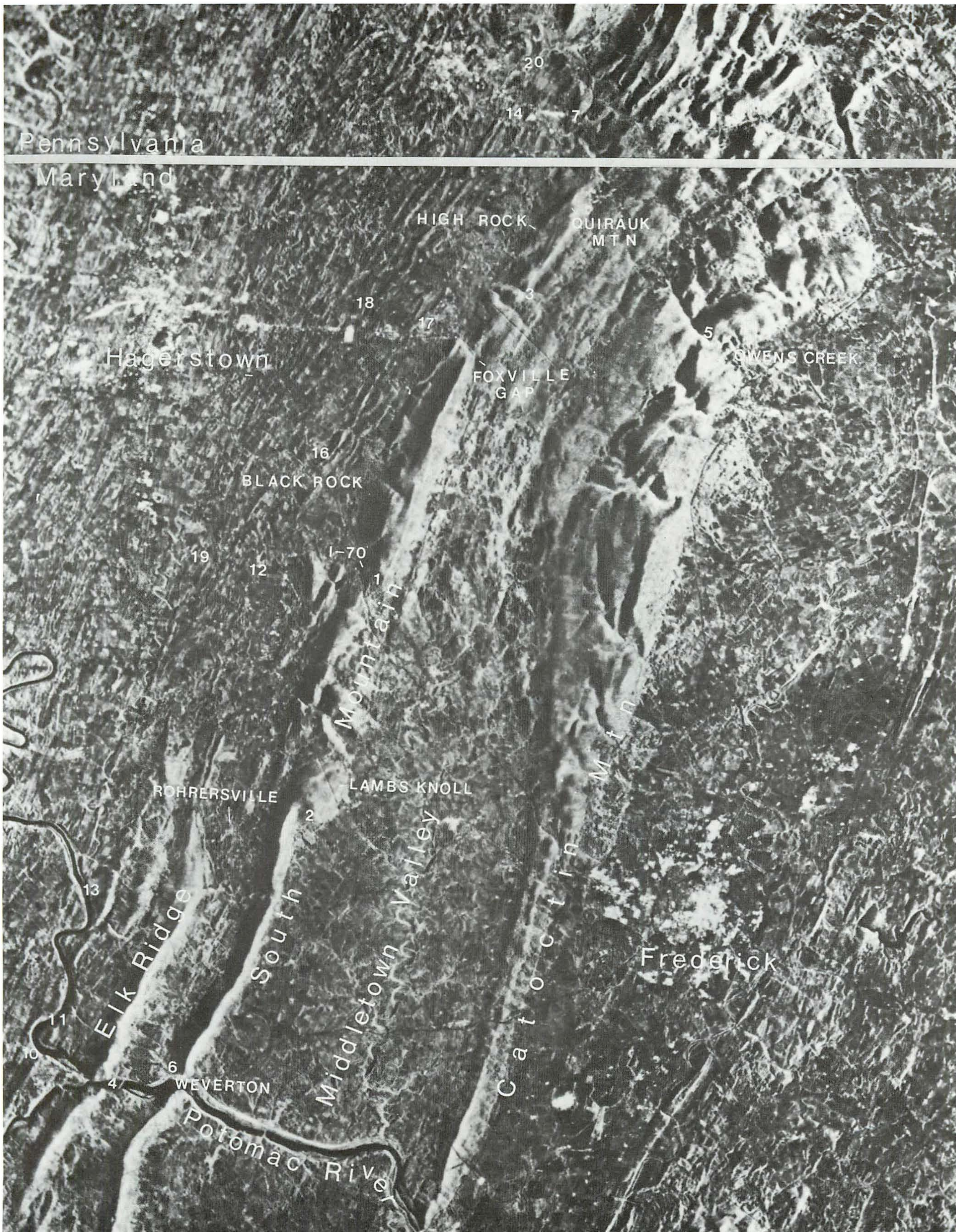


Figure 1.— Physiographic location of study area with relationship to Blue Ridge and Great Valley.

Figure 2.— Side Looking Airborne Radar image (SLAR) of the Maryland Blue Ridge and adjacent areas. Key reference localities and geographic features in white (see Appendix). ⟶


20
14
7
Pennsylvania
Maryland
HIGH ROCK
QUIRAUK MTN
3
18
17
5
OWENS CREEK
Hagerstown
FOXVILLE GAP
16
BLACK ROCK
19
12
I-70
1
South Mountain
Catoctin Mtn
ROHRERSVILLE
LAMBS KNOLL
2
Middletown Valley
13
Elk Ridge
Frederick
11
10
4
6
WEVERTON
Potomac River

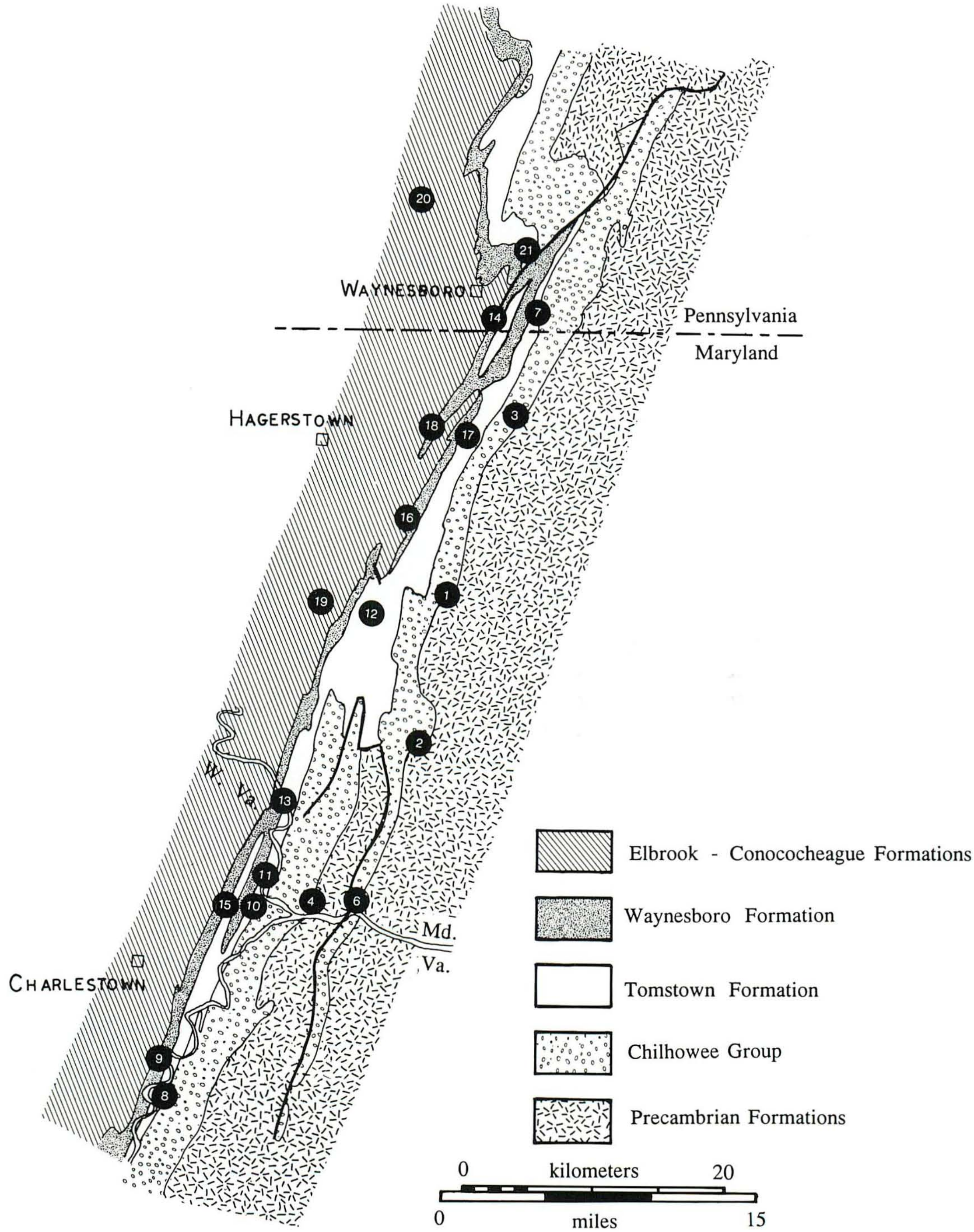


Figure 3.— General geologic map of the western Blue Ridge and Great Valley of Maryland and adjacent Virginia and Pennsylvania taken from Cleaves et al. (1968), Berg et al. (1980), and Cardwell et al. (1968). Numbers represent localities listed in Appendix.

(1955). Cloos (1951) gave a general stratigraphic outline for eastern Washington County and also provided numerous measured stratigraphic reference sections for the Weverton through Waynesboro interval.

In addition to these studies, several reports in adjacent states are notable. Nickelsen (1956), as part of his study in the area south of Harpers Ferry, described the stratigraphy of the Weverton through Tomstown interval. Likewise, Root (1968) mapped and described the cover rocks in the adjacent part of Pennsylvania. However, Root did not subdivide the clastic units of the Chilhowee Group (Cambrian).

LITHOSTRATIGRAPHY

GENERAL

Traditional stratigraphic nomenclature for the Late Proterozoic to Early Cambrian cover rocks of the Blue Ridge and adjacent Great Valley is, in ascending order: the Chilhowee Group, Tomstown Formation, and Waynesboro Formation. The Chilhowee Group can be subdivided, from bottom to top, into the Loudoun, Weverton, Harpers, and Antietam Formations (Figure 4). Although an Early Cambrian age is known for the Antietam, Tomstown and Waynesboro Formation, based on the presence of *Olenellus*, the age of the Loudoun, Weverton, and Harpers Formations remains a question since no age-specific fossils are known from these formations in Maryland. Simpson and Sundberg (1987) have documented Tommotian (earliest Cambrian) fossils from the Weverton-equivalent Unicoi Formation of southern Virginia. Consequently the Weverton Formation appears to be at least in part Early Cambrian. The age of the Loudoun Formation remains a question. The Tomstown Formation is the oldest Paleozoic carbonate unit in the Great Valley and has commonly been called the Tomstown Dolomite. The Waynesboro Formation is intercalated clastic and carbonate rocks.

Field mapping at 1:24,000 reveals that some horizons with distinctive lithologies within the Weverton, Tomstown, and Waynesboro may be traced laterally. These mappable lithologies are herein defined as members of previously recognized formations and are formally named.

CHILHOWEE GROUP

Loudoun Formation

Keith (1893, 1894) applied the name Loudoun Formation to an interval composed mainly of "black slate" which occurs between his "Catoctin Schist" and the "Weverton Sandstone." Heterogeneous lithologies commonly comprise the Loudoun interval. Such lithologies include a grayish-black to brownish-black phyllite; medium-to dark-gray, phyllitic conglomerate; dark-gray, quartz-pebble conglomerate; and medium- to light-gray, medium- to coarse-grained conglomerate. Keith (1894) and Bassler (1919) also noted the presence of limestone and marble, which were not observed during this

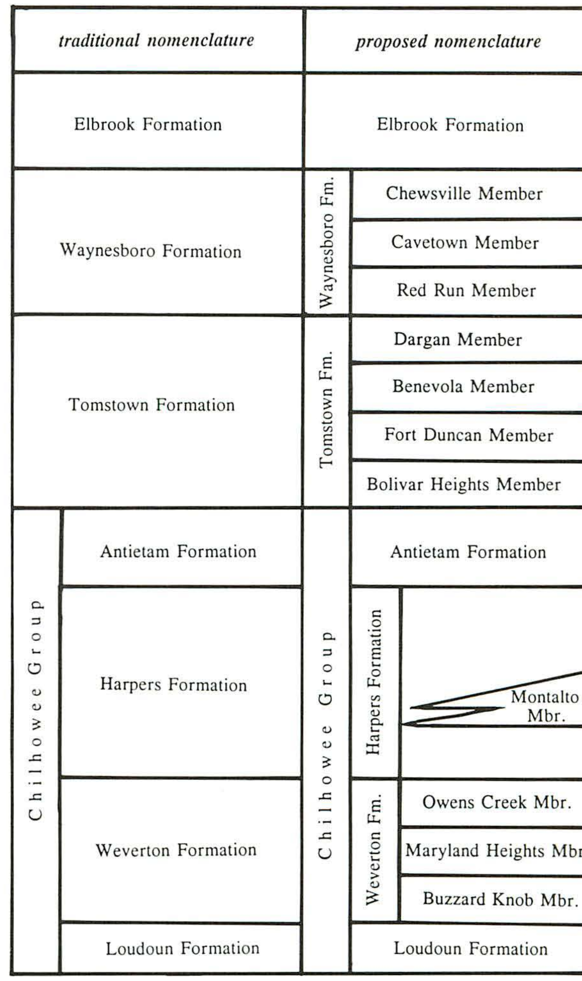


Figure 4.— Stratigraphic nomenclature proposed in this report compared to traditional terminology.

study. Typically, the dark-gray phyllite underlies the conglomerate but locally they may be interbedded.

The most pervasive lithology in the Loudoun is dark-gray phyllite. I used this lithology as a key bed in mapping much of the western Blue Ridge in Maryland. Although useful in mapping by float, good outcrops of this lithology are rare. However, several exposures are noteworthy.

On the south slope of Pine Knob (locality 1)

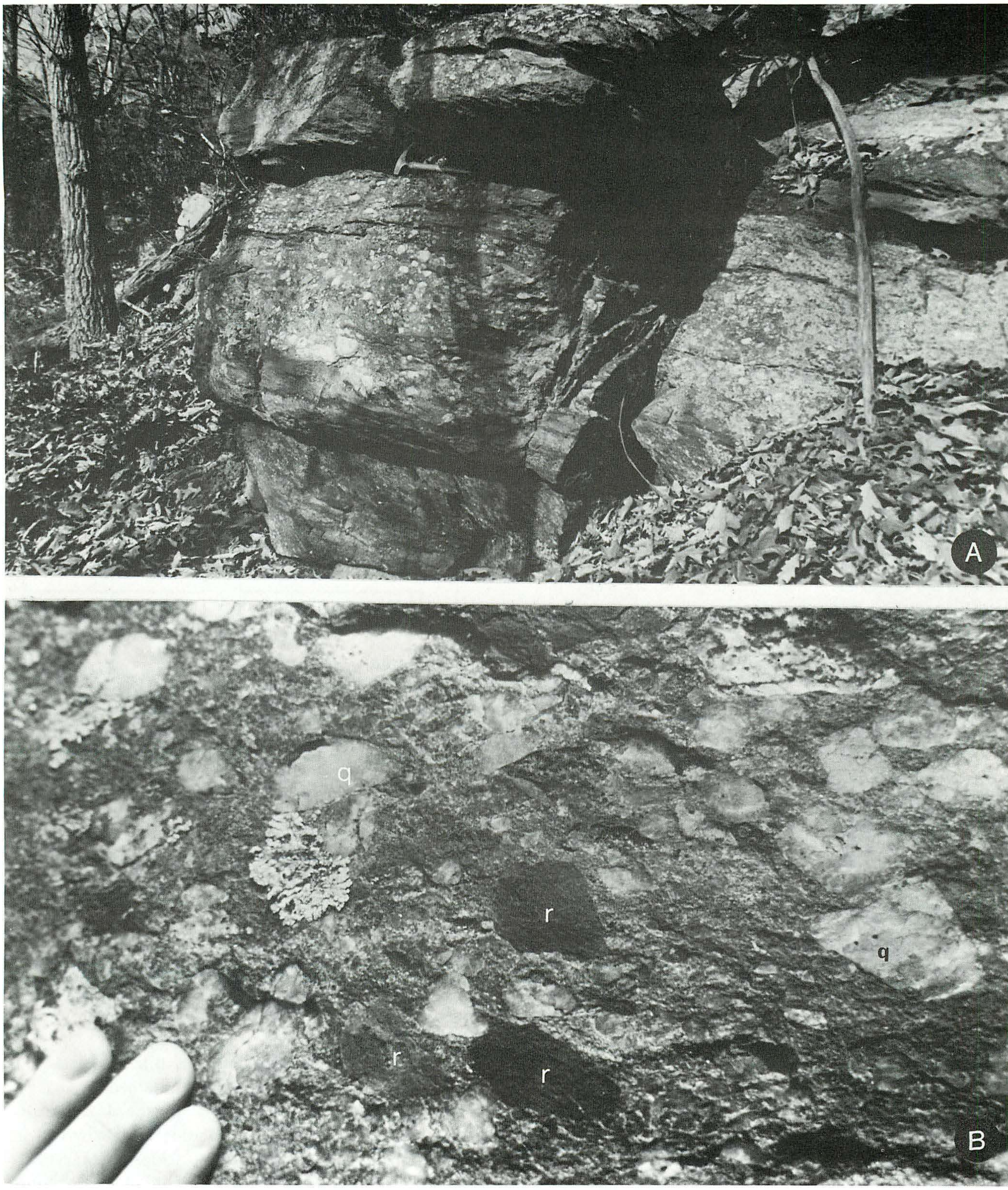


Figure 5.— A, Conglomeratic Loudoun Formation on Lambs Knoll (locality 2). B, Close-up of polylithic clasts; q = quartz, r = rhyolite.

approximately 43 feet of dark-gray phyllite are overlain (topographically) by coarse-pebble conglomerate. The dark-gray phyllite exhibits a strongly developed cleavage. No relict bedding was observed. Locally developed light-gray to grayish-pink, elongate blebs may represent volcanic amygdules. On the south flank of Lambs Knoll (locality 2), only 32 inches of dark-gray, sandy phyllite are exposed, which is overlain by a polymictic conglomerate (Figure 5). At this locality, pebbles of pink jasper are distinctive clasts scattered throughout the unit. Four miles to the north, at the south end of Monument Knob in Washington Monument State Park, 3 feet of dark-gray phyllite lie beneath medium-gray quartzite of the lowest part of the Weverton Formation. At this location no conglomeratic Loudoun is present; however, at the northern end of Monument Knob no phyllite crops out, and large float boulders of conglomerate may be observed. At Loudoun Heights near the Virginia-West Virginia State line, approximately 7 feet of dark-gray phyllite assignable to the Loudoun underlies the Weverton. At this locality the contact between the dark-gray phyllite and underlying Catoctin greenstone is difficult to place, inasmuch as the two lithologies appear to be gradational, and the Loudoun assignment there is equivocal.

The conglomeratic units are much more variable in color, composition, and distribution than are the dark-gray phyllite layers. Perhaps the best exposure of Loudoun conglomerate in Maryland is on the southwest side of Pine Knob (locality 1) along the Appalachian Trail uphill and presumably upsection from the Catoctin metabasalts and dark-gray Loudoun phyllite. More than 15 feet of conglomerate are exposed at this location and it exhibits a variable and interbedded character. More than 50 percent of some units consist of rounded to well-rounded pebbles and cobbles of white and pink quartz up to 4.5 inches in diameter. Other clasts are rounded, dark-gray phyllite, pink and red rhyolite, and tan tuff. Other beds have fewer quartz pebbles and more volcanogenic clasts contained in phyllitic matrix. Locally, pebble and granular conglomerate is cross-bedded. The conglomerate thins within a short distance north and south. Float of dark-gray conglomerate with elongate phyllite clasts can be traced north to Foxville Gap, east of Smithsburg, Washington County, Maryland but no farther. To the south, float blocks of quartz-cobble conglomerate occur on the north and west flank of Monument Knob, and a section 8 feet thick overlies gray phyllite on Lambs Knoll (Figure 5) (locality 2). South of Lambs Knoll no conglomerate was observed on either South Mountain or Elk Ridge; however, the conglomeratic facies is recognized south into Virginia at Purcell Knob and Ashby Gap.

To the east on Catoctin Mountain, Whitaker (1955) mapped a continuous conglomeratic member of the Loudoun from Emmitsburg, Frederick County, Maryland to the Potomac River. The phyllite is discontinuous in this same zone.

The variable distribution and lithologic composition of the Loudoun are attributed to the effects of the irregularities of the depositional surface upon which these lithologies accumulated. Presumably, topographic lows in the underlying Catoctin Formation accumulated sediments subsequently preserved as thick layers of phyllite and conglomerate. The highly variable composition of the conglomerate member may be related to differences in very localized source areas.

The contact between the Loudoun and Weverton Formations was observed at a single location in the western Blue Ridge of Maryland. On Lambs Knoll a Loudoun conglomerate fines upward and is interbedded with granular quartz conglomerate and very coarse-grained sandstone of the overlying Weverton (Figure 5).

No fossils were observed in the Loudoun; consequently, the age remains in question. Insofar as the Loudoun appears to be part of the same sedimentary depositional package that makes up the Weverton and Harpers Formations, a tentative Early Cambrian age is herein ascribed to it.

Weverton Formation

The main ridge-forming unit of the Blue Ridge of Maryland is the Weverton Formation. Keith (1893; 1894, p. 68) named the unit for an exposure near the town of Weverton at the south end of South Mountain at the Potomac River, Washington County, Maryland (locality 6). At the type section along U.S. Route 340, more than 600 feet of folded quartzite and metasiltstone are exposed. Numerous authors have shown that a three-fold subdivision of the Weverton is possible (Nickelsen, 1956; Gathright and Nystrom, 1974; Whitaker, 1955; Fauth, 1977; and Nunan, 1979). Most authors informally called these lower, middle, and upper members. Nunan (1979) named these three members the Loft Mountain, Oregon Hollow, and Dismal Hollow Members, in ascending order. However, according to Article 4 of the North American Statigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983), publication is required for the naming of new stratigraphic terms; a Ph.D dissertation does not suffice for such a purpose. Therefore, names proposed by Nunan cannot be considered valid. Tracing the three Weverton members along South Mountain in Maryland in addition to measuring numerous stratigraphic sections on Catoctin Mountain, which is structurally less complex, indicate that an amendation of Nunan's members is warranted. Because these names are not formalized, a thorough revision and naming of the three Weverton members are presented herein.

The Weverton Formation of northern Virginia, Maryland and Pennsylvania is equivalent to the Unicoi Formation of northeast Tennessee and southwestern

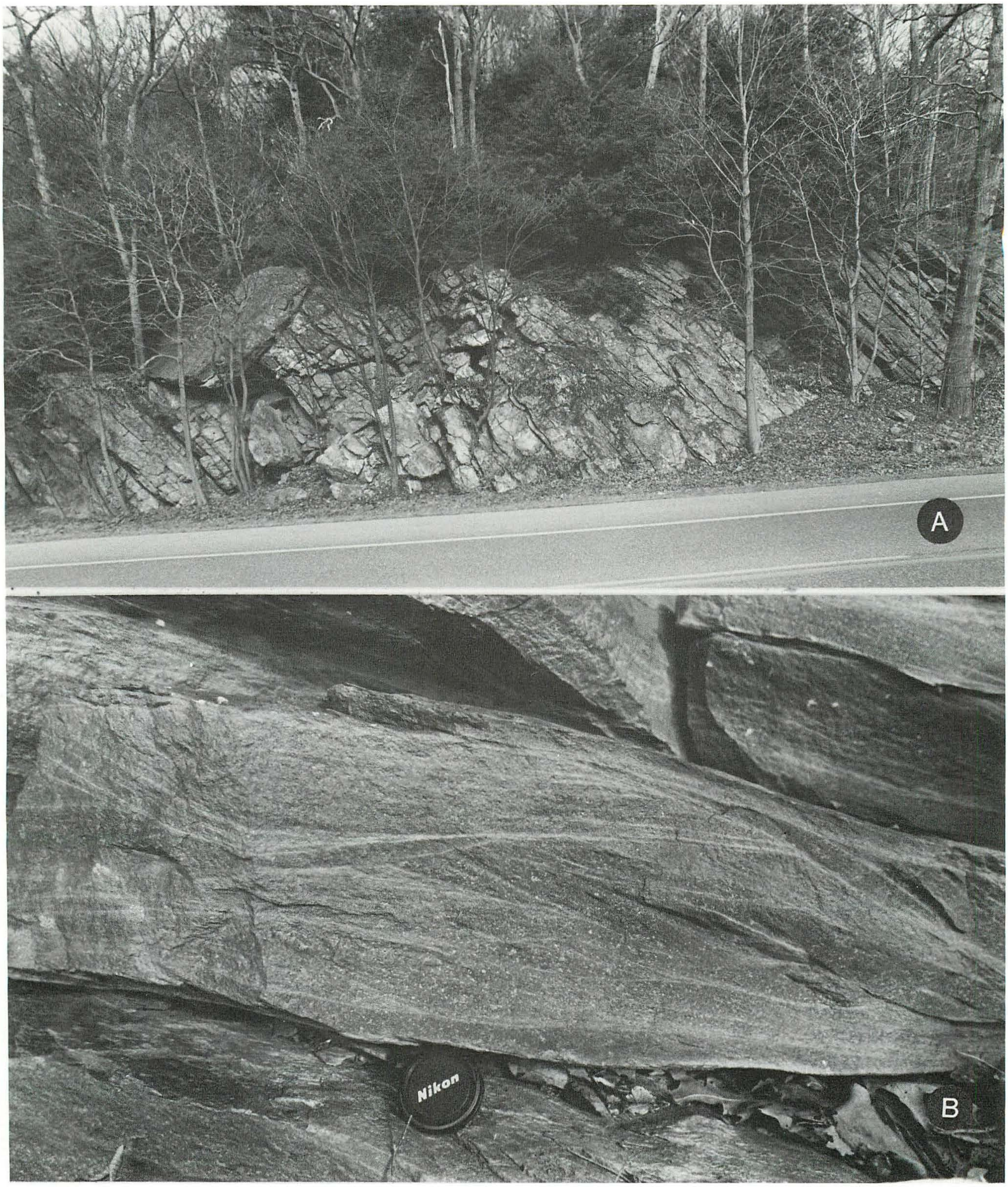


Figure 6.— A, Type section of the Buzzard Knob Member of the Weverton Formation at locality 3. B, Trough cross-bedding characteristic of the Buzzard Knob Member of the Weverton Formation.

Virginia (Schwab, 1971; Simpson and Sundberg, 1987).

Buzzard Knob Member (New): South Mountain and Elk Ridge to its west are underlain by lower Weverton, the single most significant ridge-forming unit in the northern Blue Ridge. This member is herein named the Buzzard Knob Member, based on an exposure in Raven Rock Hollow northeast of Smithsburg, Washington County, Maryland (Figure 6A). The reference section is along Maryland Route 491 just north of Buzzard Knob (locality 3). At the type section, the Buzzard Knob Member is approximately 160 feet thick, although the lower and upper contacts are concealed (Figure 6A). The lower 50 feet of this exposure include thin- to medium-bedded, light-gray to greenish-gray, chloritic, coarse-grained to very coarse-grained quartzite. Cleavage is developed in these quartzite beds. Most of the remainder of the member is medium-bedded, light- to medium-light-gray, clean, medium- to coarse-grained quartzite. Cross-beds are pervasive in these beds and are is accentuated by grayish-orange to gold-colored laminae within the foresets (Figure 6B). Locally interbedded with the pure quartzite beds are greenish-black to dusky-blue, quartzose phyllites which are intensely sheared. These phyllites range from 1 to 3 inches in thickness. Another characteristic of the quartzite beds of the interval is wispy, dusky-blue areas which fade laterally within the quartzite.

Cloos (1951, p.31-32) apparently believed that this quartzite interval constituted much, if not all, of the Weverton in Raven Rock Hollow. However, the section continues to the west, where metasiltstones of the middle part of the Weverton are evident and, even further to the west, where additional quartzites of the upper part of the Weverton are exposed. These outcrops indicate that Cloos's section is incomplete and that the three-fold subdivision of the Weverton as seen elsewhere is present here also.

North of the type section at Raven Rock Hollow, the Buzzard Knob Member forms the crest of South Mountain where noteworthy exposures exist.

At High Rock, south of Pen Mar, a cliff more than 100 feet high is made up of the Buzzard Knob Member. At the base of the cliff, cross-bedding suggests that the strata dipping southeast are overturned, whereas the rocks at the top of the cliff are upright, dipping in the same direction. Clearly, the Buzzard Knob Member at this location has been doubled by folding. East of High Rock to Quirauk Mountain, the Buzzard Knob Member is upright. At the microwave tower near the eastern side of the ridge, the unit becomes steeply overturned. Therefore, between these two sides of the ridge, South Mountain is a synclinal ridge with an overturned eastern limb. The Buzzard Knob Member is also well exposed at Fort Ritchie, both along the CSX Railroad tracks and behind the sewage treatment plant, although thickness is obscured by intricate folding. In Pennsylvania, this member has been traced to Caledonia State Park, east of Chambersburg, Franklin County, Pennsylvania.

South of the type section, the Buzzard Knob Member forms the crest of South Mountain. It is overturned and forms a sharp ridge crest between Buzzard Knob and Black Rock. At Black Rock and Annapolis Rock, the member is upright quartzite, but, just as at High Rock, the cliffs include overturned and upright strata. East of both Black Rock and Annapolis Rock, South Mountain possesses a relatively flat top. This reflects the underlying structure, which appears to be an overturned recumbent syncline (Plate 2). Thus, in this area, South Mountain is actually a synclinal ridge similar to that of Quirauk Mountain to the north.

From Interstate 70 to Monument Knob, intricate folding and faulting obscure all but thin slivers of the Buzzard Knob Member. On Monument Knob, talus of this member comprises the actual Knob, but only a few feet of upright basal beds crop out.

On the east, south, and north sides of Lambs Knoll, the Weverton Formation is upright and dips gently northeast. From Lambs Knoll south to the Potomac, the River Buzzard Knob Member forms a sharp ridge crest, but appears to bifurcate into two separate resistant units. This is evident at Weverton Cliffs. Although at Weverton Cliffs the fresh road exposure reveals only a single continuous Buzzard Knob Member, approximately 130 feet thick (Figure 7), on the weathered slope above the road, two separate resistant units are evident. The lower unit is approximately 45 feet thick and consists of very light-gray to yellowish-gray, medium-bedded, medium-to coarse-grained, well-sorted quartzite. The basal beds of this unit are very coarse-grained quartzite. The upper resistant unit is light-gray to medium-gray, coarse-grained quartzite with dusky-blue, grayish-olive, and grayish-yellow bands, and is approximately 50 feet thick. Cross-bedding is more prevalent in this unit than it is in the lower one. Separating the two resistant intervals are 38 feet of interbedded, light-gray to dusky-yellow, platy, micaceous sandstone and light, olive-gray, quartzose siltstone. This interval weathers more readily than does the surrounding quartzite layers and thus the apparent biofurcation is manifested.

It is not clear whether the middle quartzite member of Nickelsen (1956) represents the upper resistant member of the Buzzard Knob Member or, as he proposed, a separate quartzite within the phyllitic middle part of the Weverton. Based on its stratigraphic position and character, the former interpretation is ascribed to here, although at this time it is impossible to definitively determine. However, it is also plausible that it represents a thick quartzite interbed within the fine-grained middle part of the Weverton as Nickelsen suggested.

The double quartzite character for the Buzzard Knob

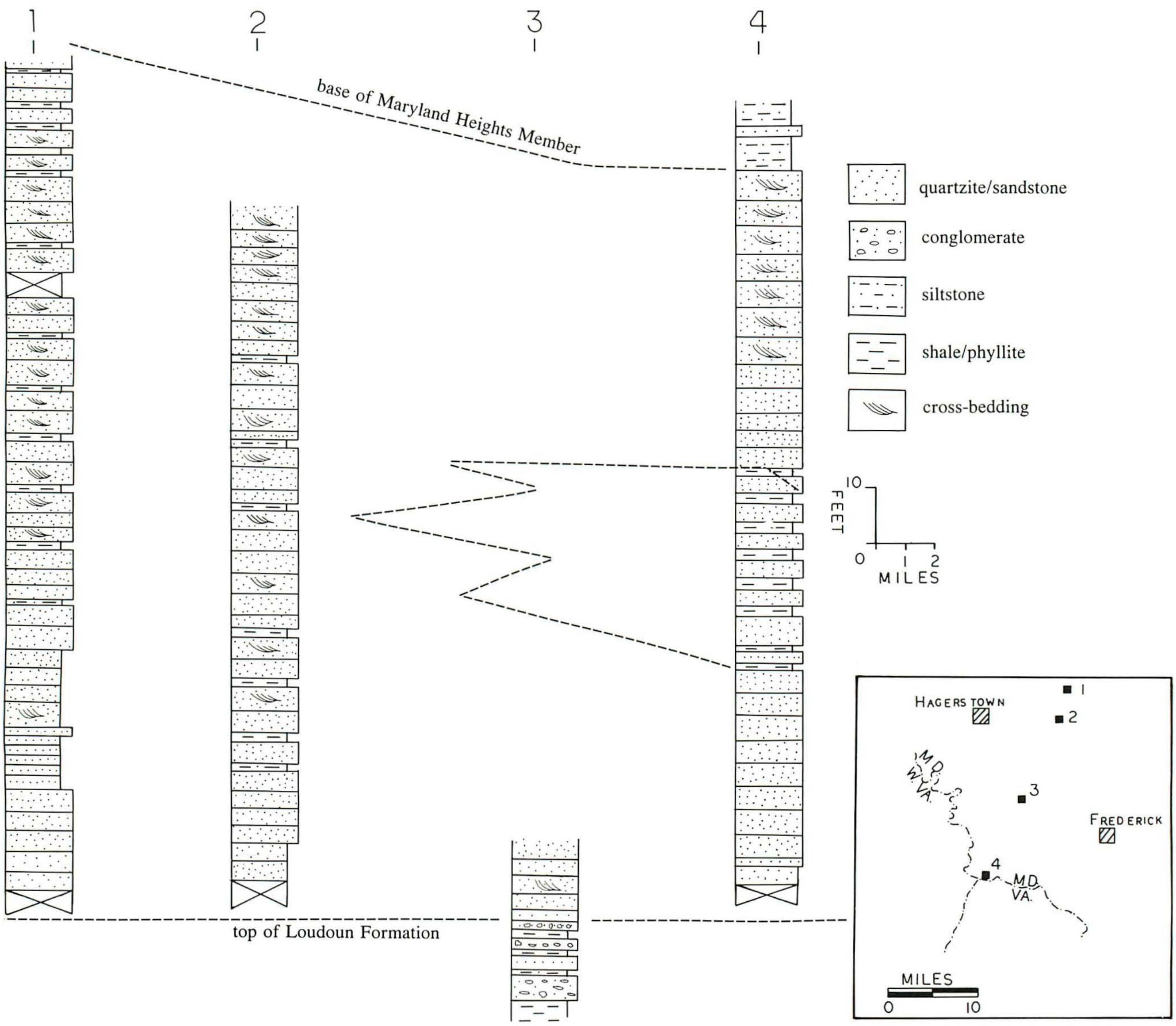


Figure 7.— Stratigraphic sections of the Buzzard Knob Member of the Weverton Formation along South Mountain in Maryland. 1, type section (locality 3); 2, Warner Gap Hollow; 3, Lambs Knoll (locality 2); 4, Weverton Cliffs (locality 6).

Member is also evident at the Potomac River at the southern terminus of Elk Ridge near the village of Sandy Hook, southern Washington County, Maryland (see Figure 11). At that location, both resistant ledge-making units have been isoclinally folded.

Along the east flank of Elk Ridge, both ledges of quartzite in the Buzzard Knob Member make up the ridge crest; however, intricate folding makes it difficult to distinguish between them. The Buzzard Knob Member extends north to Trego, Maryland. The northernmost observed exposure on Elk Ridge is along Marble Quarry Road where 90 feet are exposed.

Southward in Virginia the Buzzard Knob Member has been recognized as far as Ashby Gap, Clarke County, Virginia. On Catoctin Mountain a basal unit of the Weverton is recognizable north of Frederick (Whitaker, 1955). The Buzzard Knob Member is exposed along Owens Creek and Maryland Route 550, northwest of Thurmont, Frederick County, Maryland, where approximately 70 feet are exposed (locality 5). South of Interstate 70, faulting has removed most of the middle through upper parts of the Weverton and only a part of the Buzzard Knob Member is preserved.

The contact between the Buzzard Knob Member and the overlying middle member of the Weverton is exposed at Weverton Cliffs along U.S. 340. At this location, the upper quartzite of the Buzzard Knob Member sharply changes into the dark gray phyllite of the Maryland Heights Member. Strong cleavage obscures and modifies the contact (Figure 8A).

Maryland Heights Member (New): The middle member of the Weverton Formation, herein named the Maryland Heights Member, is the most difficult to precisely and thoroughly describe. The unit is very strongly deformed and less resistant to weathering than the massive quartzite of the adjacent upper and lower parts of the Weverton. The Maryland Heights Member is composed of alternating medium-gray quartzite, medium-dark-gray, conglomeratic graywacke, dark-gray phyllite, and metasiltstone. The incompetent metasiltstone and phyllite, being situated stratigraphically between the competent Buzzard Knob and Owens Creek Members, are deformed to the degree that stratigraphic characteristics are obscured. Typically, the Maryland Heights Member lithologies can be mapped on the basis of their recessive character. On aerial photographs the Maryland Heights can be easily recognized as it forms a swale between the ridges created by the quartzites of the Buzzard Knob and Owens Creek Members.

Incomplete exposures provide enough information so that a general composite description of this interval may be derived. At Maryland Heights, good exposures occur in cuts along the CSX Railroad tracks, east of the tunnel and Sandy Hook Road at the southern end of Elk Ridge (locality 4). This location is used as the type section. Approximately 300 feet of section crop out here. This exposure accurately reflects the regional character of this unit. The main components of this interval are units of medium-gray to olive-gray graywacke, 3 to 45 feet thick, interbedded with dark-olive-gray, sandy metasiltstones and, less commonly olive phyllite. At the road bridge over the railroad tracks, one of the numerous coarse-grained graywackes is accessible. Bedding within these metasiltstones is highly folded. The alternation of quartzite, phyllite, and metasiltstone within the Maryland Heights Member has created much confusion as to the true nature of these rocks. For example, Burford and others (1964, Fig. 14) interpreted the interbedded metasiltstone and quartzite at the Maryland Heights type section to be a result of imbricate thrust faults which repeat the stratigraphy of the Weverton and Harpers Formations in small fault slivers. Nickelsen (1956) also shows a small infold of Harpers Formation within the upper part of the Weverton on the Blue Ridge in Virginia. This may also be a case of mistaken identification of the Maryland Heights Member as indicated by recent mapping by Southworth (1991).

This member is well exposed along U.S. Route 340 at the Weverton Cliffs section (locality 6) (Figure 8). There Maryland Heights consists of olive-gray, grayish-black, and olive-black, quartzose metasiltstones containing thin intervals, 1 to 2 feet thick, of conglomerate with white quartz pebbles and 3- to 30-foot intervals of gray and greenish-gray quartzite. The thickness of the metasiltstone intervals are obscured by isoclinal folds and pervasive foliation. Near the middle of the unit is a 70-foot thick, medium-gray quartzite, which is nearly identical to the upper resistant quartzite of the underlying Buzzard Knob Member exposed at another point in the road cut. This quartzite is truncated above road level by a small fault. Nunan (1979) believed that this sandstone is part of the lower member which was faulted into place. The hypothesis proposed herein includes this medium-gray sandstone as a part of the Maryland Heights Member.

Numerous small exposures corroborate the lithologic character of this member as seen at the type section. Along U.S. Route 40 at the crest of South Mountain, more than 50 feet of sheared metasiltstone are probably the Maryland Heights Member. Thin quartzite beds within the Maryland Heights Member can be mapped for several miles. Such units are traceable on Quirauk Mountain, near Black Rock, and on the north side of Lambs Knoll. These beds exhibit considerable variation in color and texture, both vertically and laterally. Lithologic variations include very coarse-grained, dark-gray metagraywacke to light-gray, vitreous, pure quartzite.

At Raven Rock Hollow, upsection from the type section of the Buzzard Knob Member, more than 30 feet of greenish-gray metasiltstone and thin (< 3 feet) sand-

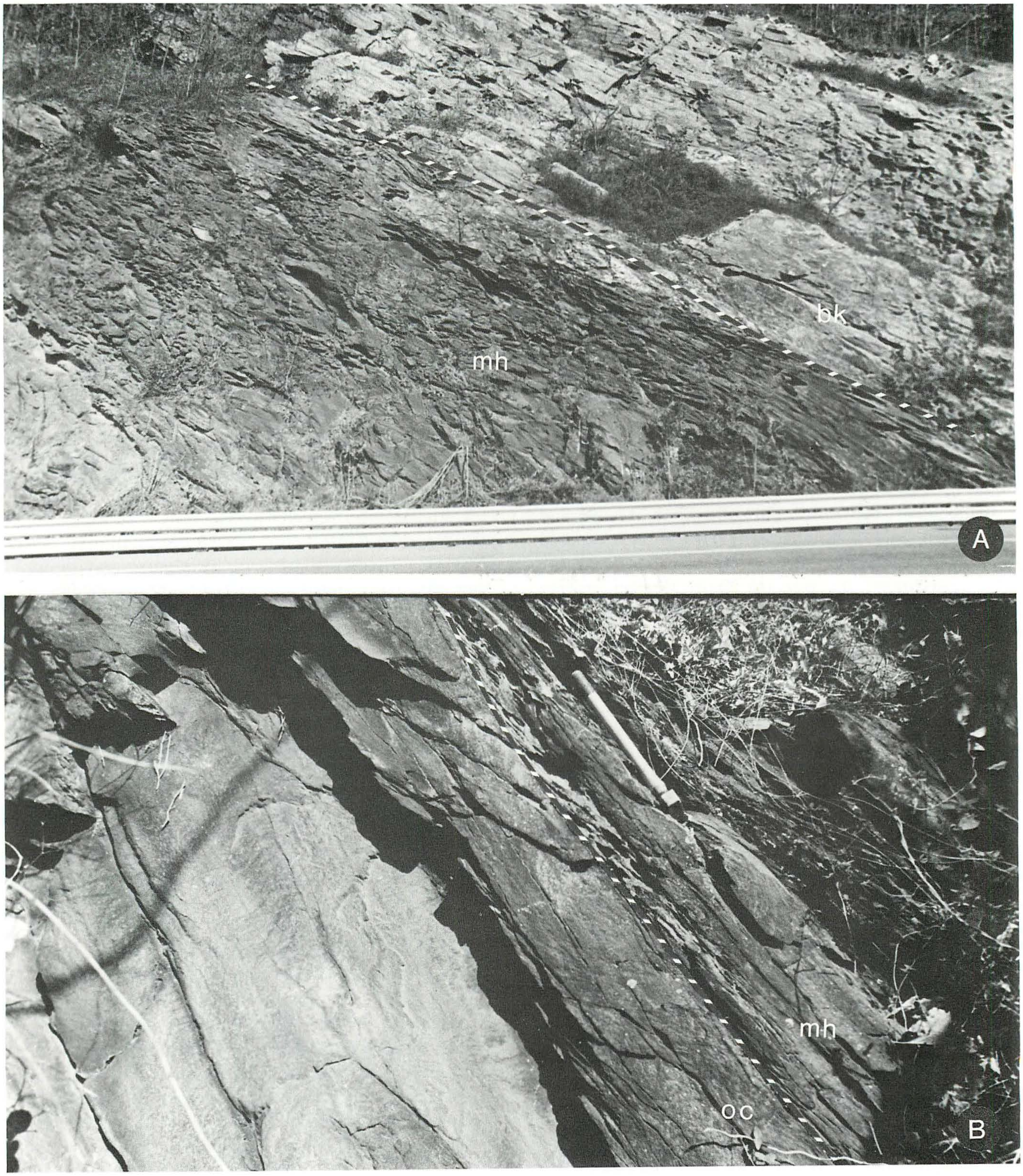


Figure 8.— A, contact between overturned quartzites of the Buzzard Knob Member (bk) and basal siltstones Maryland Heights (mh) at Weverton (locality 6). B, Contact between the Maryland Heights (mh) and Owens Creek (oc) Members at the Weverton (locality 6).

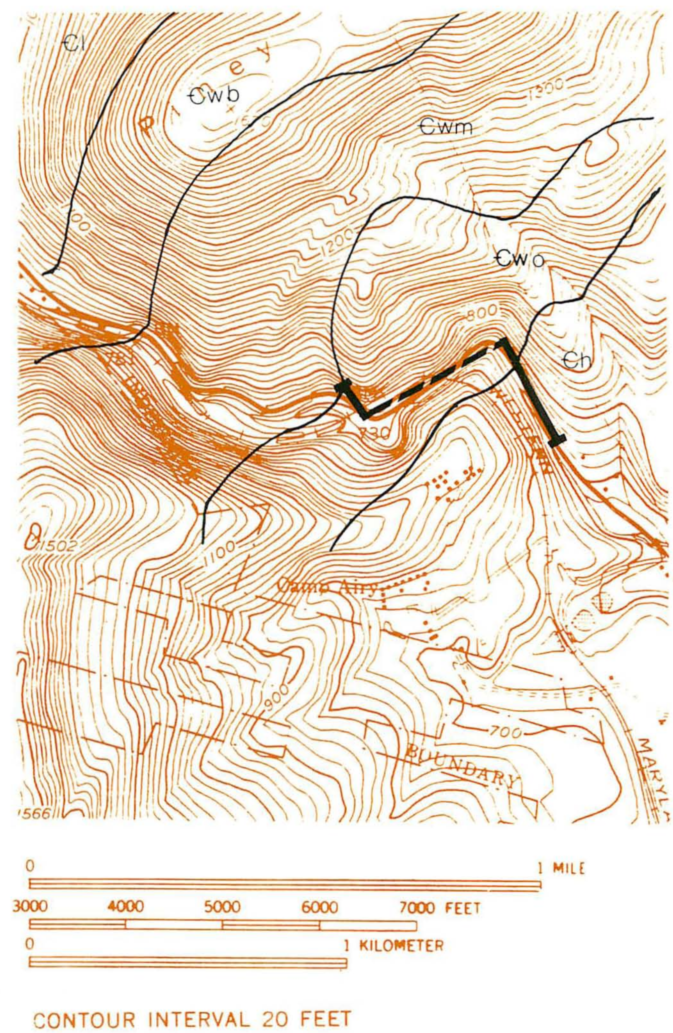
stone beds are present. At this location the Buzzard Knob and overlying Owens Creek Members are separated by approximately 450 feet of section, mostly concealed, that represents the Maryland Heights Member.

At present the Maryland Heights Member is known to extend from Maryland into northern Virginia. Gathright and Nystrom (1974) have noted a similar character for the middle member of the Weverton at Ashby Gap, Virginia, 30 miles to the south. In Pennsylvania, Fauth (1968) described the Weverton Formation at Caledonia Park. The description of the strata at Caledonia Park suggests that the lower middle and upper middle units of Fauth (1968) may be equivalent to the Maryland Heights Member.

At the type section, in Maryland, the upper part of Maryland Heights Member is medium-gray quartzite interbedded with dark-olive-green metasiltstone. The thickness and purity of individual quartzite beds increase upsection, and the thickness of metasiltstone decreases (Figure 8B). The upper contact of the member is defined where the thin-bedded siltstones of the Maryland Heights Member are replaced by the thick-bedded graywacke of the overlying Owens Creek Member.

Owens Creek Member (New): The upper member of the Weverton consists of another ledge-forming quartzite (Nickelsen, 1956). Although this member is more resistant and much better exposed than the Maryland Heights Member, rarely does it form the prominent ledges and ridge crests common to the Buzzard Knob Member. Nunan (1979) named this part of the Weverton the Dismal Hollow Member, but the name used hereafter in this report is the Owens Creek Member. The type section designated for the Owens Creek Member is along Maryland Route 550 and the Maryland Midland Railroad tracks 1.5 miles northwest of Thurmont, Frederick County, Maryland. This section is on Catoctin Mountain, which is the upright limb of the Blue Ridge anticlinorium, and therefore is relatively undeformed. At this accessible locality, a nearly complete section crops out. The base of the section is exposed along Maryland Route 550 and Owens Creek west of the westernmost railroad bridge and continues beneath the bridge to the bend in the roadway and continues southeast along strike to the eastward bend in Route 550, then proceeds eastward into the lower part of the Harpers Formation (Figure 9). The lowest strata exposed consist of interbedded, dark-gray phyllite and a thin-bedded, coarse-grained, dark-gray metagraywacke of the Maryland Heights Member. About 50 feet of the lower Owens Creek Member crop out beneath the westernmost railroad bridge and consists of medium-gray, medium-bedded, coarse- to very coarse-grained quartzite and granular conglomerate. The remaining 90 feet of the Owens Creek Member are exposed to the north of the basal beds and are comprised of interbedded, medium- to dark-gray, thin-bedded, coarse-grained graywacke; dark-gray, quartz-pebble conglomerate; and a few intervals of greenish-gray, quartzose, ferruginous siltstone. These strata are overlain by 50 feet of interbedded, thin-bedded, argillaceous graywacke and shaly siltstone which are assigned to the overlying Harpers Formation.

At the Weverton Formation type section (locality 6), more than 90 feet of the Owens Creek Member crop out (Figure 10A). At this locality the beds are overturned and the contact with the underlying Maryland Heights Member



Ꞓh - **Harpers Formation**
Ꞓwo - **Owens Creek Member**
Ꞓwm - **Maryland Heights Member**
Ꞓwb - **Buzzard Knob Member**
Ꞓl - **Loudoun Formation**

Figure 9.— Map illustrating location of Owens Creek Member type section, north-west of Thurmont, Maryland. Locality 5 on Figure 2.

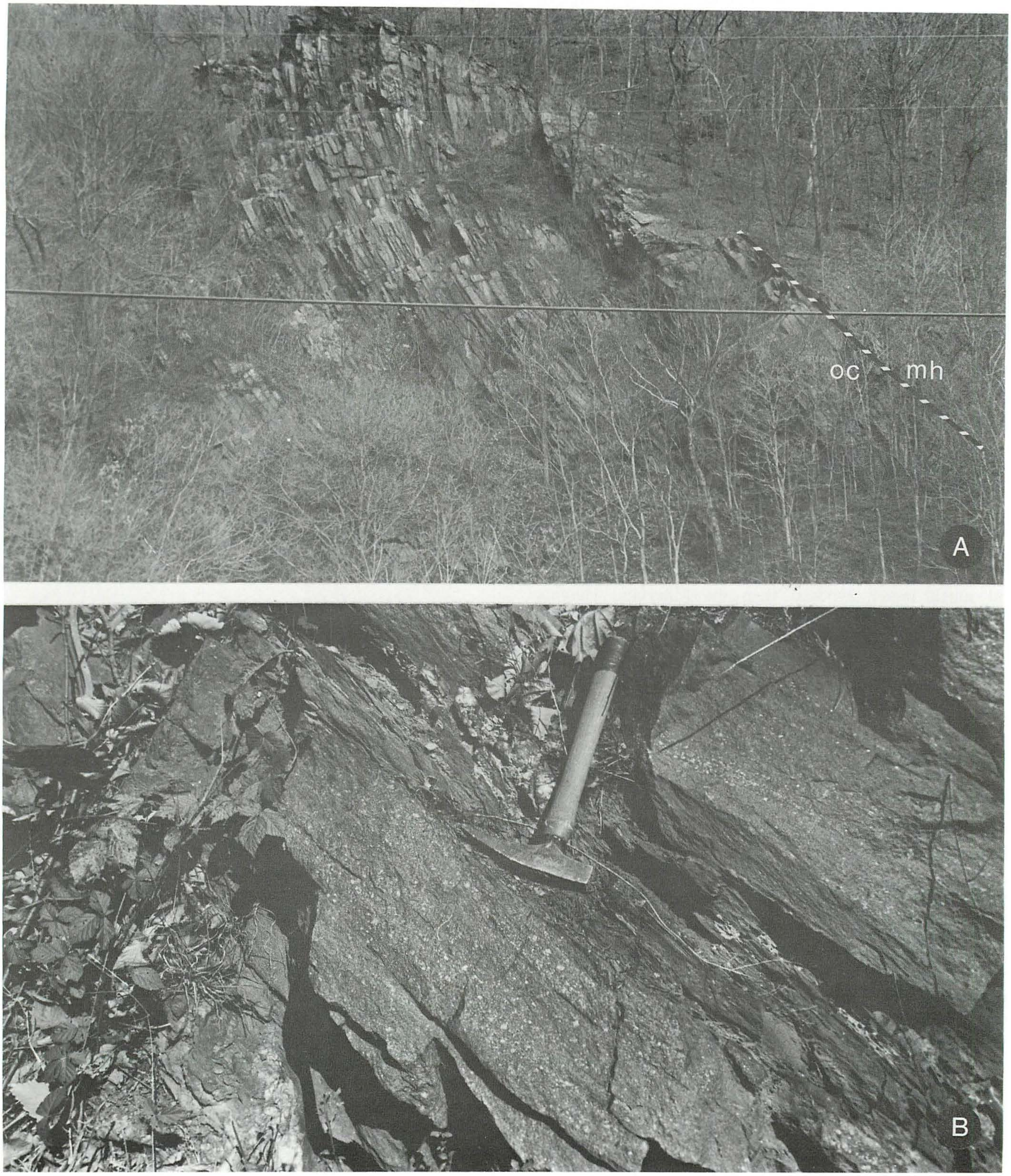
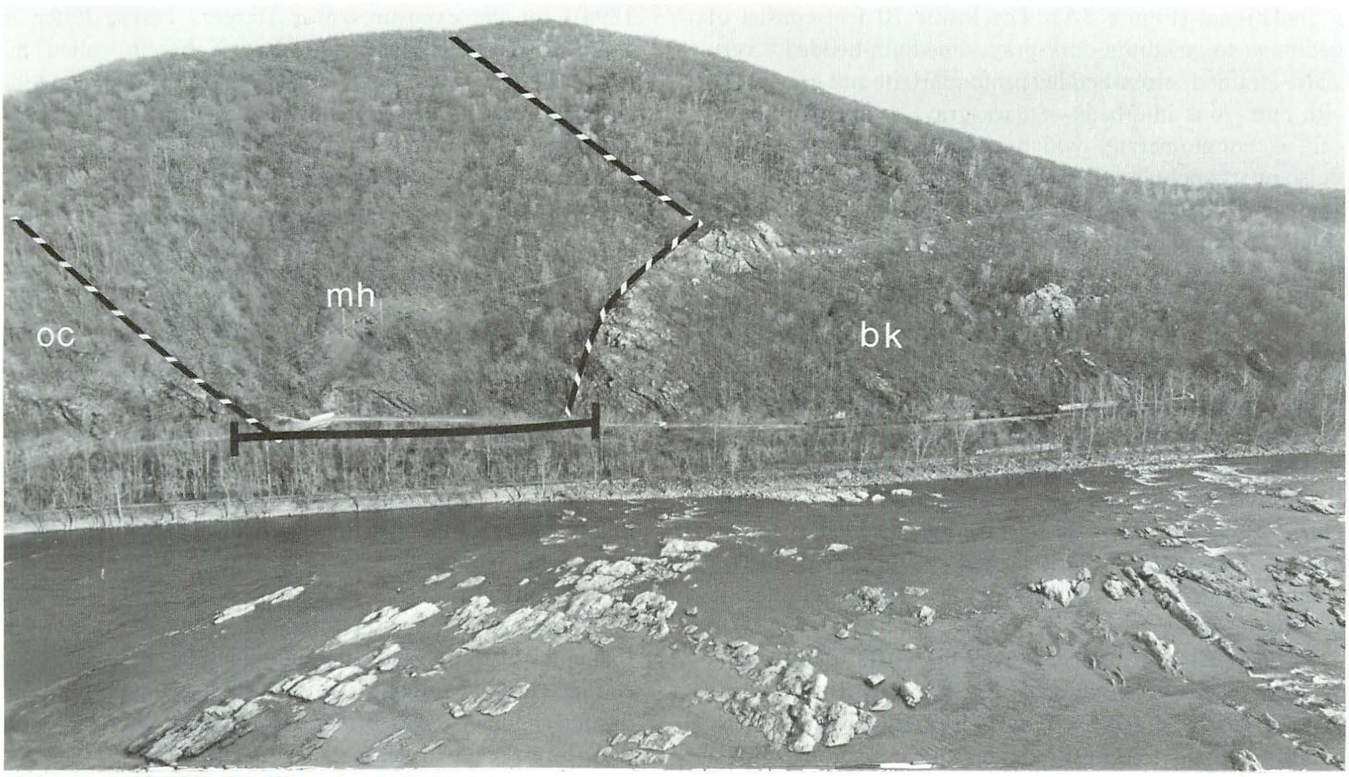


Figure 10.— A, Medium-bedded graywackes of the Owens Creek Member of the Weverton Formation at Weverton Cliffs (locality 6). B, Close-up of pebbly conglomerates within Owens Creek Member.



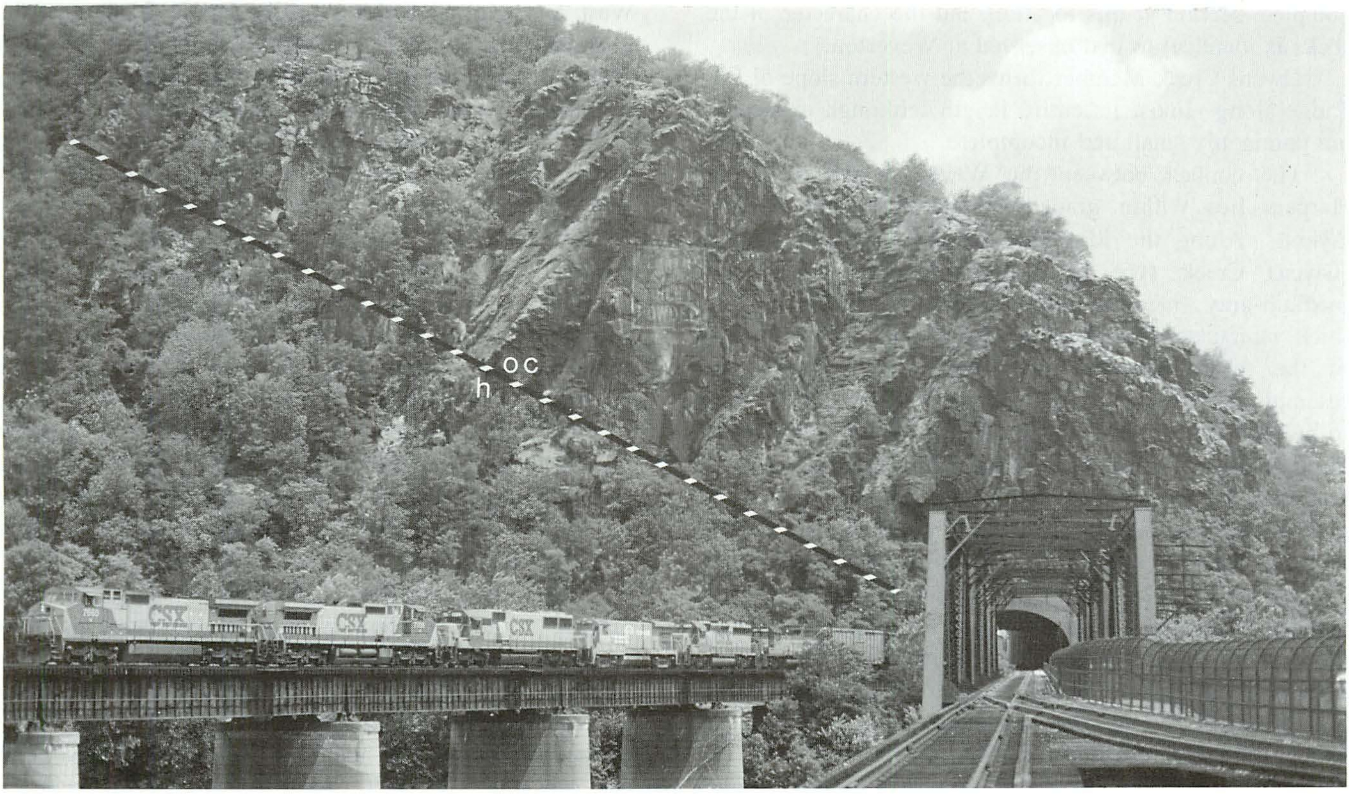


Figure 11.— A, Weverton Formation at Maryland Heights (locality 4); bk = Buzzard Knob Member; mh = Maryland Height Member type section; oc = Owens Creek Member. B, Owens Creek Member (oc) of the Weverton Formation, at Maryland Heights; h = Harpers Formation.

is gradational (Figure 8A). The lower 70 feet consist of medium- to medium-dark-gray, medium-bedded, very coarse-grained, cross-bedded protoquartzite and graywacke with numerous interbeds of dark-gray, sandy siltstone as well as conglomerate, which contains white, pink, and bluish quartz pebbles (Figure 10B). The upper 25 feet are composed of medium-light-gray to greenish-gray, medium-bedded protoquartzite. The contact with the overlying Harpers Formation is not exposed at this location. Discontinuous outcrops of this member occur along the western side of South Mountain between the Potomac River and Lambs Knoll. The same is true for the Owens Creek Members between Monument Knob and Bartmans Hill. Farther north, this member occupies the troughs of both the Black Rock and Quirauk Mountain synclines. At Raven Rock Hollow 60 feet of section are exposed. The lower 25 feet consist of thin- to medium-bedded, medium-gray, coarse-grained quartzite and the upper 35 feet of medium-bedded, very coarse-grained to conglomeratic graywacke.

Owens Creek Member forms the cliffs of Maryland Heights on the north side of the Potomac River, across from Harpers Ferry, West Virginia (Figure 11B). Intraformational folding precludes the measurement of a complete section at this location, but the character of the rocks is identical to that observed at Weverton.

Owens Creek Member forms the western slope of Elk Ridge along almost its entire length, although exposures are commonly small and incomplete.

The contact between the Weverton and overlying Harpers lies within gradational quartzite and phyllite layers. Along the Maryland Midland Railroad tracks (Owens Creek type section), numerous intervals of medium-gray, medium-bedded quartzite, 15 to 30 feet thick, punctuate the interval stratigraphically above the top of the thick Weverton quartzites. These quartzites resemble the Owens Creek Member and were interpreted to be part of the Weverton by Fauth (1977). At Raven Rock Hollow at least one medium-light-gray quartzite, 29 feet thick, is present approximately 180 feet above the Owens Creek Member. These thin quartzites are herein interpreted as part of the Harpers Formation. At Maryland Heights no such quartzites are present in the overlying Harpers Formation and the contact appears as a gradual decrease in quartzose beds and increase in shaly beds. Therefore, in northern Washington and Frederick Counties the contact interval displays an interbedded character not seen further to the south.

Harpers Formation

Overlying the Weverton Formation is an interval of shale, siltstone, sandstone and quartzite called the Harpers Formation. Initially designated as the Harper's Ferry Shale by Keith (1893) and later as the Harpers Shale (Keith, 1894), for the exposures near Harpers Ferry, Jefferson County, West Virginia, the unit is herein called the Harpers Formation. Good exposures are present along the entrance road to Harpers Ferry National Historical Park, along the CSX railroad, and the C & O Canal on the north side of the Potomac River in Maryland. However, because of structural complexity precise stratigraphic measurements are precluded. The Harpers Formation changes character between the type area and the Maryland-Pennsylvania State line where numerous quartzites are present.

In the type area around Harpers Ferry, the lower part of the Harpers Formation is characterized by several hundred feet of dark-gray to olive-black, medium-grained sandstone and siltstone with thin (1 to 4 inches) medium-gray, fine-grained sandstone. Above this lower section is 700 to 1,000 feet of greenish-black to brownish-black, highly cleaved siltstone, fine-grained sandstone, and some silty shale. Numerous fine- to medium-grained, brownish-black, olive-gray to greenish-black, medium-bedded sandstone units range in thickness from 20 to 40 feet. Examples of these sandstone units may be observed at the entrance to the National Historical Park at the north end of the Shenandoah River bridge, along the CSX tracks near the power plant at Harpers Ferry in Jefferson County, West Virginia, and along Sandy Hook Road near the junction with Hoffmaster Road in southern Washington County, Maryland. In the large area underlain by Harpers from the Potomac River north to Chestnut Grove and west of Elk Ridge, several of these sandstone units have been locally mapped, at least one of which contains abundant euhedral magnetite.

The uppermost Harpers consists of interbedded dark-greenish-gray to olive-black, sandy siltstone and shales and light-gray to medium-light-gray, fine-grained sandstone, with beds 2 to 6 inches thick. These beds contain very abundant *Skolithos* burrows. Thickness of this part of the Harpers is estimated at 500 to 700 feet. At Weverton, characterization of the Harpers is much more difficult insofar as the formation is composed of sheared siltstone and sandstone. The Harpers is poorly exposed along the east side of Pleasant Valley. Typically, quartzite boulders from the Weverton Formation cover much of the slope. Northeast of Rohrersville, two sandstone units were mapped within the Harpers and can be traced north to Alternate U.S. 40 east of Boonesboro. The lower sandstone unit consists of 25 to 30 feet of medium-light-gray weathering, dark-greenish-gray, micaceous, medium-grained sandstone with abundant *Skolithos* burrows. This unit caps the hill directly south of Zittlestown, where it was mistaken for Weverton by Jonas and Stose (1938). The upper sandstone is approximately 25 feet thick, medium-gray, and coarse- to very coarse-grained. It does not contain the pervasive *Skolithos* as does the lower unit. This sandstone is exposed along Alternate U.S. 40, just east of the intersection with Clevelandtown Road.

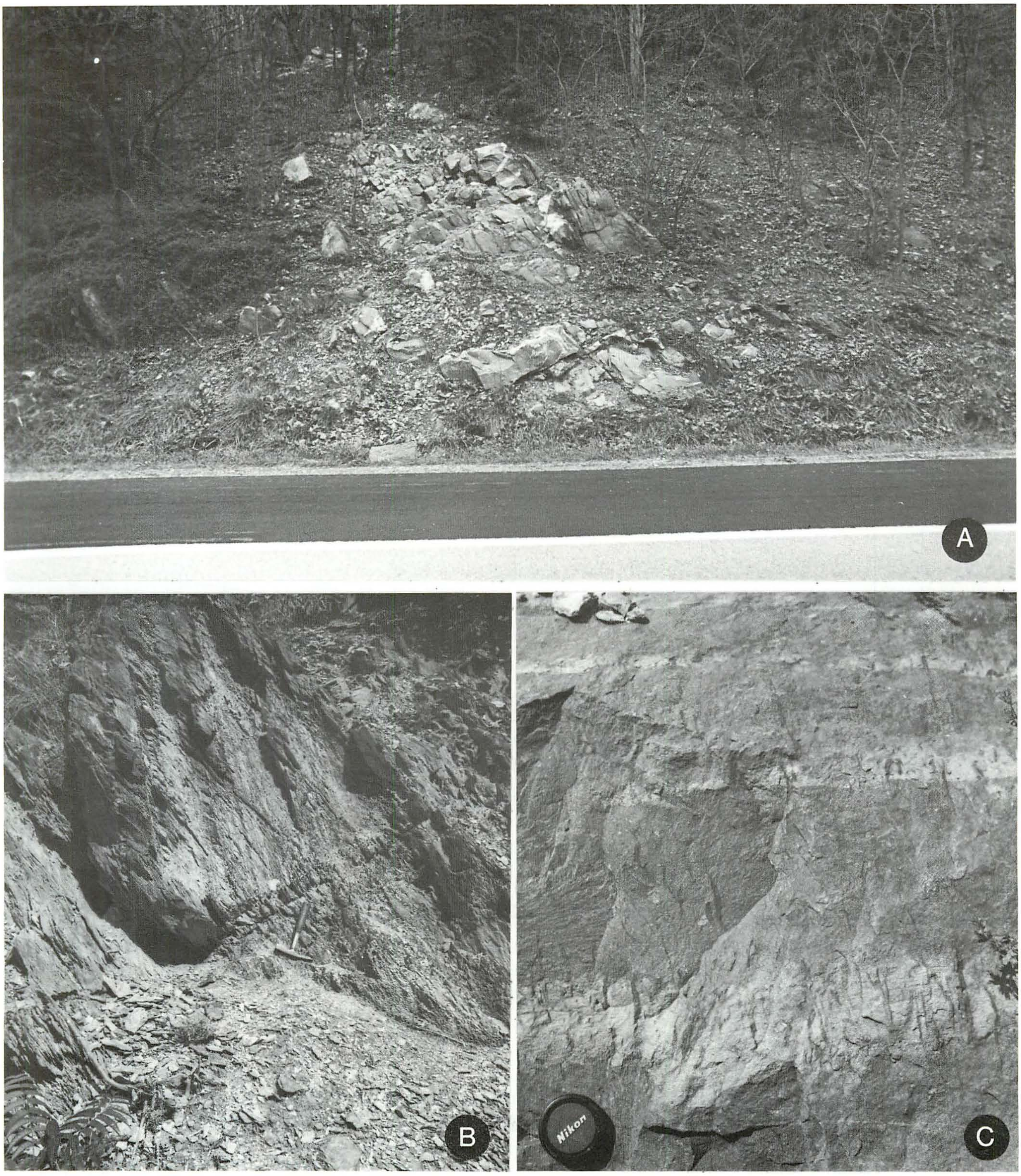


Figure 12.— A, Tongue of light-gray quartzite of the Montalto Member within darker metasiltstones of the Harpers Formation at locality 3. B, cleavage and bedding relationship within the middle part of the Harpers. Note vertical thin sandstone interbeds. C, *Skolithos* burrowed sandstones characteristic of the upper part of the Harpers.

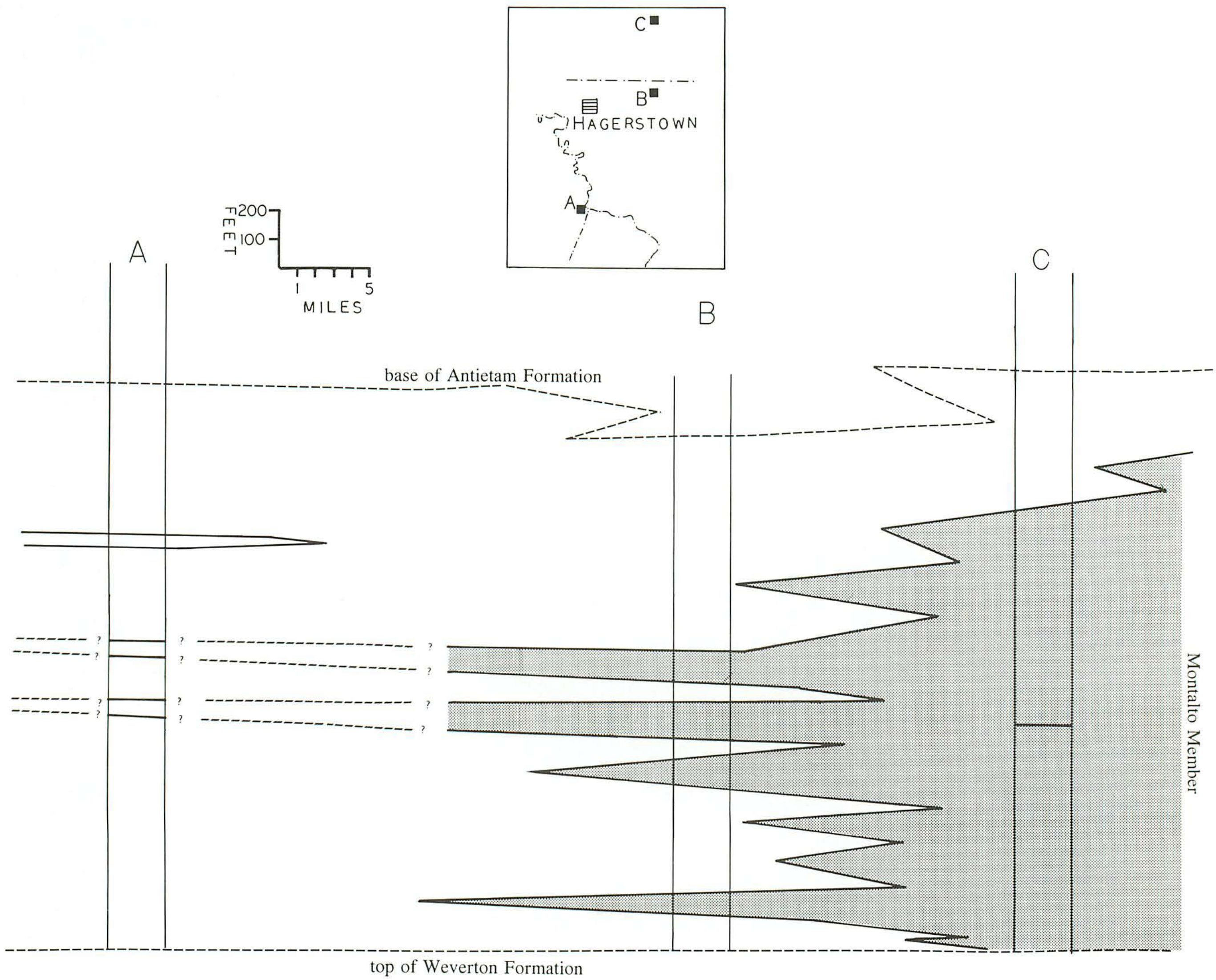


Figure 13.— Generalized interpreted relationships between the Montalto Member of the Harpers Formation near Caledonia Park and formational type area. A, the type area near Harpers Ferry, West Virginia. Quartzites of the Montalto intertongue with ferruginous siltstone and shale of typical Harpers to the south. B, Pennsylvania-Maryland State Line; C, Caledonia Park, (from Fauth, 1968).

There is little exposure of the Harpers between, Alternate U.S. 40 and Mt. Aetna. At Mt. Aetna, intensely deformed greenish-gray and medium-gray, interbedded shale, siltstone, and light-gray sandstone with *Skolithos* burrows have been mapped previously as Antietam, but more likely these beds are part of the Harpers.

From Foxville Gap north to the Maryland-Pennsylvania State line, prominent sandstone and quartzite units may be recognized within the lower part of the Harpers. The lowest of these units occurs approximately 180 feet above the Weverton (Figure 12A). This 30-foot-thick quartzite is light-gray, vitreous, medium-bedded, and coarse-grained; and it contains rare *Skolithos* burrows. This quartzite is interpreted as a tongue of the Montalto Member of the Harpers Formation of Pennsylvania.

This stratigraphic interval is occupied by quartzite at Owens Creek, where a medium-bedded quartzite, approximately 20 feet thick, occurs roughly 150 feet above the uppermost part of the Weverton. Fauth (1977) included this quartzite within the upper part of the Weverton.

However, numerous quartzite intervals are present in the Harpers section, both along the Maryland Midland Railroad tracks and Maryland Route 550 indicating that this type of interbed is not uncommon. Because these quartzites intertongue with metasiltstones of the Harpers Formation, they are herein assigned to the Harpers.

A prominent sandstone layer is also recognized from Foxville Gap north into Pennsylvania. This sandstone is partially exposed along the Edgemont Reservoir and along Falls Creek near Pen Mar where it consists of dusky-yellowish-brown, brownish-black, and dark-greenish-gray, medium- to coarse-grained, chloritic, locally ferruginous sandstone. This sandstone, which is 50 to 75 feet thick, may occur as two separate ledges. *Skolithos* burrows are common but not pervasive. Detailed mapping of this sandstone in Maryland and reconnaissance mapping extending into southern Pennsylvania show that this is correlative to the Montalto Member of the Harpers Formation of Pennsylvania, as reported by Jonas and Stose (1938). The existence of this unit in Maryland as two separate ledges may be attributable to bifurcation of massive sandstone tongues near their maximum extent (Figure 13). Fauth (1968) proposed that, in the Caledonia Park area of Pennsylvania, the Montalto is 1,600 to 1,900 feet thick and can be subdivided into lower and upper quartzite members. The lower quartzite apparently immediately overlies the Weverton. Consequently, the lower quartzite at Raven Rock Hollow and the numerous quartzite intervals observed along Owens Creek probably represent tongues of the lower part of the Montalto (Figure 13).

It is not certain whether the numerous sandstone units in the Harpers type area may represent distal parts of the Montalto tongues. Although this is plausible, discontinuous outcrops between the Pen Mar area and the Harpers Ferry area preclude demonstration of this relationship.

Cloos (1951) measured 3,100 feet of Harpers in southern Franklin County, Pennsylvania, but remeasurement of this section does not support his findings. The threefold subdivision into lower, middle, and upper members as proposed by Cloos is evident. The middle sandstone member suggested by Cloos is almost certainly equivalent to the Montalto Member. However, measurement of the upper member suggests that this member is only about 650 feet thick, and not the more than 1,900 feet proposed by Cloos (1951, p. 34). The upper Harpers in this area in dominantly interbedded light-gray sandstones with *Skolithos* burrows and fine-grained, dark-greenish-gray, silty sandstone.

The Harpers Formation of Maryland and Pennsylvania is equivalent to the Hampton Formation of southwestern Virginia and northeastern Tennessee and the Nichols Shale of east-central Tennessee (Schwab, 1971; Simpson and Sundberg, 1987). Simpson and Sundberg (1987) proposed that the Hampton Formation spanned much of the Early Cambrian *Fallotaspis* and *Nevadella* Biozones. During this study *Skolithos* and *Rusophycus* burrows were the only fossils observed from the Harpers Formation.

The contact between the Harpers Formation and overlying Antietam Formation is gradational. It is commonly difficult to place the contact, because the intercalation of sandstone and siltstones occupies a thick interval. A contact may be identified along Pennsylvania Route 16 (locality 7). Where the Harpers consists of alternating light-gray, medium-grained, *Skolithos*-burrowed sandstone, 2 to 6 inches thick, and dark-greenish-gray to greenish-black, very fine-grained sandstone and siltstone. In the contact interval, the greenish-gray to greenish-black siltstone is lighter in color and, higher in the section, is replaced by very fine-grained, silty sandstone and light-brown, medium-grained, medium-bedded sandstone (Figure 14A). These light-brown sandstone strata alternate regularly with light-gray sandstone beds. The contact is placed above the greenish siltstone and grayish-green, fine-grained sandstone of the Harpers and where tan silty sandstone and thick intervals of pure, well-sorted sandstone occur. The contact is also exposed along the C & O Canal at Lock 38, where the progression from olive siltstone to light-gray-brown sandstone may be observed.

Antietam Formation

Overlying the Harpers Formation is an interval of medium-bedded, light-colored quartzarenite that Keith (1892) called the Antietam Quartzite and, later (Keith, 1893), the Antietam Sandstone. Keith (1894) noted that the lower beds are transitional with the underlying "Harpers shale" but that the formation is entirely composed

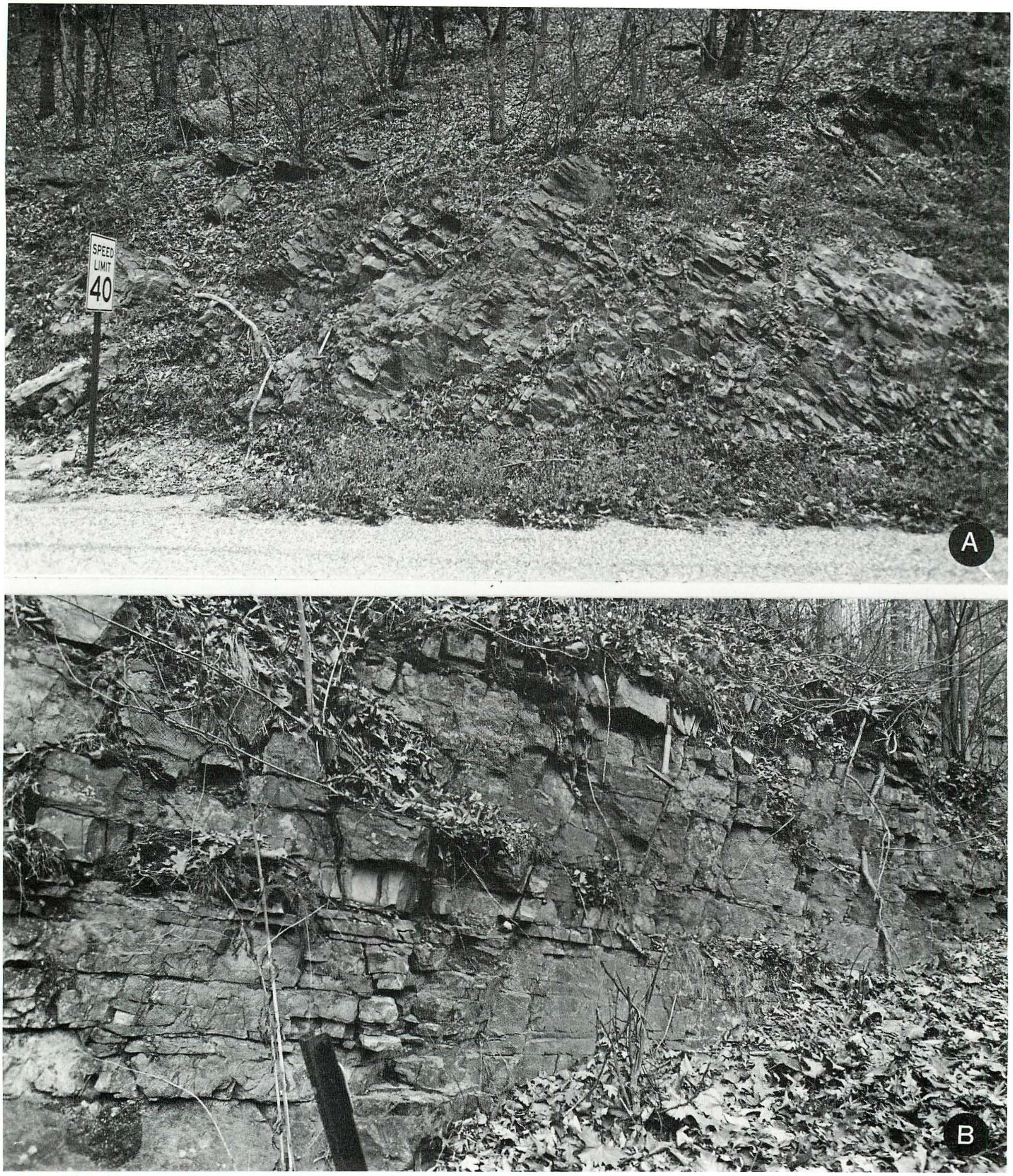


Figure 14.— A, Gradational lithologic change from greenish-gray siltstones of Harpers Formation to tan and brown siltstones of the lower part of the Antietam Formation (locality 7). B, Characteristic interbedded sandstone and shale of the middle part of the Antietam Formation along Sharmans Run, Washington County, Maryland.

of sandstone. Although the formation is dominantly sandstone, thre are numeraousthin siltstone beds and shale partings are pervasive in the lower half of the formation.

The quartzose strata of the Antietam generally form a prominent ridge, considerably lower than the ridges formed by the Weverton Formation, but parallel to them. The Antietam ridges are covered by angular sandstone blocks, but rarely is any bedrock exposed. Examples of such ridges include: Red Hill, the short ridge which extends northeast from Rohrersville for 1.5 miles; the ridge which extends north from Boonesboro to east of San Mar, from there zigzags eastward to Greenbrier State Park; and the ridge which begins east of Mt. Aetna fire station and continues north to Foxville Gap (see Plate 2).

The type area of the Antietam is along tributaries to Antietam Creek (Keith, 1894) in southern Washington County, Maryland, east of the town of Sharpsburg and village of Antietam. It is not clear which tributaries Keith meant in his initial description. Attempts by this author to locate exposures of this sandstone in this area proved fruitless. Although the Antietam typically forms a prominent ridge where it crops out, none of the numerous tributaries of Antietam Creek traverses good exposures of the formation. In fact, except for a small exposure along Sharmans Run near Mount Briar, Washington County, Maryland, no exposures of this formation occur in the type area. Furthermore, it should be noted that this formation is very poorly exposed elsewhere in Maryland. Nonetheless, small and incomplete exposures provide sufficient information as to the general lithologic progression from bottom to top.

The lower 200 to 300 feet of the Antietam contains regularly bedded, very light-gray, very fine- to fine-grained, well-sorted, quartzarenitic sandstone and interbedded darker, sandy siltstone to silty sandstone. Sandstone beds are between 1.5 to 4 inches, but become thicker upsection (Figure 14B). *Skolithos* burrows are common in these beds.

This lower part of the Antietam crops out at numerous locations. Very light-gray sandstone and interbedded, brown siltstones are prominent along the C & O Canal (at Lock 38) east of the Maryland Bank. Numerous hilltops from Hawk Hill northwest to Chestnut Grove are capped by this part of the formation. Lower strata of the Antietam also crop out on the north side of the dam in Greenbrier State Park. On the ridge just east of Mt. Aetna School and Mt. Aetna fire station, 70 to 110 feet of interbedded, white, bioturbated sandstone and tan siltstone are exposed. Although these strata have been mapped as Antietam by Fauth (1981), assignment to the upper part of the Harpers Formation is not precluded. At this location the middle and upper strata of the Antietam are not recognized. No Antietam crops out between these outcrops and Greenbrier State Park. Likewise, the Antietam is poorly expressed from Foxville Gap east of Cavetown, Washington County, Maryland north into Pennsylvania. This lack of exposure is attributed to removal by faulting. Along Pennsylvania Route 16 east of Rouzerville, the lower part of the Antietam is again exposed.

The middle 200 to 300 feet of the Antietam consist of a lithology that may be considered characteristic for the formation in Maryland. This part of the Antietam is comprised of very light-gray, yellowish-gray, and light-olive-gray, medium-bedded, fine- to medium-grained sandstone (Figure 14B). Interbeds of very coarse-grained sandstone, and thin conglomerate are common. The sandstone is well-sorted, arkosic sublitharenite.

Several small exposures of this part of the Antietam are worthy of note. Near the type area, the ridge extending from just west of Dargan, Washington County, Maryland northeast to Flickerville, Washington County, Maryland and Red Hill is covered with blocks of this lithology. From Red Hill, the outcrop curves southeastward toward Chestnut Grove. At Sharmans Run, Washington County, Maryland along Burnside Bridge Road, 52 feet of the medium-bedded sandstone are exposed (Figure 14B). In northern West Virginia, 45 feet of the middle part of the Antietam are exposed along the CSX tracks near Millville. Along Pennsylvania Route 16, discontinuous outcrops expose approximately 100 feet of medium-bedded sandstones.

The uppermost 50 to 100 feet of the Antietam are more poorly exposed than any other part of the formation. Indeed, exposures of this stratigraphic interval are not known in Maryland. However, along the Shenandoah River southwest of Shannondale, West Virginia, (locality 8) the uppermost 50 feet of Antietam crop out. The section consists of medium-gray to olive-gray, medium- to thick-bedded, medium- to very coarse-grained, cross-bedded sandstone and interbedded, green shale and tan siltstone.

In Maryland, these strata are known only from float blocks, which are quite diagnostic. Commonly, blocks are large (0.2 to 2.0 feet), irregularly shaped, medium-gray, and exhibit a pitted to vuggy, iron-stained surface. This part of the Antietam is coarser grained than the stratigraphically lower intervals and is cemented by carbonate (Nickelsen, 1956). Examples of such lithologies may be observed near the nose of Red Hill, along Churchey Road at Flickerville, and in the cove south of Greenbrier in Greenbrier State Park.

In Pennsylvania, the character of the Antietam changes. At White Rock, east of Pond Bank in Franklin County, the Antietam consists of a pure white, thick-bedded, *Skolithos*-burrowed quartzarenite. In this area fractures and bedding planes are stained with iron compounds. From this area to the north and east, the Antietam resembles the quartzite of the Montalto Member of the Harpers Formation rather than the medium-bedded sandstone common in Maryland and West Virginia.

The Antietam Formation generally correlates with the

Erwin Formation of southwestern Virginia (Palmer, 1971; Schwab, 1971; Simpson and Sundberg, 1987). The age of the Antietam is unequivocally Early Cambrian. This is documented by Walcott (1896) who found the trilobite *Olenellus* in addition to other Early Cambrian fossils such as hyolithids, ostracodes and brachiopods. Therefore, the Antietam Formation is, at least in part, assignable to the *Bonnia-Olenellus* Biozone of Early Cambrian age. During this study only the trace fossils, *Skolithos*, *Rusophycus* and *Planolites* were observed. And although these traces possess only a marginal significance for biostratigraphic zonation, some intervals within the formation are replete with their remains.

The contact between the Tomstown and underlying Antietam Formation is rarely exposed. Typically the Antietam is thrust over the less resistant Tomstown (Plate 2), and the contact is commonly covered by colluvium.

At locality 8, however, the contact between the Antietam and the basal Tomstown is relatively sharp and appears to be conformable. Fifty feet of the uppermost Antietam Formation, a medium-bedded, gray and tan, cross-bedded quartzite, are exposed. The lowest part of the Tomstown consists of tan, sandy dolomite, overlain by 40 feet of very light-gray to tan, knobby-weathering, vuggy dolomite.

In Maryland the Antietam-Tomstown contact is exposed along Little Antietam Creek at Eakles Mills. There the contact is also sharp with the tan vuggy dolomite overlying coarse-grained sandstones of the Antietam Formation.

Tomstown Formation

Stratigraphic studies of the Cambrian and Ordovician carbonate sequence of the Great Valley are numerous. However, detailed stratigraphic investigations of some individual formations are lacking. One such formation that has received very little attention is the Early Cambrian Tomstown Formation. So poorly known is this formation that its lithologies have commonly been misidentified. This has led to a number of instances where the unit has been mismapped and its thickness misrepresented.

Stose (1906) applied the name Tomstown Dolomite to carbonate rocks that occur above the Antietam Formation and below the shale of the Waynesboro Formation. In the type area of the formation, near the village of Tomstown, Franklin County, Pennsylvania, only scattered outcrops of the formation occur. From these few isolated exposures it is impossible to obtain a representative section of the entire formation. Stose (1910) estimated that the Tomstown Formation is approximately 1,000 feet thick in the type area. Root (1968) estimated a thickness of 1,350 to 2,100 feet, based upon outcrop width and general dip, but like Stose, was unable to characterize the lithology of the unit completely.

In Maryland, Cloos (1951) believed that the thickness variations previously noted for the Tomstown could be attributed to bed distortion due to South Mountain folding. Reinhardt and Wall (1975) compiled a composite stratigraphic section, based on three localities in Maryland. From this section they proposed that the Tomstown Formation in Maryland was 500 feet thick, considerably less than that proposed for adjacent states.

Detailed geologic mapping in Maryland, reconnaissance mapping in West Virginia, and study of previously undescribed sections of the Tomstown in Maryland, Pennsylvania, and West Virginia demonstrate that the composite section of Reinhardt and Wall misrepresents both the thickness and vertical arrangement of lithologies in the Tomstown Formation. The reasons for this may be attributed to errors in two of their three measured sections. Firstly, the Keedysville section, used as a basis for the lower part of the Tomstown, has been overturned and rotated more than 180°, so that the "base" of that measured section represents the stratigraphic top of the section. Consequently, this part of Reinhardt and Wall's section is reversed. Secondly, recent geologic mapping by this author shows that the Cavetown section is the middle part of the Waynesboro and not the upper part of the Tomstown as believed by Reinhardt and Wall.

In West Virginia, Woodward (1949) reported that the Tomstown attains thickness of 1,200 to 1,500 feet, but was well exposed only in Jefferson County near the Potomac and Shenandoah Rivers. Further south in Virginia, King (1950) believed that the Tomstown is about 1,000 feet thick, but noted its similarity to the Shady Dolomite in both stratigraphic position and lithology. Butts (1940) noted that the name Shady had traditionally been used south of Roanoke, Virginia and Tomstown to the north. In the area of Austinville, Wythe County, Virginia, the Shady is 1,800 to 4,000 feet thick, and subdivided into three members (Pfeil and Read, 1980).

Four laterally continuous members of the Tomstown may be mapped and traced from the type area in southern Pennsylvania through Maryland and into the eastern panhandle of West Virginia. In ascending order these are the Bolivar Heights, Fort Duncan, Benevola, and Dargan Members.

The age of the Tomstown Formation is generally considered to be Early Cambrian (Bassler, 1919). Yochelson (1970) and Reinhardt and Wall (1975) proposed the use of the problematic fossil *Salterella conulata* as a guide for Lower Cambrian correlations in the Appalachians. Palmer (1971, Figure 10) has shown that subjacent Antietam and equivalent Kinzers of Pennsylvania contain a Lower Cambrian olenellid trilobite fauna. In Maryland no identifiable trilobites were collected during this study; however, *Salterella* remains are common within the Fort Duncan Member and rare in the Bolivar Height Member. Therefore, an Early Cambrian age is herein

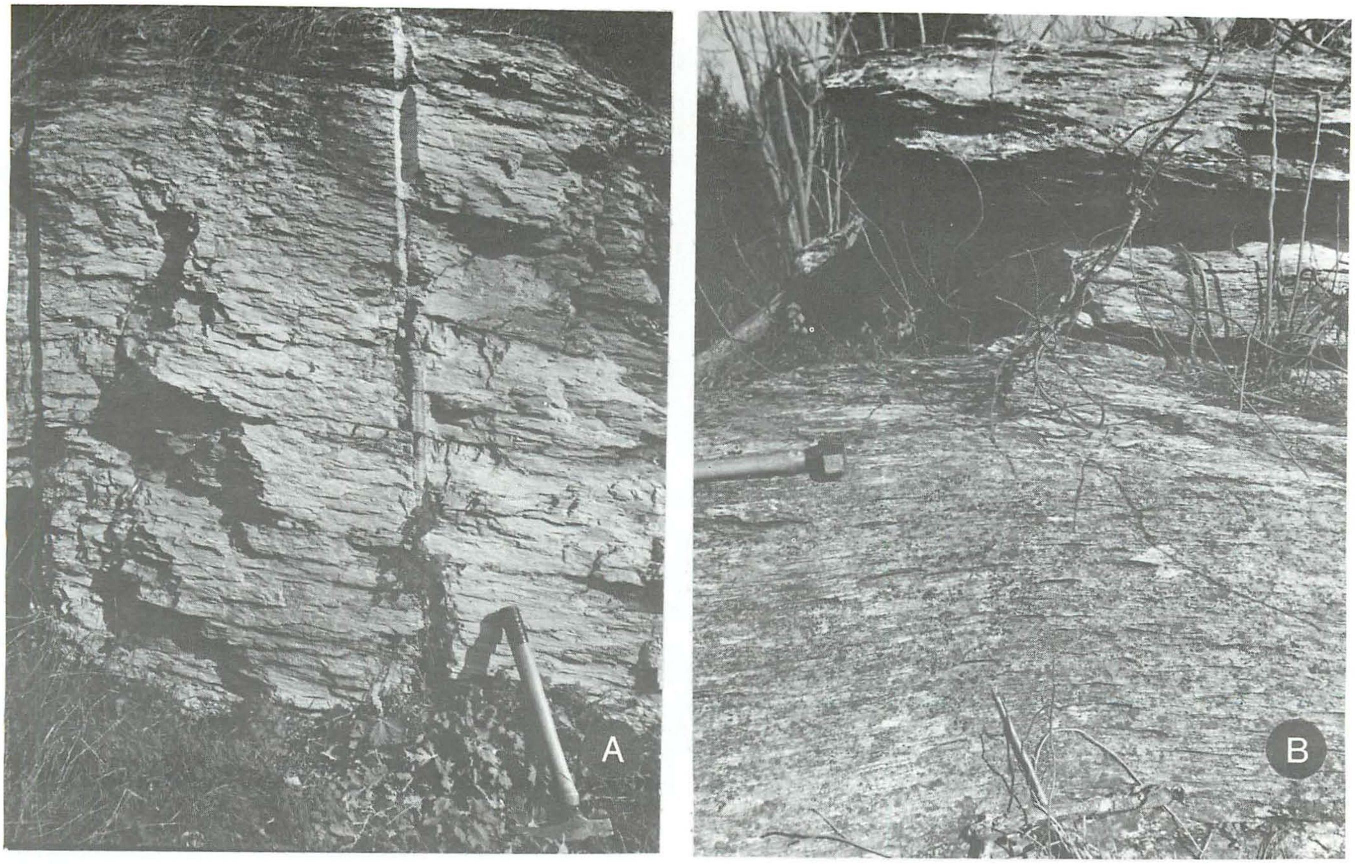


Figure 15.— A, B, Marble unit at the base of Tomstown Formation (Keedysville marble bed) along Dog Street Road, Washington County, Maryland.

assigned to the Tomstown Formation.

Bolivar Heights Member (New): The basal member of the Tomstown Formation is herein named the Bolivar Heights Member. The type section (locality 10) of this member is along the CSX Railroad tracks at the north end of Bolivar Heights, 1.5 miles west of the confluence of the Potomac and Shenandoah Rivers at Harpers Ferry, Jefferson County, West Virginia. The Bolivar Heights Member is characterized by three stratigraphically stacked lithologies. The basal lithology is a tan, vuggy dolomite that is in contact with the underlying Antietam Formation. This dolomite ranges from 10 to 40 feet in thickness, but is rarely exposed. Overlying the tan basal dolomite is an interval 40 to 50 feet thick, comprised of very light-gray, sheared, laminated, dolomitic marble (Figure 15 A,B). This marble is well exposed in the vicinity of Keedysville where it has, in the past, been quarried at numerous locations. Hereafter in this report this interval will be termed the Keedysville marble bed. The Keedysville marble bed contains layers of muscovite and chlorite blebs and is lineated throughout. Although it currently serves as a stratigraphic marker bed, it is clear that these strata have tectonic rather than sedimentologic origins. Above the Keedysville marble bed the Bolivar Heights Member consists of about 200 feet of thin- to medium-bedded, dark-gray, ribbony, burrow-mottled, lime mudstone that weathers light gray in color. The number and density of burrows varies among beds with very little burrowing in some layers and an anastomosing network of burrows in others. Throughout this member the burrows are either dolomitized or silty, and tend to stand in relief from the surrounding limestone (Figure 16A). The amount and density of bioturbation generally tends to increase upsection. This member is exposed in numerous field along Maryland Route 68, west of Boonesboro, Washington County, Maryland and in the vicinity of Keedysville. Inasmuch as the lower part of the Tomstown is commonly overturned and strongly deformed the sedimentary structures in the limestone of this part of the Tomstown commonly have been deformed by intrastratal folding (Figure 16B).

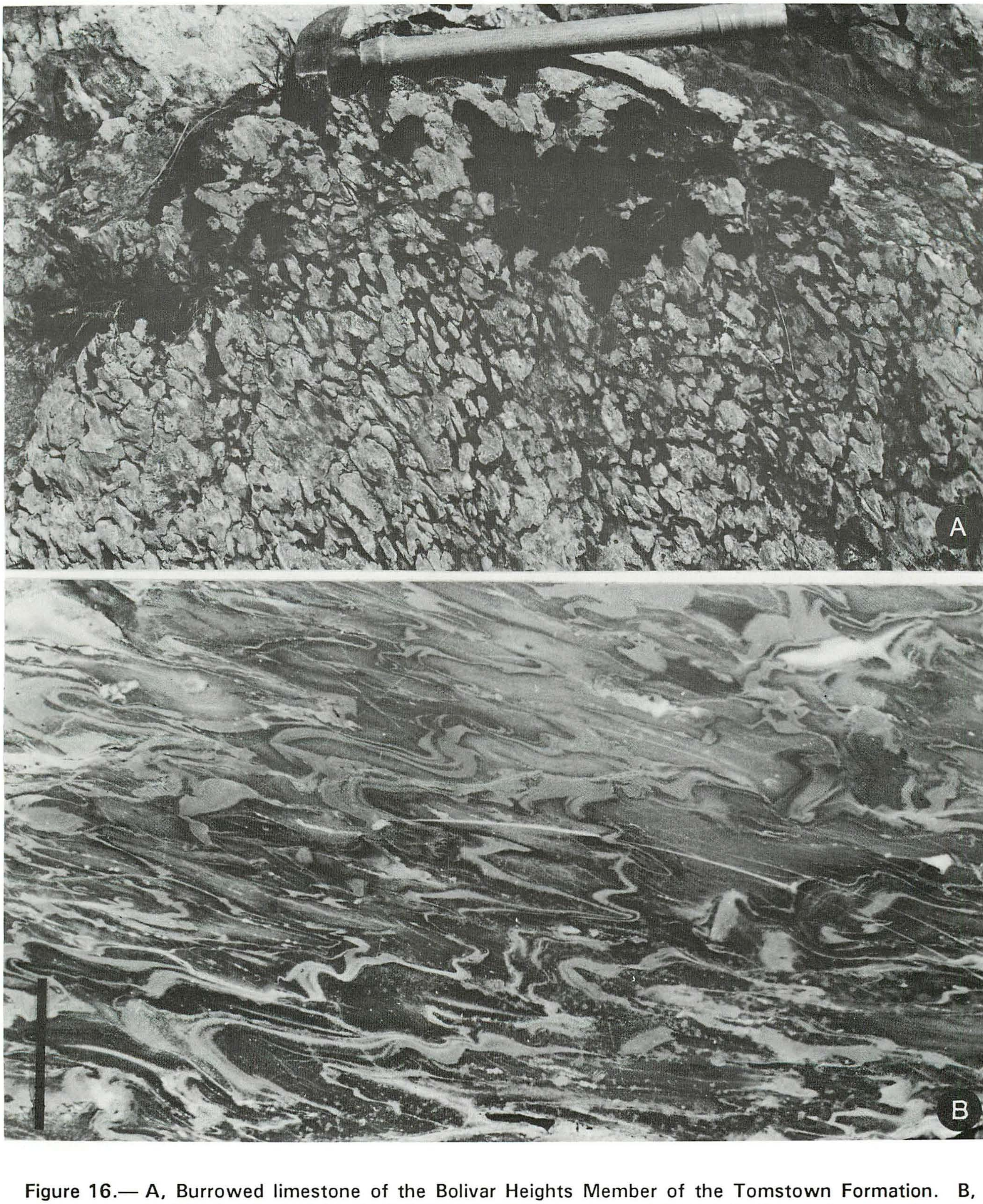


Figure 16.— A, Burrowed limestone of the Bolivar Heights Member of the Tomstown Formation. B, Polished slab of highly folded limestone from overturned fold limb. Bar scale approximately 1.0 inch.

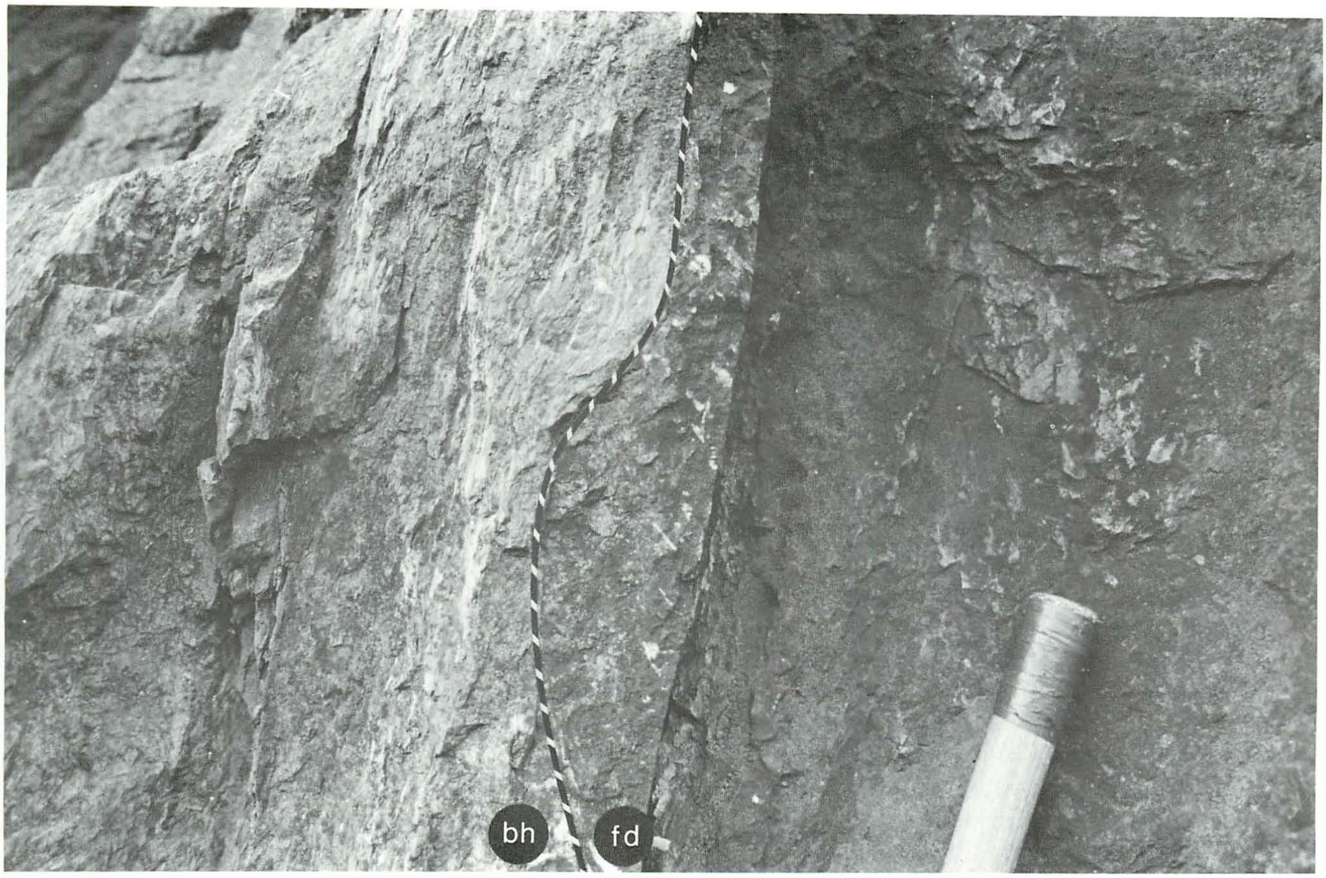


Figure 17.— Sharp contact between Bolivar Heights (bh) and Fort Duncan Members (fd) of the Tomstown Formation at locality 10.

The Bolivar Heights Member is recognizable for approximately 50 miles along the Blue Ridge Front from the Virginia-West Virginia State line south of Shannondale (locality 8), north to the Tomstown type area in Franklin County, Pennsylvania. In Pennsylvania the presence of the Bolivar Heights Member is confirmed by reconnaissance geologic mapping in that area. In Maryland, north of Interstate 70, the Bolivar Heights Member is known from a few scattered exposures.

Based on equivalent stratigraphic position, the Bolivar Heights Member of the Tomstown is considered correlative with the lower part of the Patterson Member of the Shady Dolomite in the Austinville, Virginia area. Although both members are limestone, the Bolivar Heights differs from the Patterson in that the former is characterized by burrow-mottled limestone and the latter by rhythmically bedded, ribbon limestones.

Fossils are little known from this member. They may be scarce, but deformation may have contribute significantly to the obfuscation of existing remains. However, at locations where deformation is relatively minor, *Salterella* and possibly trilobite fragments may be observed.

The contact between the Bolivar Heights and the overlying Fort Duncan Member is well exposed at locality 10, where burrow-mottled limestones of the Bolivar Heights Member are sharply overlain by dolomite. This contact may be erosional (Figure 17). This contact is also exposed along the abandoned railroad grade west of Keedysville. At this location the members have been overturned and dip to the northwest, and the contact also appears to be sharp.

Fort Duncan Member (New): Sharply overlying the limestone of the Bolivar Heights Member is an interval, 180 to 250 feet thick, of medium- to thick-bedded, dark-gray dolomite named the Fort Duncan Member. The type section for the Fort Duncan Member is along the C & O Canal, on the Maryland side of the first northward meander of the Potomac River west of Harpers Ferry. This same meander loop was the previous location of Fort Duncan, hence the name of the new member (locality 11).

Ubiquitous burrow mottling is a distinguishing characteristic of the Fort Duncan Member, especially conspicuous on weathered surfaces (Figure 18A). In polished slabs, this member typically exhibits the burrowed

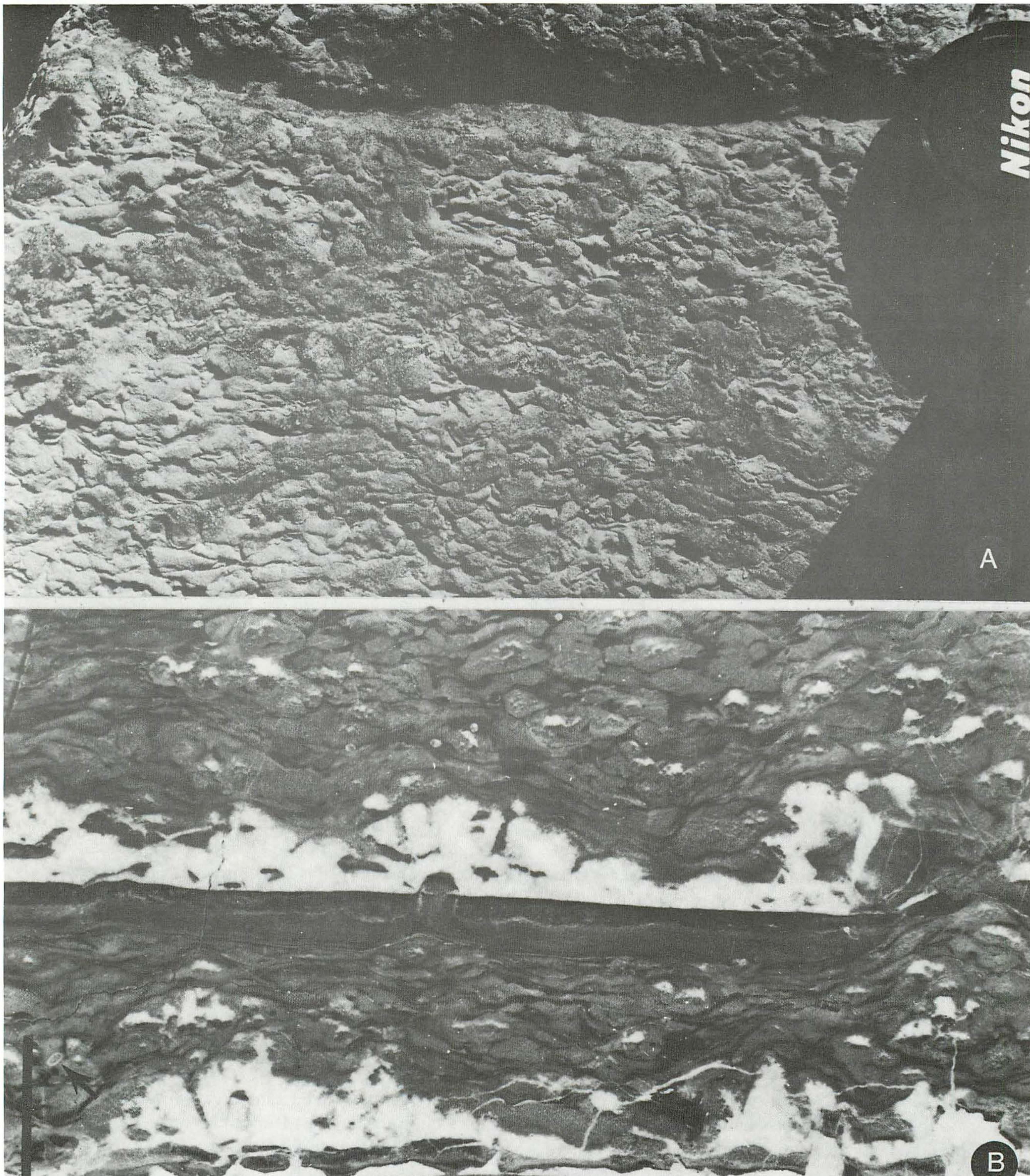


Figure 18.— A, Characteristic surface weathering characteristics of the dolomites of the Fort Duncan Member of the Tomstown Formation. B, Polished slab of dolomites of the Fort Duncan Member. White layers are sparry dolomite. Bar scale is 1.0 inch. Note *Salterella* at lower left (arrow).

texture as medium- to dark-gray, mottled aphanitic dolomite with white, void-filling, sparry dolomite (Figure 18B). Individual burrows show no internal structure, so it is not certain whether they record an anastamosing burrow network or some other organic product such as algae. At several locations, layers of the white, sparry dolomite 0.5 to 1.5 inches wide, fill voids that are continuous in beds for up to several yards (Figure 18B). Within these horizons the base of the sparry dolomite is sharp and flat and the upper surface irregular, sometimes resembling flat-pebble conglomerate. The white, void-filling dolomite so contrasts the darker, burrowed dolomite that, even in small hand samples, the texture of the rock is unmistakable. Locally, thin beds, 0.5 to 2.5 feet thick, of dense unburrowed dolomite punctuate the bioturbated sequence.

Fort Duncan lithologies crop out along the CSX tracks at the Bolivar Heights type section and along the C & O canal at numerous meander bends in Maryland. It is especially well exposed near Dargan, Washington County, Maryland (locality 13) along the C & O canal (locality 11) and in the fields south of Harpers Ferry Road, south of the junction with Mill Farm Road (see Reinhardt and Wall, 1975, location c). This member forms a nearly continuous outcrop band on the western flank of the Red Hill anticline. It is not present on the eastern limb of this fold and is apparently removed by faulting. North of Wagners Crossroads, this member is known from only a few scattered exposures in the vicinity of Pondsville, Washington County, Maryland. Scattered outcrops near Tomstown, Pennsylvania indicate that this member extends at least that far north.

In most polished slabs and in many hand specimens, outlines of *Salterella* abound (See arrow of Figure 18B). Other than this genus, no other fossils are known within this member.

The contact of the Fort Duncan Member with the overlying Benevola Member is gradational over approximately 15 feet. The first indication of change is the gradual decrease in the amount and distinction of bioturbation combined with a gradual change from dark-gray dolomite to very light-gray dolomite. The contact is placed where no more distinct burrows are evident, as is exhibited in the exposure along the C & O Canal at Fort Duncan (locality 11) and Lime Kiln Road, northeast of Dargan (locality 13).

Benevola Member (New): Stratigraphically above the dark-gray, burrowed beds of the Fort Duncan Member are 70 to 140 feet of light-gray to white, unbedded dolomite named the Benevola Member. This dolomite is currently quarried near the town of Benevola, in a quarry owned by Martin Marietta Corporation. Brezinski (1991) included this member within his informal upper member. However, the lithogic character, laterally continuous nature, ease of recognition, and economic utilization of this interval prompt this subdivision into a separate member. The type section is at the south end of the quarry, where 120 feet of the member are exposed (Figure 19). The dolomite is quarried because of its high purity.

The dolomite that characterizes the Benevola Member varies from white to very light-gray both on fresh and weathered surfaces and has a sugary appearance. Bedding is rarely evident within the Benevola Member; however, the unit is typically highly fractured (Figures 19, 20A). In polished slabs, faint ghosts of cross-bedding are common (Figure 20B).

At the type section the Benevola Member consists of two massive dolomite units. Separating a lower 50-foot-thick massive dolomite from an upper 60-foot unit is an interval, 17 feet thick, comprised of laminated and bioturbated, gray dolomite.

This same white dolomite is also quarried near Millville, Jefferson County, West Virginia. The abandoned quarry east of Millville extends northward for approximately 1.5 miles, tracing the distribution of the pure dolomite (Figure 20A).

Other reference sections include: along the C & O Canal west of Dargan, Washington County, Maryland (locality 13); and along the Shenandoah River southwest of Shannondale, Jefferson County, West Virginia (locality 9) (Figure 21). From the type section near Benevola northward into Pennsylvania, only a few scattered exposures are known. In the formational type area this same lithology is present along a road 0.6 mile south of Tomstown, Pennsylvania. No fossils have been recovered from this member.

Based on descriptions by Butts (1940), the Benevola Member of the Tomstown Formation may be correlative to the Austinville Member of the Shady Dolomite of southern Virginia. Both are white, thick-bedded to massive, saccharoidal dolomite. The Benevola Member is also similar to the Early Cambrian Ledger Dolomite of York County, Pennsylvania. Unfortunately, these correlations are based on gross appearance, and no fossil evidence is available to substantiate these lithologic correlations.

The contact between the Benevola Member and the Dargan Member of the Tomstown is gradational. It occurs within a section of light-gray, thick-bedded to massive dolomite, alternating with thinly laminated dolomite. The contact is placed where light-gray, coarse-grained dolomite, typical of the Benevola Member, acquires a burrow-mottled to laminated appearance (Figure 19).

Dargan Member (New): The uppermost part of the Tomstown is named the Dargan Member. The type section designated for this member is along the Chesapeake and Ohio Canal and adjacent Lime Kiln Road, 1.5 miles northwest of the village of Dargan, Washington County, Maryland (locality 13).

Figure 19.— East wall of quarry at Benevola (locality 12) exhibiting Benevola-Dargan contact. b = top of unbedded Benevola Member of the Tomstown Formation, d = medium-bedded dolomites of the Dargan Member.

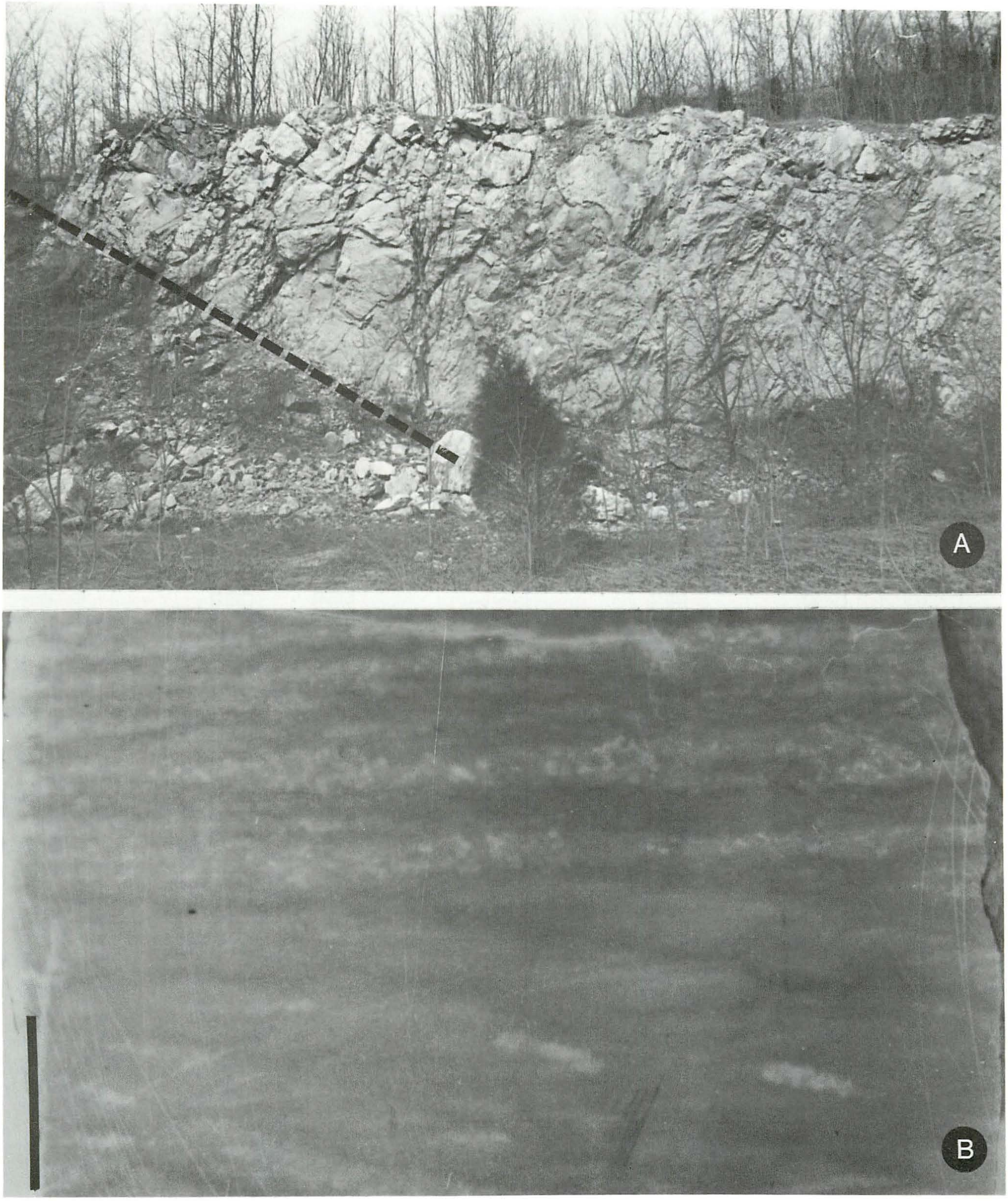


Figure 20.— A, Overturned section of the Benevola Member of the Tomstown Formation on the north face of the abandoned quarry near Millville, Jefferson County, West Virginia. Evergreen tree at foot of quarry face is approximately 10 feet in height. B, dolomitic ghosts of cross-beds within the Benevola Member. Bar scale is approximately 1.0 inch.

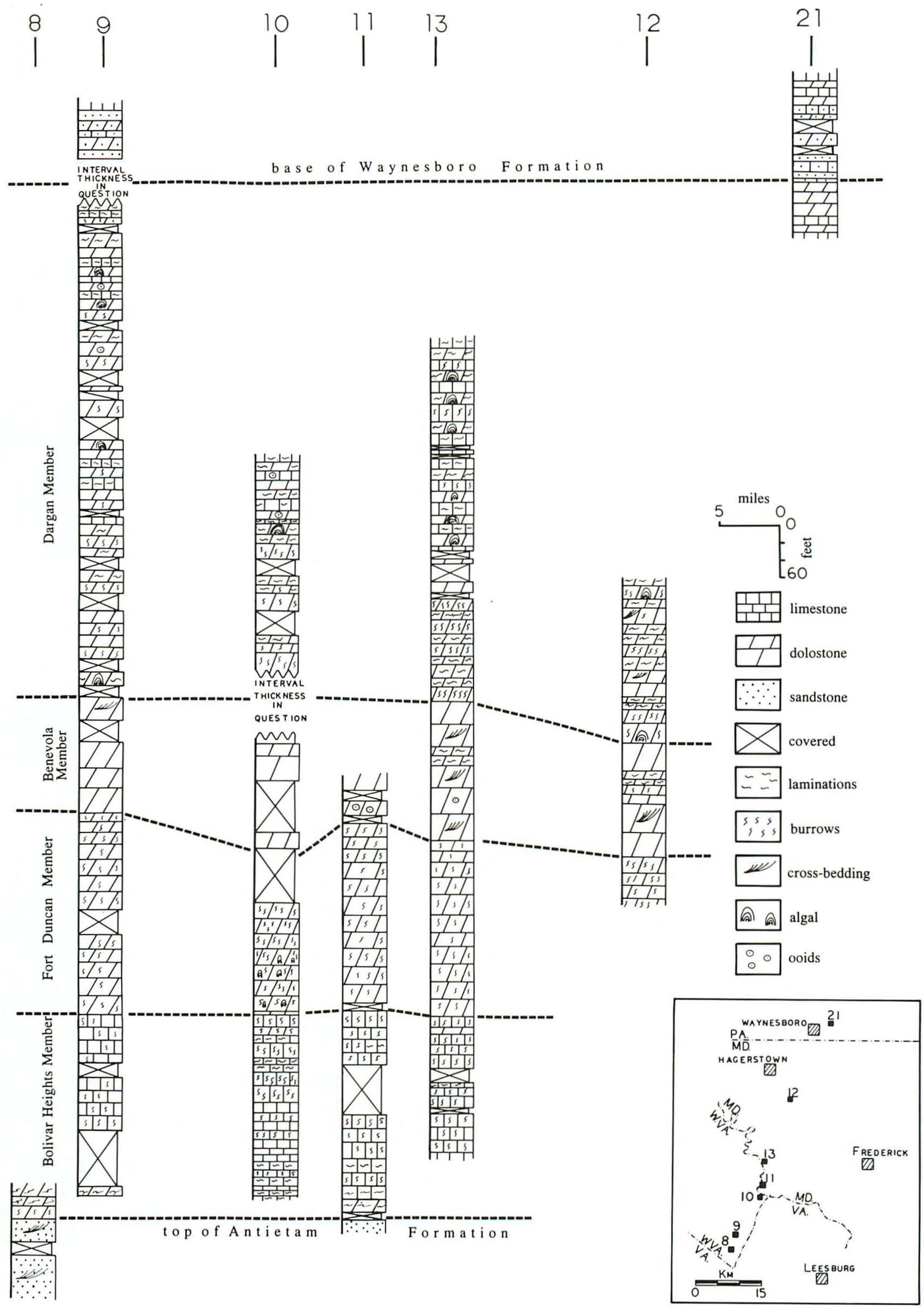


Figure 21.— Correlation of measured sections of the Tomstown Formation from Shannondale, Jefferson County, West Virginia to Roadside, Franklin County, Pennsylvania. Column numbers correspond to section numbers in appendix.

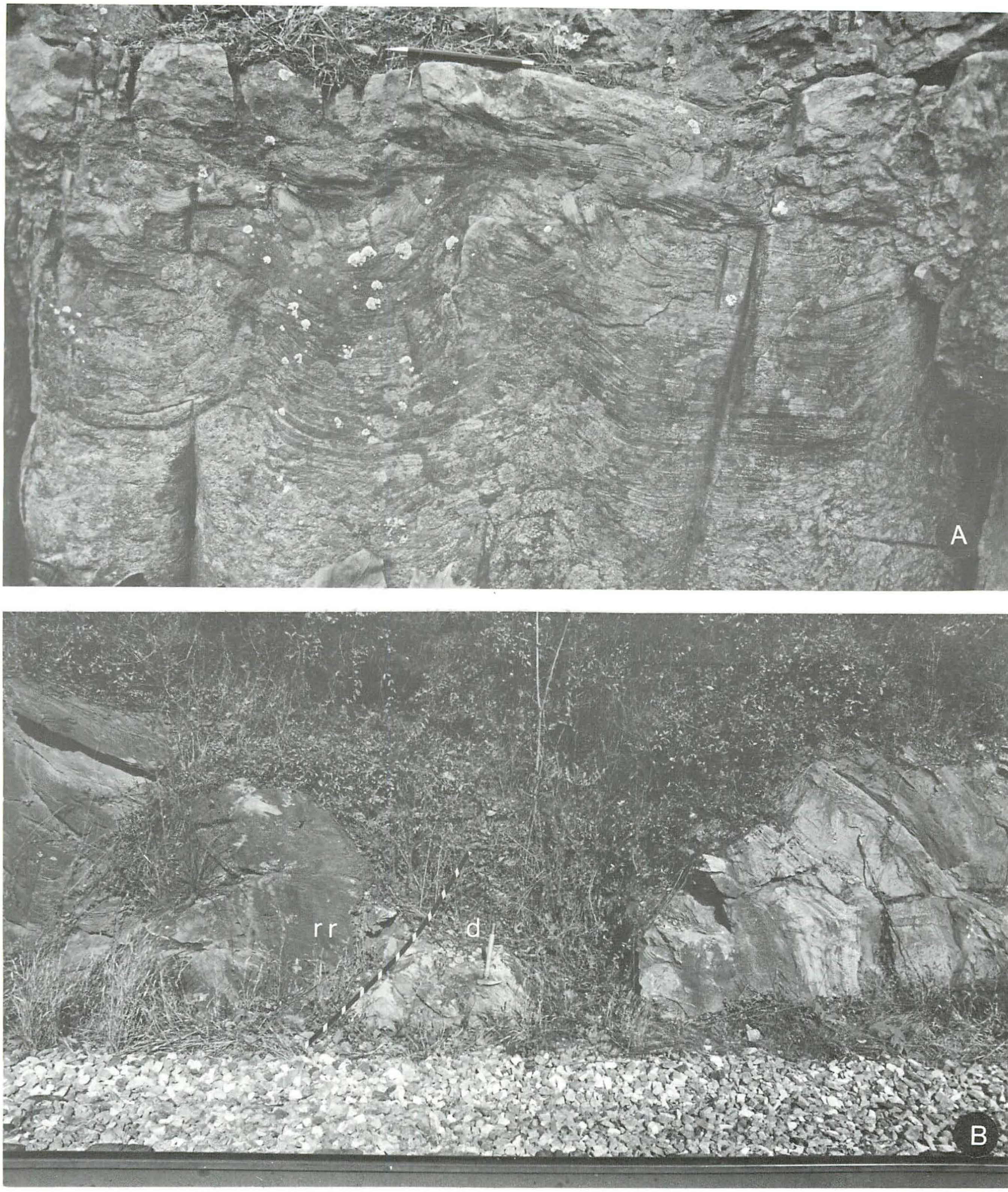


Figure 22.— A, Stromatolitic dolomite of the Dargan Member of the Tomstown Formation. B, Contact between the Dargan Member of the Tomstown Formation (d) and the Red Run Member of the Waynesboro Formation (rr) at locality 10.

The Dargan Member is characterized by vertically stacked, alternating, cyclic lithologies. The lower section is 180 to 220 feet of dark-gray, bioturbated dolomite, 3 to 9 feet thick, alternating with intervals of medium- to dark-gray, laminated dolomite, 1 to 6 feet thick. The upper 300 to 400 feet consist of interbedded, dark-gray, bioturbated and oolitic dolomite; dark-gray, laminated limestone; and tan, laminated, silty dolomite. Mudcracks, laminated cryptalgal and domal stromatolites, and ooids are present in some horizons (Figure 22A).

At the type section, almost 450 feet of continuous section are exposed, but the uppermost 120 to 200 feet of the member are concealed. The character of this member may also be observed at locality 9, where approximately 600 feet of discontinuous exposure are present. Unfortunately, at both of these localities, the contact with the overlying Waynesboro Formation is not exposed.

No invertebrate fossils were observed in this member during this study. However, Yochelson (1970) reported *Salterella* from the upper part of the Tomstown near Roadside, Franklin County, Pennsylvania (locality 21).

Based on the stratigraphic position of this member at the top of the Tomstown Formation, it is interpreted to be correlative, at least in part, with the Ivanhoe Member of the Shady Dolomite of Virginia (Figure 23).

<table>
<tr><th colspan="2">southwest Virginia</th><th colspan="2">Maryland</th><th>Conestoga Valley</th></tr>
<tr><td colspan="2">Rome Formation</td><td colspan="2">Waynesboro Fm.</td><td rowspan="3">Ledger Formation</td></tr>
<tr><td>Ivanhoe Member</td><td rowspan="4">Shady Formation</td><td>Dargan Member</td><td rowspan="4"></td></tr>
<tr><td>Austinville Member</td><td>Benevola Member</td></tr>
<tr><td rowspan="2">Patterson Member</td><td>Fort Duncan Member</td><td>Kinzers Formation</td></tr>
<tr><td>Bolivar Heights Member</td><td>Vintage Formation</td></tr>
<tr><td colspan="2">Erwin Formation</td><td colspan="2">Antietam Formation</td><td>Antietam Formation</td></tr>
</table>

Figure 23.— General correlation of Lower Cambrian members of the Shady Dolomite of southwest Virginia with members of the Tomstown Formation of Maryland, and units of the Conestoga Valley, York County, Pennsylvania.

The contact between the Tomstown and Waynesboro Formations may be observed at several localities within the study area. The contact is placed where interbedded limestone and dolomite of the Dargan Member become interbedded with calcareous shales. The basal Waynesboro is distinguished by the occurrence of the first 3-foot-thick sandstone interval. This contact is well exposed along the CSX Railroad tracks west of the type section of the Bolivar Heights Member (locality 10; Figure 22B). This contact is also well exposed near Roadside, 2 miles northeast of Waynesboro, Pennsylvania. At this location the cyclic nature of the upper 60 feet of the Dargan Member is displayed by an alternating tan, laminated dolomite and stromatolitic limestone and thin, olive-gray, calcareous shales. The contact is placed at the base of the first 3-foot-thick shale interval. North of Interstate 70 the uppermost 35 to 45 feet of the Dargan Member consist of lineated and laminated white marble interbedded with tan laminated dolomite. The significance of these strata is not clear at this time, and further work is necessary to completely document their character and distribution.

Waynesboro Formation

Perhaps the most recognizable Cambrian and/or Ordovician formation in the Great Valley of Pennsylvania, Maryland, northern Virginia, and West Virginia is the Waynesboro Formation. Named by Stose (1906) for exposures near the town of Waynesboro, Franklin County, Pennsylvania, the Waynesboro has traditionally been characterized by red shale and sandstone (for example, see Allen, 1967; Radar and Biggs, 1975; Fauth, 1981). As early as the work of Stose (1910) a three-fold subdivision was distinguished in the Waynesboro Formation in Pennsylvania. These subdivisions include a lower sandstone and limestone member, a middle limestone and dolomite member, and an upper red shale and sandstone member. Bassler (1919) recognized these three members in Maryland. Cloos (1951) recognized only two subdivisions along the Western Maryland Railroad tracks (now CSX tracks) east of Chewsville, Maryland: a lower carbonate and upper red shale and sandstone. In West Virginia, Woodward (1949) did not subdivide the Waynesboro. However, later work (Radar and Biggs, 1975) showed that as far south as Front Royal, Virginia, the three-fold subdivision of the Waynesboro, roughly equivalent to that proposed by Stose (1910), may be recognized. In Virginia, Edmundson and Nunan (1973) and Gathright and Nystrom (1974) have divided the correlative Rome Formation into four members. The upper member of this sequence would be included with the Elbrook Formation (Figure 24). Recently, Haynes (1991) recognized a triparte subdivision of the Waynesboro Formation of southern Virginia.

Although the three-member subdivision of the Waynesboro has been recognized by many authors, none attempted to name or map individual units. Individual members may be mapped in Maryland. In most locations, mapping of the three members is facilitated by their

<table>
<tr><th colspan="2">Virginia
Gathright and Nystrom, 1974</th><th colspan="2">Maryland
this report</th></tr>
<tr><td rowspan="4">Rome Formation</td><td>upper limestone</td><td colspan="2">Elbrook Formation (part)</td></tr>
<tr><td>upper clastic</td><td>Chewsville Member</td><td rowspan="3">Waynesboro Fm.</td></tr>
<tr><td>middle limestone</td><td>Cavetown Member</td></tr>
<tr><td>lower clastic</td><td>Red Run Member</td></tr>
</table>

Figure 24.— Correlation of the Waynesboro Formation of Maryland and Rome Formation of central Virginia.

physiographic expressions. Typically, the lower and upper units, composed of sandstone, form lines of low hills along strike, whereas the middle carbonate member underlies low areas between the clastic units. The three members herein named are the Red Run, Cavetown and Chewsville in ascending order.

No fossils were recovered from the Waynesboro Formation during this study; however, Reinhardt and Wall (1975) report the Lower Cambrian fossil *Salterella conulata* from the quarry at Cavetown. This quarry is in fact in the middle Waynesboro rather than upper Tomstown as Reinhardt and Wall reported. Barnaby and Read (1990) suggested that the Waynesboro-equivalent Rome Formation of southern Virginia may span the Lower Cambrian-Middle Cambrian boundary. However, Palmer (1971) documents Early Cambrian fossils from the upper Waynesboro of Pennsylvania. Consequently, an Early Cambrian age is proposed for the Waynesboro of Maryland pending further biostratigraphic studies.

Red Run Member (New): The lowest member of the Waynesboro Formation is herein named the Red Run Member. The type section of this member is along the abandoned grade of the Edgemont cut-off of the Western Maryland Railroad adjacent to Red Run Creek, 0.75 mile north of the Maryland-Pennsylvania State boundary line. The location is 2.1 miles northeast of Ringold, Maryland and 0.5 mile south of Wayne Heights, Pennsylvania. Here approximately 140 feet of the Red Run Member are exposed (see Figure 25, Column 2). The Red Run Member consists of interbedded, gray, calcareous sandstones, laminated and ribbony, sandy dolomite, and olive-gray, silty, calcareous shale. Thin (< 1 foot thick), red-brown shale and shaly stringers are locally developed (Figure 26). Weathering of the calcareous sandstone strata commonly produces blocks of tan, soft, friable sandstone which litter fields beneath their outcrops. Tan, weathering olive-gray, shale chips which may be utilized in tracing this unit are another distinguishing feature. The reddish-brown shale beds and shaly stringers, although a minor lithologic component, may lead one to confuse this unit with the Chewsville Member of the Waynesboro. However, these reddish units are rare relative to their occurrence in the Chewsville Member. Consequently, discerning between the two members may generally be facilitated by determining the abundance of red strata.

South from the type section to Leitersburg-Smithsburg Road, the Red Run Member crops out as a low ridge lying east of the main Waynesboro ridge (Plate 2). South of Leitersburg Road along the CSX tracks, the Red Run Member is absent owing to faulting. It is here that Cloos (1951) recognized only two members in the Waynesboro Formation. The Red Run Member also forms small ridges in the area between the main Waynesboro ridge and the base of South Mountain (Plate 2), where it is preserved in a synclinal valley (Weltys Church syncline of Plate 1). Another outcrop belt of this member begins along Maryland Route 64, 1 mile north of Smithsburg High School, and continues south through Smithsburg, crosses Route 64 east of Cavetown, and forms small hills from Pondsville Road to Interstate 70, where it terminates (Plate 2). The straight low ridge from I-70 south to Maryland Route 66 is also formed by this member. Where it is crossed by U.S. Route 40 east of Wagners Crossroads, road cuts expose olive shale and tan sandstone. Southwest of Wagners Crossroads several small hills are capped by this member. It again forms a somewhat continuous ridge, from north of Benevola and through Benevola, to Monroe Chapel, and Porterstown. One mile south of Porterstown, the member again underlies a continuous narrow outcrop band to the Potomac River. Several notable exposures are present along this belt. Where Burnside Bridge Road crosses a small tributary of Antietam Creek, 2 miles southeast of Sharpsburg and 0.5 mile north of its junction with Churchey Road, approximately 60 feet of interbedded tan sandstone, shale, and sandy stromatolitic dolomite are exposed. The member is less well exposed along Harpers Ferry Road, 0.5 mile east of the village of Antietam, and along Lime Kiln Road, 0.9 mile southeast of Antietam.

In West Virginia, the Red Run Member is well exposed at Halltown along the CSX tracks beneath the U.S. Route 340 bridges. At this location approximately 145 feet of the Red Run Member are exposed (Figure 25, Column 5). Along the Shenandoah River near Shannondale, 93 feet of interbedded sandstone and sandy dolomite are assigned to this member; however, the subjacent strata are highly folded and this may indeed represent a stratigraphically higher Waynesboro interval.

Where the upper contact of the Red Run Member is exposed, it appears to be gradational. Typically, there is a general decrease upsection in laminated dolomite and

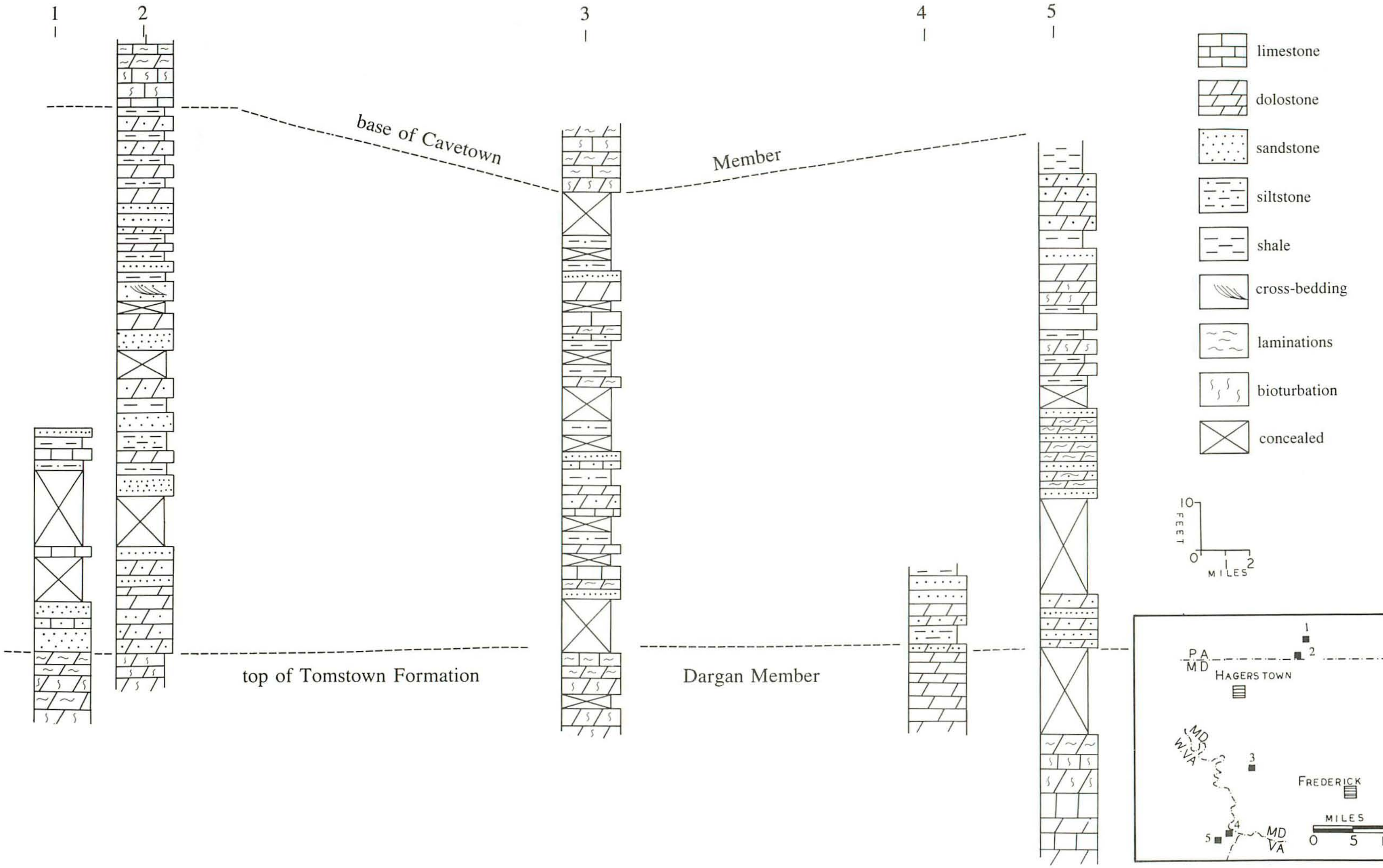


Figure 25.— Lateral extent and vertical stacking of lithologies of the Red Run Member of the Waynesboro Formation. 1, Roadside, Pennsylvania (locality 21); 2, type section (locality 14); 3, Keedyville Road; 4, locality 10; 5, Halltown (locality 15).

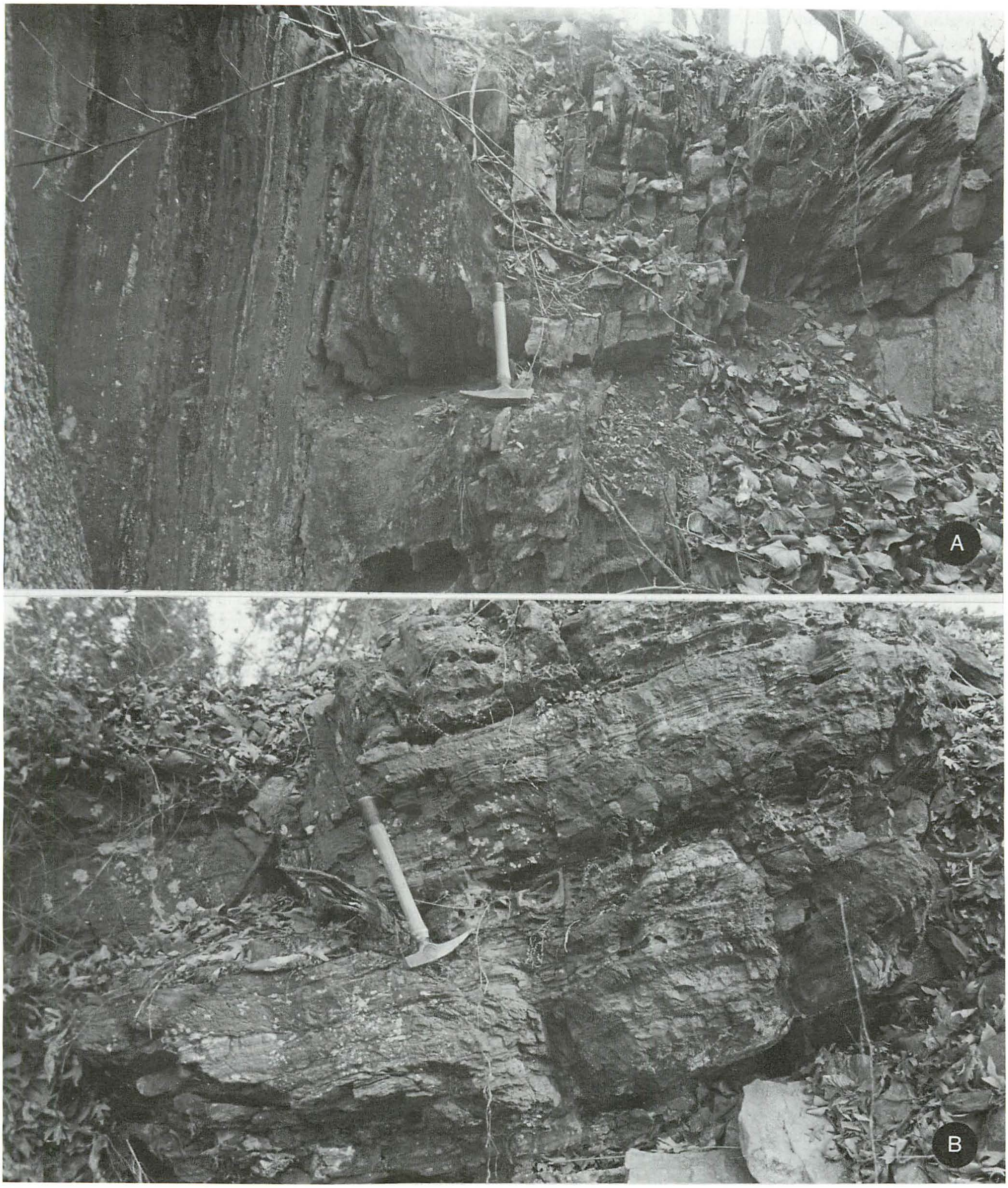


Figure 26.— A, Interbedded thin sandstones, and sandy, argillaceous limestone and shale of the Red Run Member of the Waynesboro Formation at type section (locality 14). B, Interbedded Red Run lithologies as exposed along Beaver Creek near Benevola.

siliciclastic intervals. Along Lime Kiln Road in southern Washington County, Maryland, the gradual decrease in siliciclastic content is complemented by an increase in carbonate purity and numerous small abandoned quarries mark the base of the middle member.

Cavetown Member (New): The medial part of the Waynesboro, herein named the Cavetown Member, is the thickest member, but also the least exposed and therefore the least known. The middle Waynesboro commonly forms a recessed valley between the adjacent ridge-forming members. Because good exposures of this interval are rare, it has not been fully characterized. The Cavetown Member of the Waynesboro contains lithologies common to the Dargan Member of the Tomstown and lower part of the Elbrook Formation. For this reason the Cavetown Member has been mistaken for the Tomstown Formation (for example, Bassler, 1919; plate IV, Reinhardt and Wall, 1975, fig. 2), and the Elbrook Formation (Cloos, 1941). Recognition of the Cavetown Member depends upon knowledge of its stratigraphic relationship with either the Red Run or Chewsville Members, rather than any intrinsic criteria. Nowhere has a complete exposure of the Cavetown Member been recognized or the exact thickness been established. Based on outcrop width and the composite assemblages of lithologies presented above, the thickness is estimated to be 400 to 600 feet. Key exposures permit characterization of the Cavetown Member, one of which is the type section. The type section is in the abandoned quarry at Cavetown where only about 200 feet of the upper part of the member are exposed. At the type section the Cavetown Member consists of 55 feet of dark-gray, thick-bedded, bioturbated dolomite overlain by 55 feet of massive intraclastic dolomite, which in turn grades upward into 35 feet of interbedded, laminated and ribbony dolomite at the top of the Member. A more complete section is exposed in the quarry (Beaver Creek quarry) along Maryland Route 66 and Beaver Creek 1 mile south of Mt. Aetna, and 0.5 mile north of the Interstate 70 interchange, where all but approximately the basal 150 feet are exposed. Although the contact with the Red Run Member is not exposed, approximately 300 feet of the Cavetown Member are exposed (Figure 27).

The lowest 100 feet exposed consist of thick-bedded to massive, medium-gray limestone and bioturbated dolomite (Figure 28A). The limestone typically exhibits flow-folds, making recognition of bedding difficult. The middle 100 to 120 feet of strata consist of interbedded, medium- to dark-gray, bioturbated, dolomitic limestone and dolomite (Figure 28B), and at least two, thin (< 10 feet thick) intervals of interbedded, laminated dolomite, light-gray, fine-grained, calcareous sandstone, and olive-gray, calcareous shale. These interbedded sandstone and carbonate intervals are almost identical to lithologies characteristic of the Red Run Member; however, they constitute only a minor lithologic component of the Cavetown Member. Above this the Cavetown Member is a thick-bedded to massive, medium- to dark-gray, bioturbated, dolomitic limestone and dolomite. Numerous oolitic intervals are also present.

The uppermost 75 to 100 feet of this member are inaccessible at the Beaver Creek quarry; however, this interval may be closely observed at the quarry at Cavetown (Figure 29A). Between Cavetown and the Beaver Creek quarry, this member extends as a band that overlaps and is parallel to both Beaver Creek and Maryland Route 66 (Plate 2). One mile north of Smithsburg, the outcrop band swings due west and ends abruptly. A second band begins along the CSX tracks 1 mile east of Chewsville, where approximately 350 feet of section are poorly exposed, and continues north to the Pennsylvania State line and beyond.

South of the type section and Beaver Creek quarry, the Cavetown Member is poorly exposed in several fault slices between Wagners Crossroads and Benevola. In this area, the only notable exposure of this member is along a meander in Beaver Creek 1 mile northwest of Mt. Zion Church, where 60 feet of bioturbated dolomitic limestone crop out. Southwest of Benevola, the Cavetown Member underlies a continuous outcrop band to Porterstown. In this area, exposures are along Keedysville Road and the tributary to Antietam Creek that leads to the Upper Bridge.

Folding complicates the outcrop pattern of the Cavetown Member between Porterstown and Churchey Road. This fold is defined by thin sandstone beds in the Cavetown Member. To the south, dissection by Antietam Creek has revealed numerous small exposures. One accessible area of these outcrops is along Harpers Ferry Road 1 mile east of Antietam. In this section, a 50-foot thick interval of massive, pure dolomite in the lower part of the member has been quarried. Another abandoned quarry occurs along Lime Kiln Road and in the uplands between the two roads. Also along Lime Kiln Road, one may observe several intricate folds within the Cavetown Member. These folds are delineated by thin sandstone beds within the middle part of the member. In West Virginia nearly 400 feet of this member is partially exposed along the Shenandoah River (locality 9).

The contact between the Cavetown and overlying Chewsville Member is exposed along the CSX tracks 0.25 mile west of the Cavetown quarry, as well as in the quarry wall (Figure 29A). This exposure illustrates that interbedded dolomite and shaly limestone of the upper part of the Cavetown Member abruptly grade into siliciclastic beds of the Chewsville Member. This abrupt gradation is also exposed in the east wall of the Beaver Creek quarry (Figure 29B).

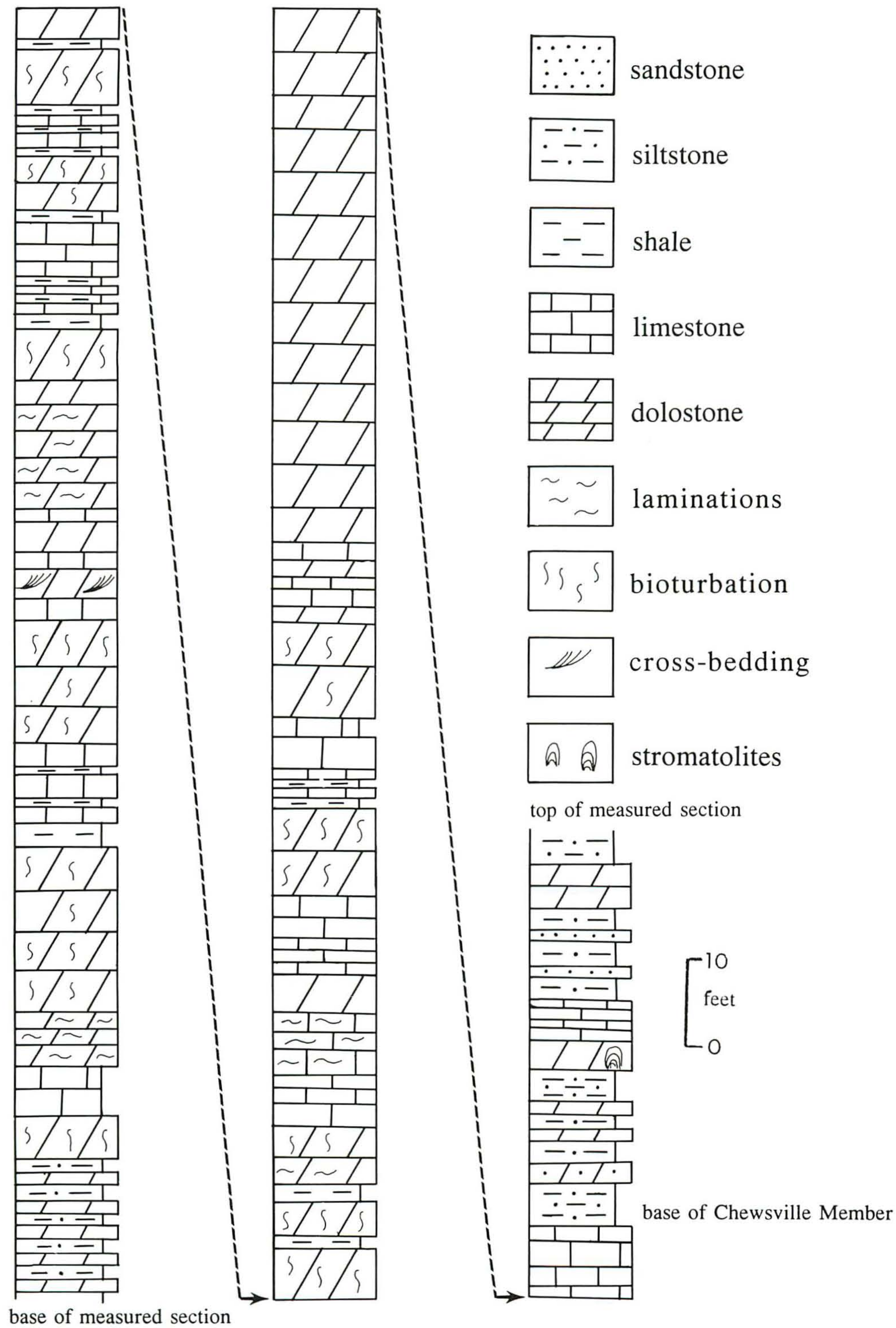


Figure 27.— Stratigraphic section of Cavetown Member and Chewsville Member of the Waynesboro Formation as exposed at the Beaver Creek quarry (locality 16).

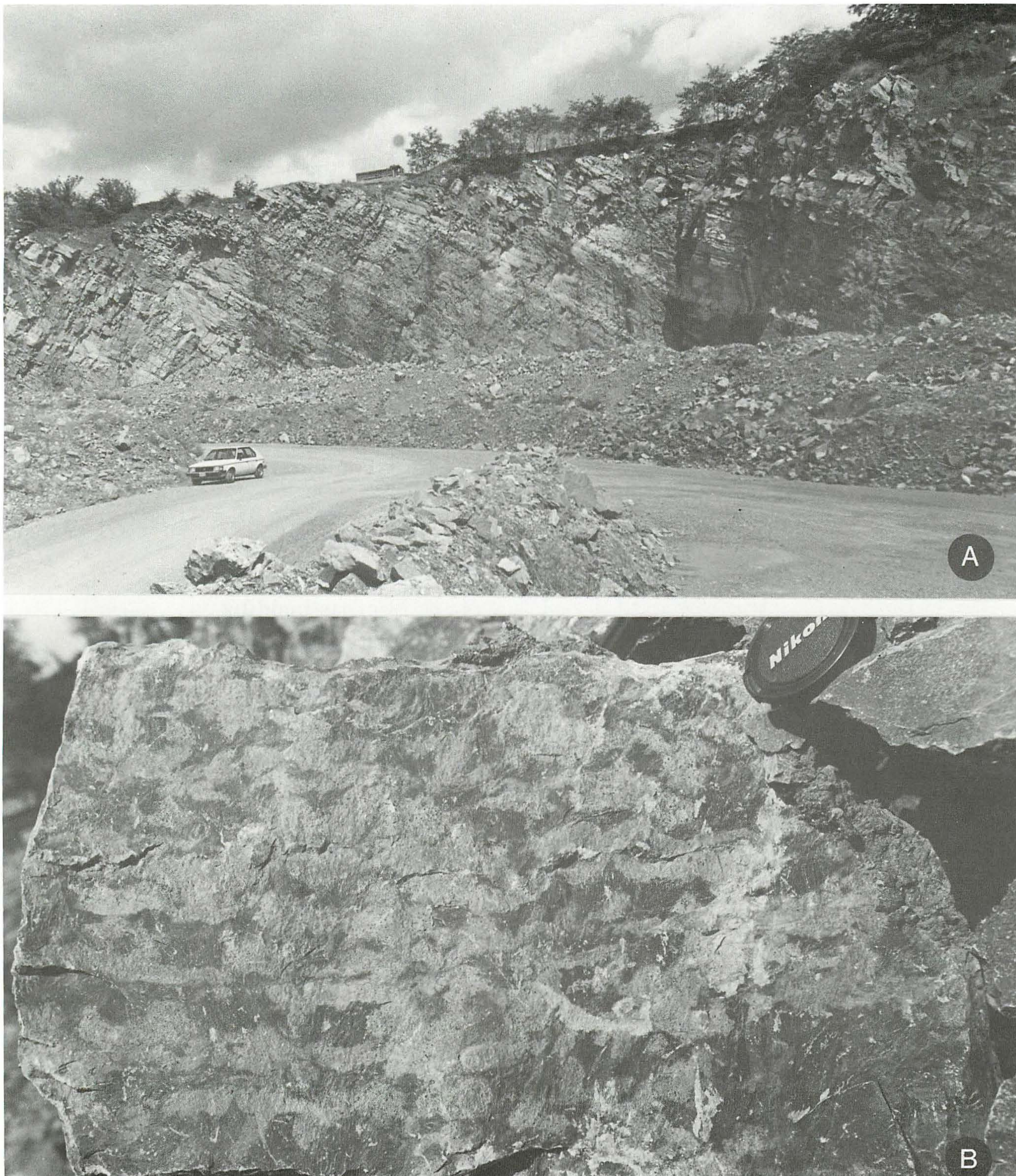
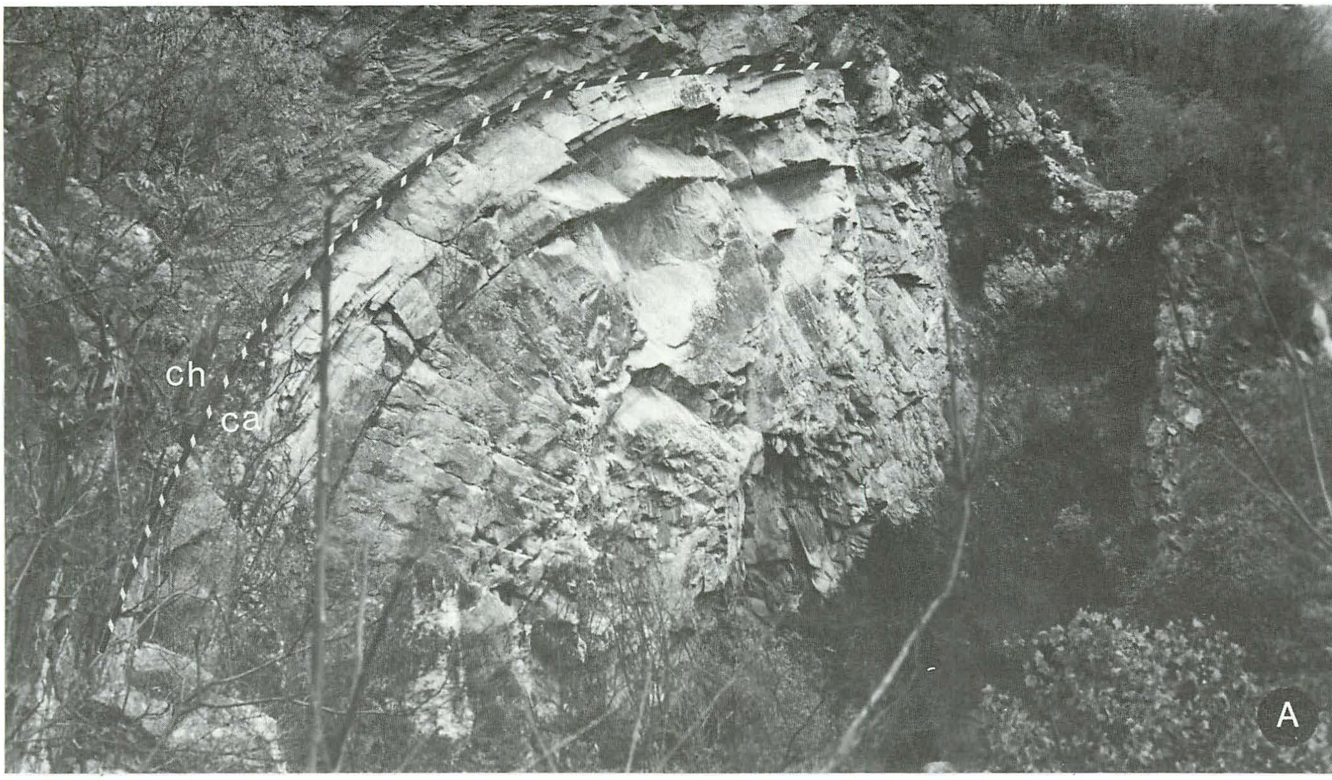


Figure 28.— A, Bedded dolomites and limestones of the Cavetown Member of the Waynesboro Formation at Beaver Creek quarry (locality 16). B, Characteristic bioturbated dolomite of the Cavetown Member.



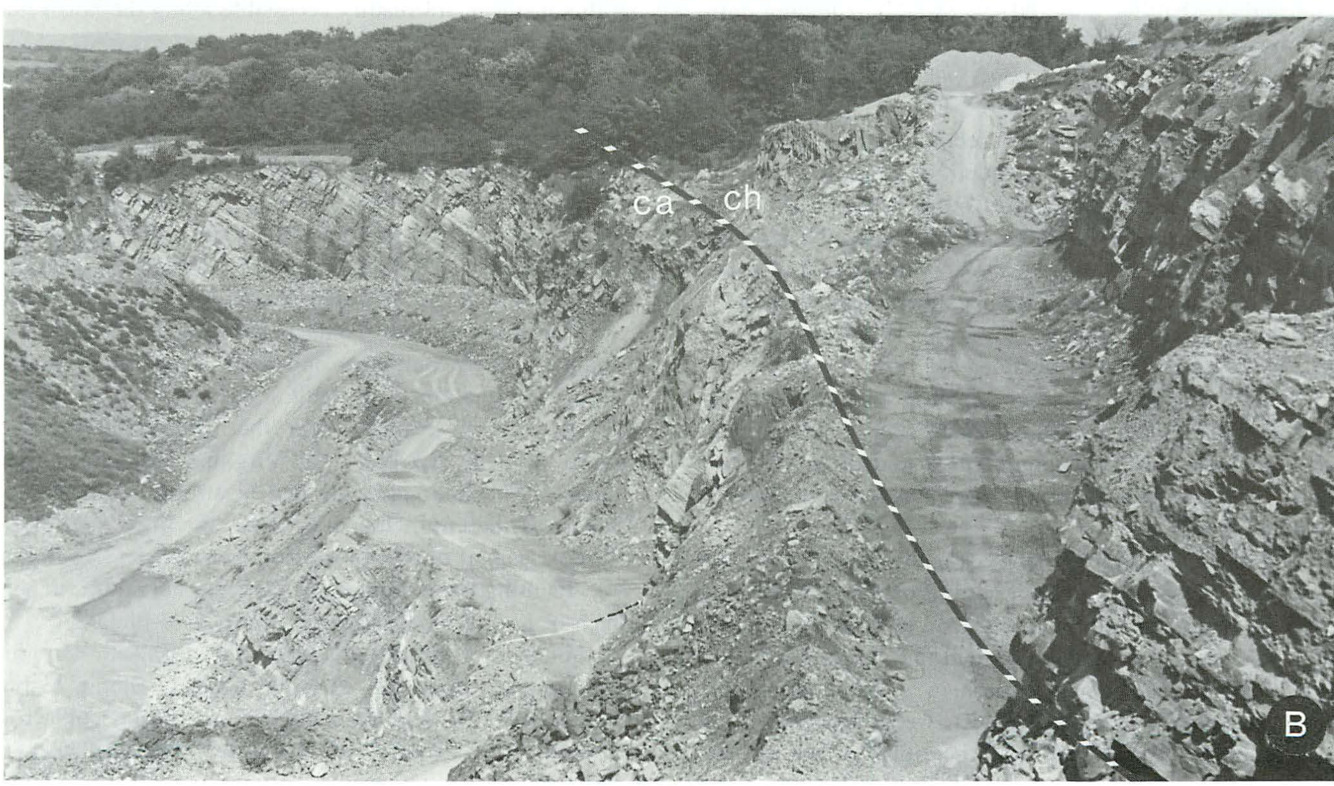


Figure 29.— A, Contact between the Cavetown (ca) and Chewsville (ch) Members of the Waynesboro Formation at Cavetown quarry (locality 17). B, Same contact as above exposed in the east wall of the Beaver Creek quarry (locality 16).

Chewsville Member (New): The most distinctive unit of the eastern Great Valley of Maryland is the upper part of the Waynesboro, herein called the Chewsville Member. This distinctive unit consists of interbedded dark-reddish-brown siltstone, sandstone, and shale. Aside from thin, comparable beds in the Red Run Member, these lithologies are restricted to the upper part of the Waynesboro. The combination of distinctive lithology and topographic expression makes the Chewsville Member one of the units most easy to trace and map in the Great Valley.

At the type section, along the CSX railroad tracks 1 mile east of Chewsville, Washington County, Maryland (locality 18), the Chewsville Member consists of approximately 150 feet of intimately interbedded, dusky-red and dark-reddish-brown, sandy siltstone and shale, grayish-red, grayish-pink and pinkish-gray, medium- to fine-grained sandstone, and light-brown to grayish-orange, silty and sandy, laminated dolomite (Figure 30). Less common lithologies include light-olive-gray shale and medium-gray, stromatolitic and bioturbated dolomitic limestone. The reddish-brown siltstone units are commonly rippled and mudcracked, whereas the sandstone beds are pervasively cross-bedded and exhibit *Skolithos* burrows. The arrangement of repetitive lithologies such as thin-bedded limestone and dolomite are interpreted as representing shallow subtidal deposits, shallowing into cross-bedded intertidal sandstones, and then into supratidal red, mudcracked siltstone and shale suggest cyclic conditions.

From the member type section, the Chewsville Member forms a continuous band of outcrop north to Ringgold, northern Washington County where it is cut by a cross-fault (Plate 2). North of Ringgold, the outcrop band continues to the Waynesboro Formation type area. Along Red Run, 105 feet of this member are incompletely and discontinuously exposed. From this location north into Pennsylvania, measurable sections are rare.

In Maryland, a second outcrop belt begins at Smithsburg High School and continues south to Cavetown. Between these two end-points, the Chewsville Member occurs in the trough of an overturned syncline (Smithsburg syncline Plate 1).

Between Cavetown and Pondsville Road the Chewsville Member is present as thin bands, rarely more than a few feet wide and is interpreted to be faulted out in this area. South of Pondsville Road the member is better developed and once again occurs in a synclinal trough extending south to Interstate 70 (Mt. Aetna syncline, Plate 1). South from Interstate 70, the outcrop belt of the Chewsville Member shifts west to Daubs Mill along U.S. Route 40. Between Daubs Mill and Benevola, the outcrop belt is broken by a number of cross faults. Outcrops in this area are sparse; however tracing of the member is facilitated by occurrences of red shale in fields and topographic expressions. South from Benevola the Chewsville Member forms a continuous belt extending to the Potomac River. In this area, several excellent reference sections provide additional opportunity to characterize the Chewsville Member.

Along Keedysville Road 0.8 mile west of Keedysville, approximately 120 feet of the Chewsville Member crop out, both along the road and the adjacent stream. At this location, light-gray to grayish-pink sandstone beds 2 to 4 inches thick, are interbedded with red-brown siltstone (Figure 30A). Near Porterstown, 1.25 miles to the south, much of the carbonate interval within the Chewsville Member may be examined. This exposure is along both Maryland Route 34 and the adjacent Porterstown Road. The approximately 65 feet of strata exposed along Route 34 consist of interbedded, laminated dolomite and limestone, and calcareous shale of the lower part of the Chewsville Member. Beautifully preserved sedimentary structures, indicating shallow-water deposition (mudcracks, ripplemarks), abound. Other structures, such as burrows, flame structure, and ball and pillow, are well preserved. South of Porterstown, numerous partial exposures of the Chewsville Member may be observed. One prominent exposure occurs approximately 100 yards southeast of Burnside Bridge and another at Snavely Ford. At a Antietam Furnace, reddish siltstone and shale characteristic of this member are readily accessible along the north side of the stream.

Two exposures of this member were visited, in West Virginia. At Halltown, Jefferson County, about 50 feet crop out opposite the paper factory, but much of this is incompletely exposed. Aside from the type section, the best reference section for the Chewsville Member is along the Shenandoah River (locality 9), where 120 feet of the member are well exposed (Figure 31, Column 5). Because the lower contact is concealed, the thickness is a minimum.

Placement of the contact between the Chewsville Member of the Waynesboro and the stratigraphically higher Elbrook Formation is difficult. Not only is the interval typically poorly exposed, but the Chewsville Member grades into the Elbrook. In Virginia, Edmundson and Nunan (1973) and Gathright and Nystrom (1974) include shaly beds, herein included as within the lower part of the Elbrook, as part of the coeval Rome Formation (see Figure 24). Faulting has disrupted the contact interval throughout much of northern Washington County (see Plate 2).

South of Monroe Chapel the contact may be stratigraphic. West of Monroe Chapel, along Manor Church Road at Antietam Creek, where the contact is exposed, red siltstone of the Chewsville Member is overlain by olive-gray siltstone interbedded with argillaceous limestone. The contact is placed at the top of the uppermost red sandstone. Along Keedysville Road, a similar relationship exists between the Waynesboro and Elbrook; however, stratigraphically above the highest red

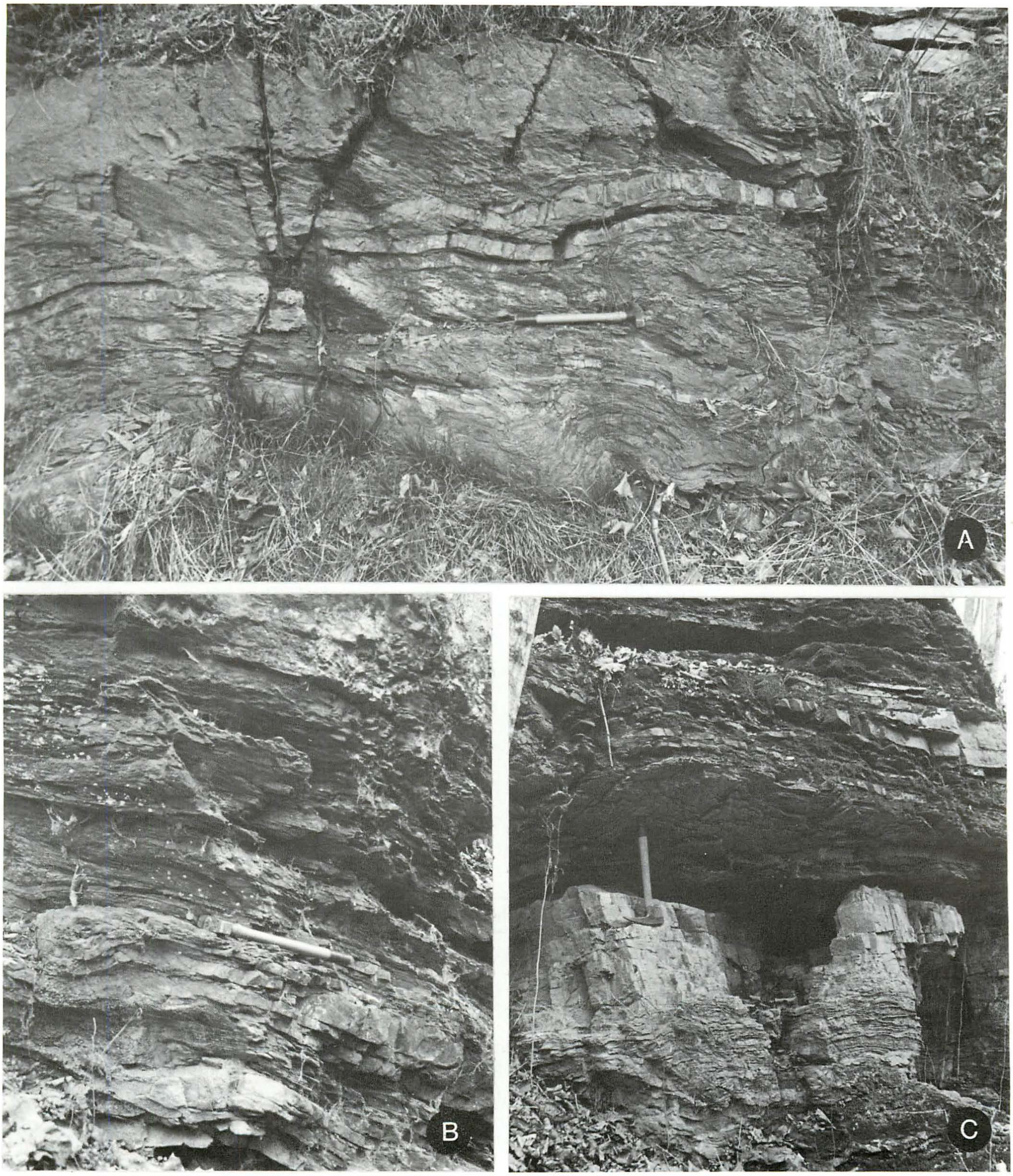


Figure 30.— A, B, Interbedded red-brown shales, siltstones and thin, gray sandstones of the Chewsville Member of the Waynesboro Formation exposed along Keedysville Road. C, Dolomite interbed within the red clastic interval of the Chewsville Member at same locality.

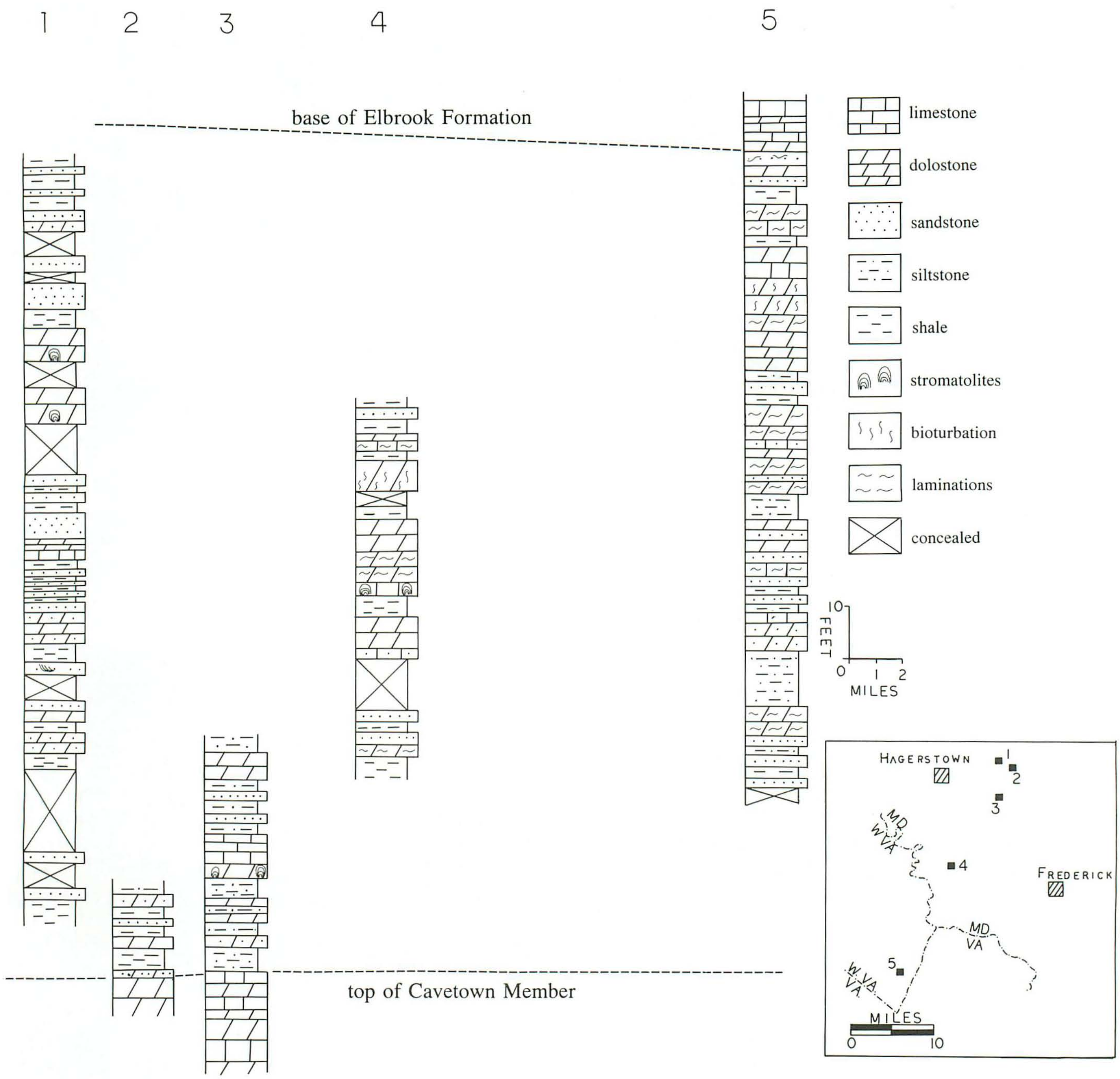


Figure 31.— Vertical and lateral arrangement of lithologies within select measured sections of the Chewsville Member of the Waynesboro Formation. 1, type section (locality 18); 2, Cavetown (locality 17); 3, Beaver Creek Quarry (locality 16); 4, Porterstown; 5, Shannondale, West Virginia (locality 9).

unit is olive, shaly sandstone. The contact would be at the top of the highest sandstone unit. At Shannondale (locality 9), a similar sandy unit occurs stratigraphically above the highest reddish shale, and the contact is placed at the top of this sandstone.

Elbrook Formation

Detailed stratigraphic study of the Elbrook Formation is not included as part of this study. Its relationship to the Waynesboro and even the Tomstown is unclear at numerous locations. Study of the Elbrook Formation

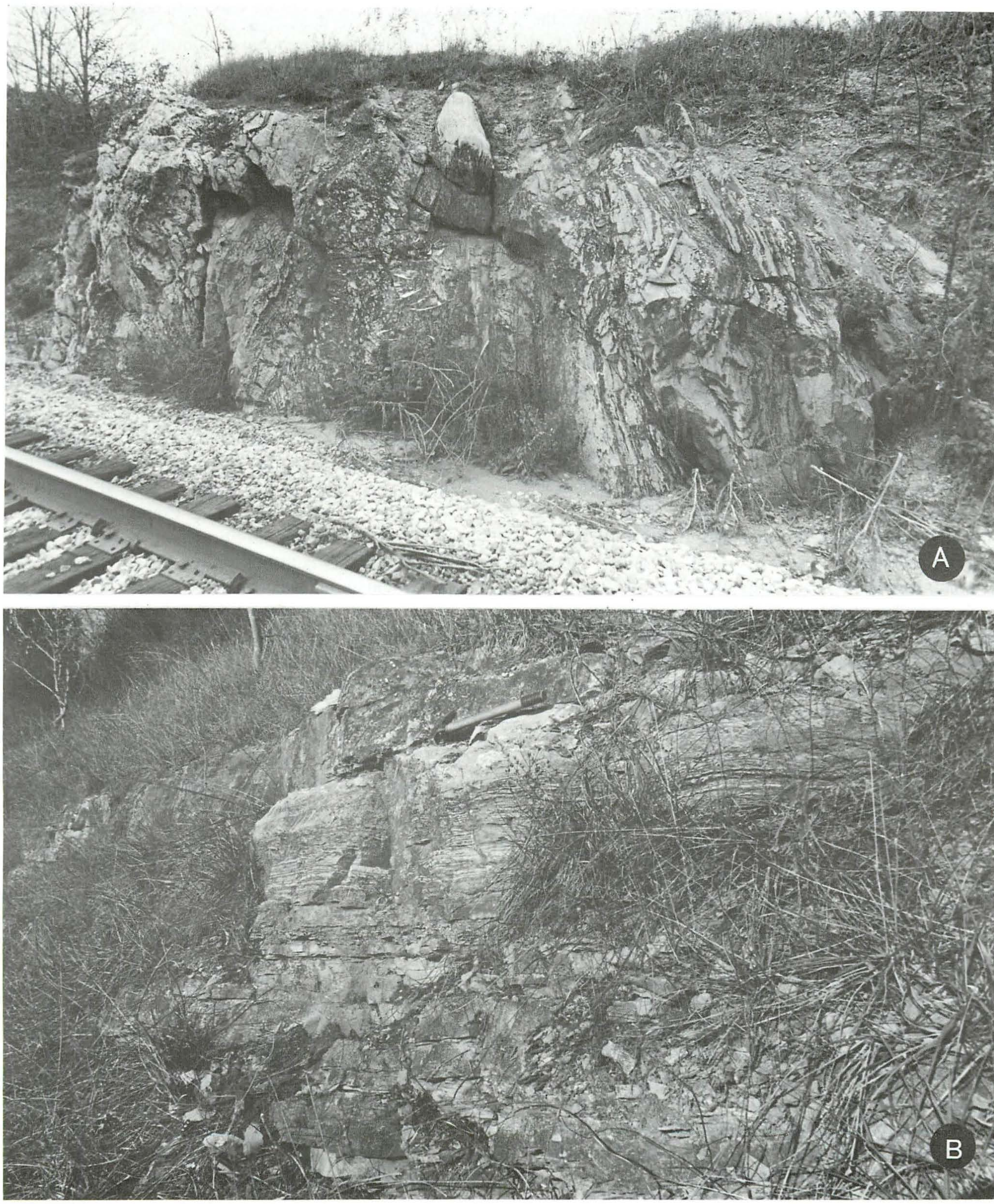


Figure 32.— A, Interbedded dolomites and thin-bedded limestones of the Elbrook Formation near Altenwald, Franklin County, Pennsylvania (locality 20). B, Interbedded laminated limestone and dolomite characteristic of the Elbrook Formation in Maryland.

should be undertaken. Because the formation underlies extensive areas in eastern Washington County, the lithologic characteristics are summarized.

Stose (1906) named the Elbrook for the sequence of gray, shaly limestone and calcareous shale occurring between the Waynesboro and Conococheague Formations. Stose (1910) proposed a thickness of 3,000 feet for the type area near Elbrook, Franklin County, Pennsylvania. Outcrops in that area are sparse. However, 2 miles north of Elbrook at Altenwald the lithologies are well exposed. Along the railroad tracks at Altenwald, the Elbrook Formation consists of interbedded, light-gray laminated limestone and tan laminated and shaly dolomites (locality 20). It is herein recommended that this locality be used as the stratotype section for this formation (Figure 32A). Because this formation is so poorly exposed in Maryland, its character can be described only from composite sections.

The lower 200 to 300 feet of the Elbrook consist of interbedded, olive-gray to medium-gray, calcareous shale and medium-dark-gray, platy and thin-bedded, argillaceous limestone and medium-bedded dolomite. This part of the formation is exposed at the west end of Burnside Bridge, and along Antietam Creek near the Sligo Church camp, 1 mile southwest of Monroe Chapel.

The middle portion of the formation consists of cyclic, medium- to thick-bedded, medium-dark-gray to dark-gray limestone, tan dolomite; light-gray, thin-bedded marble; and platy, laminated, argillaceous limestone. This part of the formation is exposed along Burnside Bridge Road between Antietam Creek and the east side of Sharpsburg. Thickness of this part of the Elbrook may be between 500 and 1,000 feet.

Above this thick interval, the Elbrook consists of 500 feet of interbedded, medium-dark-gray, thin-bedded limestone; medium-bedded, tan, laminated dolomite; and olive-green and grayish-red shales (Figure 32B). This part of the formation is exposed along Alternate U.S. 40, 200 yards west of Cool Hollow Road, adjacent to Antietam Creek (locality 20). The shales in this interval range from 0.5 to 2.0 feet thick and superficially resemble shale of the Chewsville Member of the Waynesboro Formation. In fact, it appears that these shales were mistaken for the Waynesboro by Bassler (1919) and Jonas and Stose (1938) in the fields south of Maryland Route 64 and Chewsville. These same shale beds misled Cloos (1941), and he continued the outcrop pattern of the Waynesboro back to the northeast in order to create his anticline east of Chewsville. The anticline does not exist.

The uppermost 100 to 300 feet of the formation consist of dark-gray, stromatolitic limestone, interbedded with medium-gray and tan dolomite. When weathered these dolomites produce chips of dolomite that litter fields beneath their outcrop.

STRATIGRAPHIC DISCONTINUITIES

Significant stratigraphic discontinuities are revealed if the stratigraphic subdivisions described above are utilized in geologic mapping at 1:24,000 or larger scale. The general continuity of subdivisions (members) across Washington and Frederick Counties suggests that occasional disruptions may be attributable to faulting. Several of the probable fault structures are named and discussed.

HIGH ROCK FAULT

This fault is named for High Rock near Pen Mar, Washington County, Maryland (Plate 2), where it places the Buzzard Knob Member of the Weverton Formation in the hanging wall onto the Harpers Formation. At High Rock, the Buzzard Knob Member is folded into an overturned anticline, so that at the cliff base the member is overturned, whereas at the top of the exposure the unit is right side up. This is interpreted as drag along the fault. North of Fort Ritchie, Frederick County, Maryland, the fault is lost in the Catoctin Formation; however, it should be noted that this fault possesses a strike in line with the Jacks Mountain fault of Pennsylvania (see Fauth, 1978).

East of Edgemont, Washington County, Maryland, the fault obliquely truncates the Sandy Hook and Owens Creek Members, which occur in the core of the Quirauk Mountain syncline. Between Warner Gap Hollow (the Edgemont Reservoir) and Foxville Gap, the High Rock fault truncates all Weverton Members, so that at Foxville Gap, the Catoctin Formation, in the hanging wall, is above the Montalto Member of the Harpers. South of Foxville Gap, this fault strikes directly into a fault within the Catoctin, as mapped by Fauth (1981). It is possible that the High Rock fault continues south to Wolfville Crossing at Interstate 70.

BLACK ROCK FAULT

This fault has its best development in Black Rock Hollow, east of Bagtown, Washington County, Maryland (Plate 2). Jonas and Stose (1938) also recognized this fault, but continuation of the structure farther to the north and south, as they suggested, is tenuous. In Black Rock Hollow and on Black Rock, the Buzzard Knob Member of the Weverton Formation is present in the form of an overturned anticline. This fold continues to the south to Annapolis Rock. At both Black Rock and Annapolis Rock, the Buzzard Knob Member is in normal orientation at the top of the cliff and overturned at the base. Furthermore, this fold, an apparent drag fold on the fault, juxtaposes the Buzzard Knob Member in the hanging wall with the Harpers Formation in the apparent footwall. To the north of Black Rock Hollow, this fault has not been unequivocally traced. South of Annapolis Rock, the drag fold in the Buzzard Knob Member is truncated and the Loudoun and Catoctin Formations are progressively emplaced on the Harpers Formation and Owens Creek Member of the Weverton. The Black Rock fault is terminated by the I-70 cross-fault near where U.S. Route 40 crosses Interstate 70 (Plate 1).

MONUMENT KNOB FAULT

Between Interstate 70 and Alternate U.S. 40, the Catoctin Formation, Loudoun Formation and Buzzard Knob Member of the Weverton Formation are in discontinuous contact with the Maryland Heights and Owens Creek Members of the Weverton Formation. This is interpreted as representing a fault, herein named the Monument Knob fault. Jonas and Stose (1938) believed this was part of the Black Rock fault, but it is clear that the I-70 cross-fault cuts and separates these into two structures. The Monument Knob fault exists on the east side of Bartmans Hill, where the Buzzard Knob Member is above the Owens Creek Member. More throw, or vertical displacement, may be observed on the south side of Monument Knob, where the Catoctin and Loudoun Formations and the Buzzard Knob Member of the Weverton, in apparent normal stratigraphic position, are emplaced upon overturned sandstones of the Owens Creek Member. Furthermore, on the north side of the knob, conglomeratic Loudoun Formation is in contact with the Maryland Heights Member of the Weverton. This fault appears to be truncated at Zittlestown by a cross-fault that passes through Turners Gap (Turners Gap fault), but may actually transfer into a tear with strike-slip movement at that point.

SOUTH MOUNTAIN FAULT SYSTEM

Along the western base of South Mountain, the stratigraphic succession of Harpers-Antietam-Tomstown shows inconsistencies that suggest the presence of a fault (Brezinski, et al., 1991). Between Pen Mar, Pennsylvania and Foxville Gap, the Antietam Formation is absent in a number of places. Along the CSX tracks at the east end of Smithsburg, shale of the Harpers Formation lies close to the Tomstown Formation. This relationship may also be observed in an outcrop along the road to Edgemont, where the Harpers Formation directly overlies the Tomstown. In Pennsylvania, between Rouzerville and Glen Forney, the Antietam is present; however, north of Glen Forney, it is absent. Unfortunately, north of Glen Forney, current mapping prevents definitive determination of stratigraphic relations. Between Foxville Gap and Mt. Aetna, the stratigraphic relations between Antietam and Tomstown Formations appear normal. However, at Jugtown, the Dargan Member of the Tomstown and the Antietam Formation are too close to satisfy normal stratigraphic thickness. East of the Mt. Aetna School, the Antietam has been mapped (Fauth, 1981) as forming the initial foothill for South Mountain. Examination of this exposure shows that this outcrop is not the upper part of the Antietam, as would be expected in a normal succession, but may be lower Antietam or upper Harpers. Jonas and Stose (1938), Cloos (1941), and Fauth (1981) have shown the outcrop belt of the Antietam to be continuous between Mt. Aetna and Greenbrier State Park. However, in this area, no outcrops or unequivocal float assignable to the Antietam have been found. There is also no topographic expression to indicate the presence of the Antietam. Furthermore, one-half mile south of Bagtown, along strike of this supposed belt of Antietam sandstone, lie several small exposures of the Dargan Member of the Tomstown Formation. It is proposed that in this area the Antietam has been omitted by faulting, and that the Harpers Formation overlies the upper strata of the Tomstown Formation.

The ridges that constitute the Antietam Formation between Greenbrier State Park and Boonsboro suggest a normal stratigraphic package in this area. However, throughout this area, a paucity of exposure precludes gaining better understanding of the stratigraphic relationships. The closest outcrops (at Mapleville and Mt. Pleasant) are gently folded dolomite of the Dargan Member of the Tomstown Formation. Nonetheless, the author concludes that the Antietam is in fault contact with the Tomstown Formation in this area, although intrinsic evidences are weak. Bassler (1919) also theorized that this area of Antietam was faulted into place.

Between Alternate U.S. 40 at Boonsboro and Reno Monument Road at Amos Reeder Road, there is no indication of Antietam, even though Jonas and Stose (1938) and Cloos (1941) report continuous outcrop. At the east end of Boonsboro, where the ridge of Antietam terminates at Alternate U.S. 40, dolomite of the Fort Duncan and Benevola Members of the Tomstown Formation occur downhill and presumably beneath Antietam sandstone. Moreover, in the field south of Alternate 40, limestone of the Bolivar Heights Member of the Tomstown is present within the area where the Antietam would be expected.

Singewald (1911) has discussed iron ore workings along what is now Maryland Route 67, approximately one-half mile south of the current intersection with Alternate U.S. 40. The ore was found "at the fault contact of the Shenandoah Limestone [i.e., Tomstown] and the Harpers shale." A water well in this vicinity produced dolomite chips that are interpreted as being the Benevola Member of the Tomstown Formation. Other indirect evidences supporting the omission of the Antietam in this area are numerous sinkholes and the lack of physiographic expression.

The Antietam forms a ridge, 2 miles in length, from

Amos Reeder Road south to Route 67, east of Rohrersville. Once again, a colluvial apron on the western side of the ridge obscures bedrock outcrops. In the fields north of Millbrook Road, only rocks of the Dargan Member of the Tomstown Formation crop out. The position of the individual members of the Tomstown, which may be traced between Boonesboro and Rohrersville, also suggests that they are progressively overridden to the south (Plate 2).

These relationships indicate that the South Mountain fault may be traced from Pennsylvania to Rohrersville. It is characterized by hanging-wall rocks of Antietam or Harpers Formations, above footwall rocks of various members of the Tomstown Formation.

From Rohrersville south into Virginia, Harpers is in the hanging wall of a well-described fault, which Cloos (1941) believed was tensional, because Cambrian shales of the Harpers Formation are above Proterozoic basement gneiss. Although this may simply be part of the South Mountain fault, the fundamental stratigraphic approach applied here cannot explain these field relationships completely. From this point south the South Mountain Fault may be coincident with the Rohrersville fault (see Plate 1).

In conclusion, it is proposed that the South Mountain fault is a single fault or group of faults that places South Mountain over Lower Cambrian carbonate strata of the eastern Great Valley, and that nowhere in Maryland is this interface a normal stratigraphic sequence.

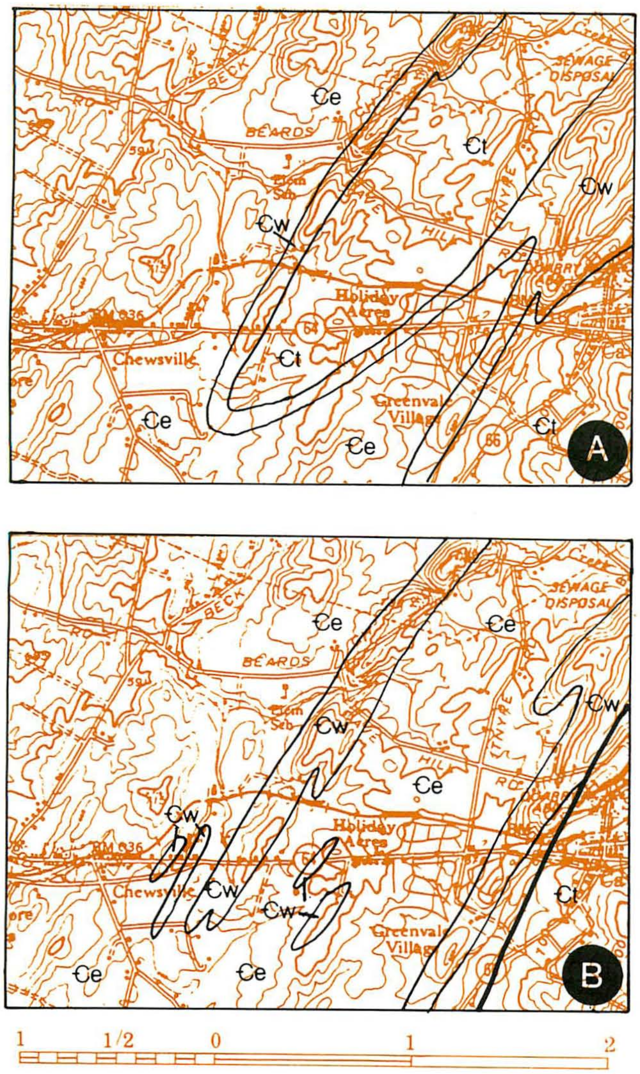
BEAVER CREEK FAULT

Stratigraphic discontinuities recorded by disrupted sections of Waynesboro Formation may be traced from near Roadside, Pennsylvania south into Maryland. Near Roadside, northeast of Waynesboro, the Waynesboro Formation is juxtaposed against Weverton, Harpers, and Antietam Formations. Root (1968) called this structure the Antietam Cove fault. Because Waynesboro is faulted against older Chilhowee Group rocks, Root (1970) interpreted the fault as strike-slip. This fault may be extended south to the Maryland-Pennsylvania State line, where it juxtaposes Waynesboro and Elbrook Formations. Previous mappers (Jonas and Stose, 1938; Cloos, 1941) in Maryland did not recognize this fault because their interpretation of the Waynesboro-Elbrook relationship does not require a fault.

The northernmost indications that this structure extends into Maryland may be observed between Chewsville and Cavetown. Bassler (1919, p. 70) believed that the Waynesboro occurred at the surface in this area "with such depth that the underlying limestone is occasionally plowed up in the fields". Considerable differences between the map patterns shown by Jonas and Stose (1938) and those of Cloos (1941) reflects differences in observation and interpretations (Figure 33). Jonas and Stose's map indicates that they mapped Waynesboro south from Pennsylvania to just south of Maryland Route 64, where it ends. East and west of this belt are parallel belts of Elbrook. Jonas and Stose (1938) suggested that this belt of Waynesboro is an inlier, surrounded by younger rocks of the Elbrook. However, Cloos (1941) continued the belt of Waynesboro to the east and connected it with a second Waynesboro exposure near Cavetown. Cloos interpreted the rocks mapped by Jonas and Stose east of the Chewsville Waynesboro belt as Tomstown Formation, not Elbrook. Therefore, in the Cloos interpretation, the area between the western and eastern Waynesboro belts is the core of a south-plunging anticline. Although strikes and dips of bedding in this area indeed suggest an anticline, the outcrops along the CSX tracks and fields to the north are unquestionably Elbrook strata.

Recognition of three members in the Waynesboro provides insights that lead to a different interpretation. Red Run and Cavetown Members are truncated against the Elbrook Formation. This is evident along the western Waynesboro exposure belt between the Leitersburg-Smithsburg Road and the CSX tracks (Plate 2)(Figure 34). For the eastern belt, this can be demonstrated between Maryland Route 64 and the CSX tracks west of Cavetown. The intervening belt of Elbrook does not, however, extend to the State line, as proposed by Jonas and Stose (1938). The northernmost exposure of Elbrook in this belt occurs in the field south of Route 64 and Welty's Church. To the north of Welty's Church, the area is comprised of outcrops of the Tomstown and Waynesboro Formations (Figure 34) (Plate 2). Consequently, this discontinuity is marked by the juxtaposition of all three Waynesboro members and the Tomstown Formation against the Elbrook. This truncation is interpreted as a continuation of the Antietam Cove fault of Pennsylvania. However, in the area west of Cavetown, the fault is conspicuously not strike-slip in nature. Clearly, the trace of the fault is very sinuous, indicating that it either has a very low angle or has been gently folded. Because a single, low-angle fault cannot explain all of these discontinuous relationships, it is interpreted as a single, folded fault. The western Waynesboro outcrop is interpreted as representing an incompletely isolated klippe, and the area of Elbrook between the two Waynesboro belts represents a fenster, or erosional window, through the fault plane (Figure 34). North of Maryland Route 64, the fault plane dips gently north beneath the Tomstown and Waynesboro outcrops.

The fault may be traced, by virtue of the related stratigraphic truncations, to the south from Cavetown toward Beaver Creek. From this location to the south the fault parallels Beaver Creek; therefore, it is named the



Ꞓe - **Elbrook Formation**

Ꞓw - **Waynesboro Formation**

Ꞓt - **Tomstown Formation**

Figure 33.— Comparison of geologic maps of Chewsville-Cavetown area as shown by A, Cloos, 1941, B, Jonas and Stose, 1938. Contour interval 20 feet, scale in miles.

Beaver Creek fault. South of Cavetown, only narrow slivers of the Chewsville Member of the Waynesboro Formation occur for 1.5 miles. South from Pondsville and Chewsville Road, along Maryland Route 66, the Chewsville Member again is well developed. Between Mt. Aetna Road and Interstate 70, the fault progressively truncates the three Waynesboro members from top to bottom, so that on the hill behind the Beaver Creek Park and Ride, the Red Run Member is emplaced against the Elbrook (Figure 35). The fault then swings sharply to the east along Interstate 70 for approximately 0.5 mile, then south toward U.S. 40 and Wagners Crossroads. Along this segment Red Run Member is faulted against Elbrook Formation. From the south end of this segment the fault trace has not been mapped. The I-70 cross-fault may extend this far into the valley and truncate the Beaver Creek fault. Red Run lithologies have been traced continuously to the south for more then 9 miles, terminating west of Rohrersville. This may be the trace of the trailing surface of the Beaver Creek fault, but may also represent a separate fault (San Mar fault) altogether.

The Red Run Member caps two small hillocks to the west of Maryland Route 66 and southwest of Wagners Crossroads. In the valley below these hills lies the Elbrook Formation. Cloos (1951) stated that, in this area, "the section may be reversed. Faulting or recumbent folding may play an important part in the distribution of the formations here." Inasmuch as these hilltops consist of Red Run Member and the Cavetown and Chewsville Members are absent, the Red Run lithologies are interpreted as klippen of the Beaver Creek thrust.

From U.S. Route 40 at Daubs Mill, south to where Beaver Creek has eroded through the ridge, the Chewsville, Cavetown, and Red Run Members are progressively truncated along the eastern side of the ridge. This again appears to be the trace of the Beaver Creek fault (Figure 35) although this may be the northern terminus of the Eakles Mills fault. Immediately to the west along Beaver Creek a small fenster is present where the Red Run Member lies upon marble of underlying Elbrook Formation.

South from Benevola, evidence of the Beaver Creek fault is not as strong. A small klippe of the Chewsville Member crops out along Maryland Route 68, at Millpoint. Between Millpoint and Monroe Chapel, the Chewsville Member is repeated. South of Wheeler Road the three members of the Waynesboro are offset along what is interpreted as the Beaver Creek fault. From this point south, hanging-wall rocks are notably right-side-up and foot-wall strata overturned and sometimes recumbent. The fault continues to cut down stratigraphic section until at the nose of Red Hill the fault merges with the Keedysville fault.

KEEDYSVILLE FAULT

The lineated Keedysville marble bed, which occurs near the base of the Bolivar Heights Member, is interpreted as representing a fault surface; however, no stratigraphic offset can be demonstrated. At all locations the marble is bedding parallel, but has been folded along with the adjacent strata. This suggests that the carbonates have been detached from the underlying Chilhowee Group, although the amount of movement is impossible to

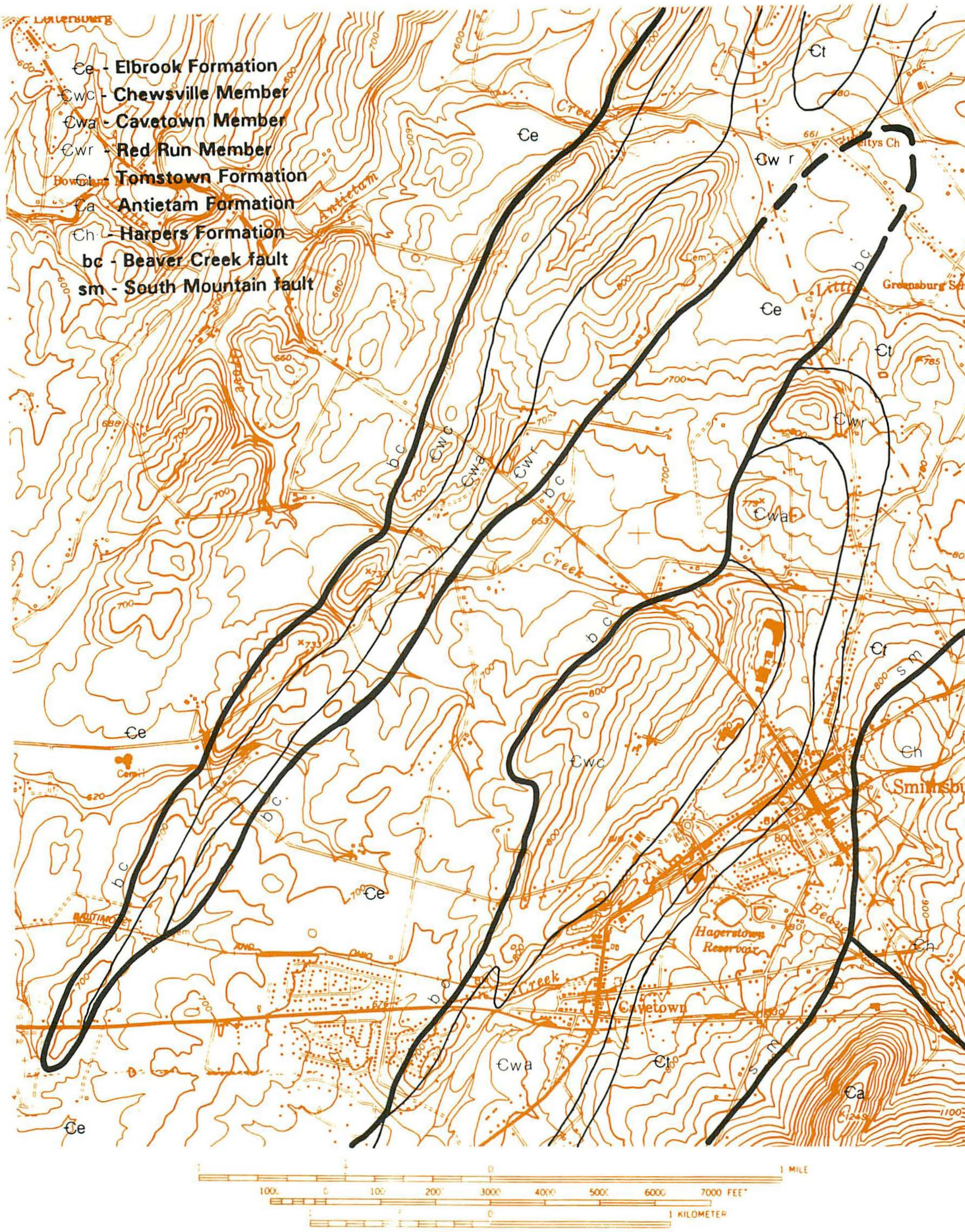


Figure 34.— Geologic map of the Cavetown and Chewsville Maryland area illustrating trace of Beaver Creek fault (bc) and truncated units of the hanging-wall. Contour inerval 20 feet.

determine. Judging from the lateral extent of this marble, from Berryville, Virginia to Glen Forney Pennsylvania, it may represent a structure of quite some significance.

SAN MAR FAULT

As mentioned above a belt of Red Run Shale extends south from the I-70 cross fault through San Mar to just west of Rohrerville. Although this structure may be an

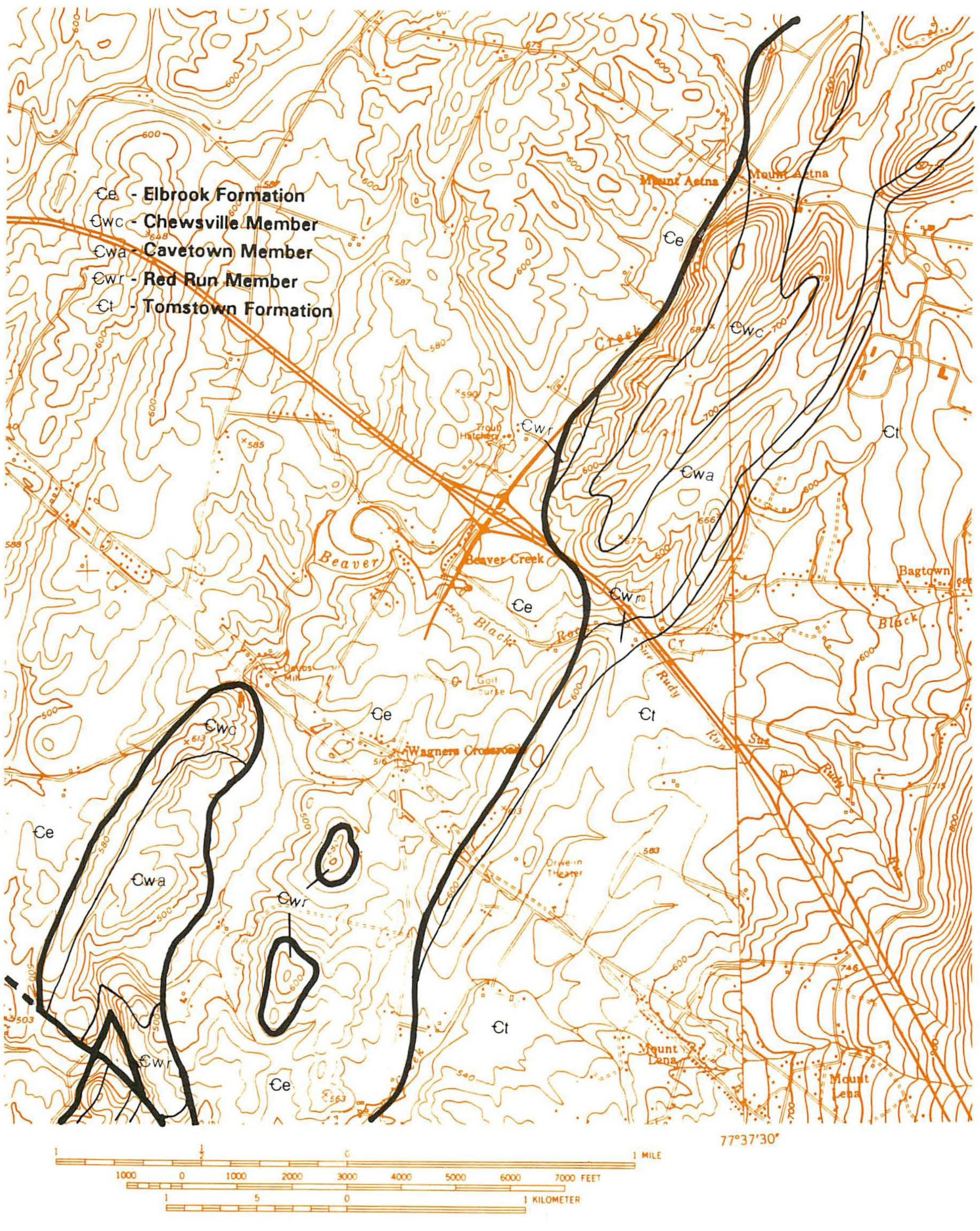


Figure 35.— Geologic map of the Beaver Creek area illustrating trace of Beaver Creek fault and truncation of hanging-wall units. Contour interval 20 feet.

extension of the Beaver Creek fault, unclear relations in the vicinity of the I-70 cross-fault precludes definitive determination. To the east of the Red Run shale, overturned and sometimes recumbent Dargan, Benevola, Fort Duncan, and Bolivar Heights Members are exposed. To the west interbedded sheared marble, tan dolomite, and ribbony dolomite are present. These lithologies are mapped on Plate 2 as Elbrook. Consequently, it appears that the Cavetown and Chewsville Members of the Waynesboro have been totally removed by faulting.

EAKLES MILLS FAULT

At Eakles Mills the Antietam Formation and lower Bolivar Heights Member of the Tomstown Formation including the Keedysville marble bed are truncated by a structure that places the Elbrook west of the San Mar fault against them. At Eakles Mill sheared, laminated, platy marble is juxtaposed to gently dipping Antietam. As the structure is followed northward, it truncates the eastern flank of the Red Hill anticline, progressively cutting the Fort Duncan and Benevola Members north of Dog Street Road and again southeast of Benevola. At several locations this fault appears to place the interbedded marble and dolomite lithologies in the hanging-wall upon the differentiated members of the Tomstown in the footwall. Because its trace is straight and it truncates a fold within the Tomstown members, it is interpreted to be a high-angle late structure.

ROHRERSVILLE FAULT

Along the stream at Rohrersville is exposed a stratigraphic discontinuity of considerable magnitude. At that location the Catoctin Formation is in contact with the Tomstown Formation. The stratigraphic relationships have fueled sizeable controversy over the years. Stose and Stose (1946 fig. 23, 25) proposed that the Catoctin Formation and adjacent Weverton Formation of Elk Ridge were thrust westward over the Tomstown Formation. However, Cloos (1951), interpreted the relationship as simply a high-angle normal fault juxtaposing the Tomstown against the Catoctin. This fault was interpreted as extending southward along the west flank of South Mountain where it placed Harpers shales against the basement complex. Recent core-drilling at Weverton by the Maryland Geological Survey and the U.S. Geological Survey and at Rohrersville by the U.S. Geological Survey has shown that this fault is low-angle (< 30 degrees) and exhibits indications of northwest thrusting. Current mapping in the vicinity of Rohrersville indicates that this fault indeed has a sinuous trace as proposed by Stose and Stose and not the straight trace shown by Cloos. Furthermore, the recumbent Tomstown Formation overlies the Catoctin. This structure is the most problematic feature in this region of the Blue Ridge. It is herein interpreted a representing an Early Paleozoic normal fault which placed Harpers against basement at Weverton and Tomstown against Catoctin at Rohrersville. During Blue Ridge formation this fault was tilted, folded, and, along some segments faulting reactivated, so that it now appears to be compressional in origin. Furthermore, the South Mountain fault system may now impart the thrusting character to the fault between Rohrersville and its southern terminus in Virginia.

CROSS-FAULTS

A number of discontinuities appear to trend across the regional strike, truncating both stratigraphy and structures. These trends are interpreted as cross-faults that appear to have developed very late in the deformational history of the area, inasmuch as they offset many of the large structures.

At Foxville Gap, east of Cavetown, the ridge of Antietam Formation terminates abruptly against the shales of the Harpers Formation parallel to Maryland Route 77. Along this same trend the Weverton, Loudoun and Catoctin on the south side of the fault are abutted against the Harpers Formation on the north side. This unnamed structure appears to be a tear fault that connects the High Rock fault with the South Mountain fault.

Where Interstate 70 crosses South Mountain a structural trend subparallel to the Interstate can be recognized. This structure truncates the Catoctin, Loudoun, and Weverton of the Black Rock syncline to the north and the same formations on Bartmans Hill to the south. Jonas and Stose (1938) and Fauth (1981) recognized this structure by its offsetting of the Catoctin through Antietam Formations. This fault is herein named the I-70 fault since it is subparallel to the highway. Along the same trend there are recognizable offsets in the Tomstown, Waynesboro and Elbrook Formations. Although relative directions of motion are not always consistent with that observed on South Mountain these offsets are interpreted to represent the same cross-fault. The I-70 cross-fault is the largest cross-strike feature observed in this study.

Another larger cross-strike feature can be demonstrated where Alternate U.S. 40 crosses South Mountain at Turners Gap. At the crest of the mountain the Harpers and Weverton Formations south of the highway abut the Catoctin Formation on the north side of the road. Farther to west, near Boonsboro, this same structure appears to juxtapose the Tomstown Formation on the south with the Antietam Formation on the north. Clearly this fault appears to be a thrust fault east of Lambs Knoll and yet possesses left-lateral relative motion south of Boonsboro. This fault (Turners Gap fault) appears to be a large tear connecting the South Mountain fault with a thrust that emanates from the basement complex of the Middletown Valley.

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APPENDIX — MEASURED SECTIONS

Locality numbers listed in the follow sections correspond to numbers listed in the text and on text figures. Sections were measured with a 5-foot Jacob's staff or by Brunton and pace methods.

LOCALITY 1

Composite section of the Loudoun Formation along the south side of Pine Knob. Dark-gray phyllite and conglomeratic sandstone occur in two separate exposures separated by approximately 200 yards. Section begins at lowest exposed phyllite unit.

Thickness (feet)

Loudoun Formation

43.0 Dark-gray, to dusky-blue, sandy phyllite.

6.0 Medium-gray, conglomerate containing pebbles of white quartz, rhyolite, phyllite and vessicular tuff. Clasts 0.25 to 1.0 inch in diameter.

5.4 Dark-gray, pebble to cobble conglomerate. Clasts of white quartz rhyolite, basalt and phyllite. Pebbles average 1.75 inches in diameter; matrix made of granular quartz.

0.25 Olive-gray phyllite.

5.0 Dark-gray, coarse-grained, pebble conglomerate, with clasts 1.5 inches in diameter.

Section continued to west of Appalachian Trail.

3.6 Medium-to dark-gray, pebble conglomerate. Composed mainly of rounded, white quartz pebbles, also contains pink or red quartz clasts. Other clasts include rhyolite, phyllite, and tan tuff. Matrix is granules and coarse-grained black phyllite.

1.8 Dark-gray, moderately well-sorted, granular to pebble conglomerate. Clasts typically less than 0.5 inch in diameter, few larger clasts.

4.75 Medium- to dark-gray, pebble conglomerate, with phyllite and granular quartz matrix. Clasts up to 2.0 inches in diameter.

2.2 Dark-gray, sandy phyllite and cross-bedded, phyllitic conglomerate. Clasts 1.5 to 2.5 inches in diameter.

2.9 Dark-gray, pebble conglomerate. Pebbles of white and pink quartz, pink rhyolite, tan and dark-gray phyllite. Maximum clast size, 4 inches.

LOCALITY 2

Section on south side of Lambs Knoll. Section begins in phyllite of the Loudoun Formation and ends in the Buzzard Knob Member of the Weverton Formation.

Thickness (feet)

Loudoun Formation

2.7 Dark-bluish-gray, sandy phyllite with amygdules.

4.2 Medium-gray, pebble conglomerate. Clasts of white quartz, red rhyolite, jasper, tan tuff and gray phyllite. Upper 1.0 foot thin-bedded.

2.25 Very dark-gray, fine-grained quartzite, purplish at base, becoming phyllitic upsection.

0.29 Dark-olive-gray, pebbly sandstone.

0.58 Lens of dark-gray, medium-grained sandstone.

1.7 Olive-gray, pebble to cobble conglomerate. Clasts of white quartz, up to 5.5 inches in diameter. Clasts also made of red rhyolite, and gray basalt, with chloritic matrix.

0.2 Olive-gray, sandy siltstone to phyllite.

1.0 Olive-gray, thin-bedded, quartz-pebble conglomerate.

0.2 Dark-gray, sandy siltstone.

Weverton Formation

Buzzard Knob Member

0.75 Olive-gray, granular conglomerate with pink and purple quartz clasts.

0.15 Olive-gray, shaly sandstone.

14.0 Light-olive-gray, thin- to medium-bedded, coarse-grained quartzite, with layers of granular conglomerate, and abundant purple laminations and cross-beds. Some tan laminations near top.

LOCALITY 3

Section along Maryland Route 491, in Raven Rock Hollow, 1 mile southeast of Edgemont, Washington County, Maryland. Section begins near the base of Buzzard Knob Member of the Weverton Formation and continues into the lower part of the Harpers Formation. This is type section of Buzzard Knob Member.

Thickness (feet)

Weverton Formation

Buzzard Knob Member

20.0 Pale-olive, medium-bedded, chloritic, coarse-grained sandstone.

11.0 Yellowish-gray, coarse-grained, thin-bedded sandstone.

16.0 Very light-gray, sugary, medium-bedded, cross-bedded, coarse-grained quartzite; few dark-grayish-purple areas.

62.0 Light-greenish-gray, medium-bedded quartzite, with dark-purplish-gray sandy phyllite layers 2-

3 inches thick. Some distinctive laminations of tan to gold prevalent.

6.0 Covered.

42.0 Light-greenish-gray, medium-bedded, coarse-grained, pebbly quartzite. Abundant chlorite and cross-bedding. Few dark-gray phyllite interbeds. Shaly at top.

Maryland Heights Member

90.0 Covered.

30.0 Dark-greenish-gray, sandy siltstone and fine-grained sandstone. Dark-gray sandstone beds less than 3 feet thick, weather rusty.

11.0 Covered.

5.0 Light-greenish-gray, medium-grained shaly sandstone.

50.0 Covered.

Owens Creek Member

35.0 Medium-gray, medium- to thin-bedded, coarse-grained, cross-bedded quartzite.

7.0 Covered.

5.0 Medium-greenish-gray to dark-gray, coarse-grained, granular sandstone with abundant pink quartz granules and chlorite.

15.0 Medium-gray, thin-bedded to platy, coarse-grained sandstone; very chloritic.

Harpers Formation

70.0 Covered.

32.0 Medium-gray, coarse-grained sandstone.

2.0 Light-brown, very coarse-grained sandstone.

110.0 Dark-greenish-gray, sandy siltstone.

29.0 Light-gray, coarse-grained quartzite with black shaly interbeds containing *Skolithos*.

LOCALITY 4

Sections along Sandy Hook Road and CSX railroad tracks west of the village of Sandy Hook, Washington County, Maryland, and west of the tunnel beneath Maryland Heights. Section begins in the upper ledge-forming quartzite in the Buzzard Knob Member of the Weverton Formation and ends in the Owens Creek Member. Section begins along Sandy Hook Road.

Thickness (feet)

Weverton Formation

Buzzard Knob Member

60.0 Light-greenish-gray, medium- to thick-bedded, cross-bedded quartzite. Cross-beds accentuated by goldish and purple foresets.

Maryland Heights Member

20.0 Covered (possible fault; section stratigraphically above is in normal stratigraphic position).

27.0 Dark-gray to dark-olive-gray, sandy siltstone. Dips northwest.

15.0 Covered.

10.0 Greenish-black, sandy siltstone.

10.0 Dark-gray, medium- to coarse-grained, conglomeratic sandstone (section overturned).

17.0 Interbedded, greenish-black, sandy siltstone and medium-grained sandstone.

5.5 Greenish-black, coarse-grained sandstone.

22.0 Interbedded, sheared, greenish-black siltstone and medium-gray, coarse-grained, folded sandstone (thickness in question).

35.0 Greenish-black, coarse-grained, massive sandstone; sheared and folded. Offset in section on railroad tracks beneath bridge.

2.0 Medium-gray, coarse-grained sandstone.

11.0 Greenish-black, sandy siltstone to fine-grained, silty sandstone.

3.0 Dark-gray, coarse-grained sandstone.

3.0 Medium-gray, sandy siltstone (sheared).

11.0 Dark-gray, phyllitic, coarse-grained sandstone.

27.0 Interbedded, greenish-black, sandy siltstone and sandstone; highest beds strongly sheared.

13.0 Greenish-black, coarse-grained, massive sandstone.

6.0 Greenish-black, sandy siltstone.

28.0 Greenish-black to dark-gray, highly cleaved, silty, coarse-grained sandstone, phyllitic at top.

East end of rail road tunnel, section offset to road.

11.0 Medium-gray, coarse-grained, medium-bedded sandstone.

4.0 Medium-gray, sandy siltstone to fine-grained sandstone.

10.0 Interbedded, dark-gray, sandy siltstone and sandstone.

Owens Creek Member

40.0 Medium-gray, coarse-grained, thick-bedded sandstone to conglomerate.

24.0 Interbedded, dark-gray, massive, quartz-pebble conglomerate to coarse-grained sandstone.

LOCALITY 5

Section along Maryland Route 550 and Owens Creek 2 miles northwest of Thurmont, Frederick County, Maryland. Section begins in the Maryland Heights Member of the Weverton Formation and is the type section of the Owens Creek Member of the Weverton Formation.

Thickness (feet)

Weverton Formation

Maryland Heights Member

9.0 Interbedded, greenish-black to dark-gray, sandy siltstone and conglomeratic sandstone.

7.0 Covered.

23.0 Interbedded, greenish-black and dark-gray, coarse-grained sandstone and sheared siltstone.

26.0 Covered.

Owens Creek Member

35.0 Medium-bedded, medium-dark-gray, coarse-grained to conglomeratic sandstone.

14.0 Greenish-black, coarse-grained sandstone.

Section continues at next westward bend in Route 550.

11.0 Medium-bedded, medium- to dark-gray, coarse-grained sandstone.

17.0 Thin-bedded, very dark-gray, very coarse-grained sandstone to granular conglomerate.

3.0 Thin-bedded, medium-gray quartzite.

0.8 Sheared, dark-gray sandstone.

3.5 Medium-gray, granular, conglomerate with white quartz pebbles.

4.0 Interbedded, shaly, dark-gray sandstone and conglomerate.

0.5 White quartz zone.

1.0 Medium-gray, cross-bedded, granular conglomerate.

3.0 Dark-gray, sheared, sandy siltstone.

3.0 Medium-gray, cross-bedded, granular conglomerate.

11.0 Thick-bedded, medium-gray graywacke, with quartz zone at base.

3.3 Interbedded, medium-bedded, dark-gray sandstone and sheared siltstone, and granular conglomerate.

Harpers Formation

5.0 Medium-gray-green, sandy siltstone.

23.0 Interbedded, thin-bedded, coarse-grained sandstone and olive-gray phyllite.

115.0 Covered.

35.0 Interbedded, greenish-black, thinly bedded, shaly sandstone and sheared siltstone.

20.0 Thin-bedded, medium-greenish-gray sandstone.

25.0 Covered.

19.0 Thin-bedded, greenish-black sandstone.

LOCALITY 6

Section along U.S. Route 340 at the south end of South Mountain east of the village of Weverton, Washington and Frederick Counties, Maryland. Section begins at east end of exposure within the Buzzard Knob Member of the Weverton Formation and ends in the Owens Creek Member. Section is overturned dipping to the southeast.

Thickness (feet)

Weverton Formation

Buzzard Knob Member

2.0 Grayish-green, phyllitic, coarse-grained sandstone.

1.0 Medium-light-gray, medium-grained sandstone.

10.0 Medium-light-gray, medium- to coarse-grained quartzite, with dark-gray streaks.

25.0 Brownish-gray to grayish-green, medium-bedded quartzite with thin goldish streaks and laminations.

11.0 Grayish-green, medium-bedded quartzite, with platy partings.

0.8 Grayish-green, quartzose siltstone.

6.0 Medium-light-gray, micaceous sandstone to quartzite.

32.0 Interbedded, medium-gray to grayish-green, platy quartzite and soft micaceous sandstone.

11.0 Medium-light-gray, medium-grained quartzite, with dusky-blue areas, and goldish yellow laminations. Cross-bedding abundant.

38.0 Medium-gray, medium- to thick-bedded, medium- to coarse-grained quartzite. Dusky-blue and dark-yellowish-orange streaks and lamination outline cross-bed foresets. Thin, dark-gray phyllite interbeds locally present.

Maryland Heights Member

30.0? Dark-gray, sandy siltstone, medium-gray at base, with a few medium-grained conglomeratic quartzite interbeds. (Actual thickness in question).

0.8 Medium-gray sheared siltstone.

25.0? Dark-gray to greenish-black siltstone and phyllitic shale with thin sandstone interbeds and pebbly conglomerate. (Section folded; thickness in question).

37.0 Dark-gray siltstone and shale with sandstone interbeds (section folded thickness in question).

15.0 Medium-gray, medium-grained quartzite. Folded and faulted.

73.0 Grayish-green to light-medium-gray, medium-bedded quartzite, with abundant cross-bedding. Laminations of dark-yellowish-orange and dusky-blue areas present throughout.

15.0	Medium-gray to grayish-green, medium-bedded quartzite.
3.0	Dark-gray to greenish-black shale.
6.0	Greenish-black, phyllitic shale.
17.0	Interbedded, greenish-black, platy sandstone, and phyllitic beds.
4.0	Medium-gray, thin-bedded, coarse-grained sandstone.
3.0	Medium-dark-gray, platy siltstone.
10.0	Dark-greenish-gray, medium-bedded quartzite.
5.0	Dark-greenish-gray, platy siltstone.
23.0	Greenish-black, medium-bedded, coarse-grained sandstone with shaly interbeds.
10.0	Medium- to dark-gray, medium-bedded, coarse-grained sandstone with black streaks.
90.0	Mostly covered.

Owens Creek Member

9.0	Dark-gray, coarse-grained graywacke to quartzite.
5.0	Covered.
80.0	Medium-dark-gray to medium-gray, very coarse-grained, graywacke to quartzite and interbedded, pink and dusky-blue, quartz-pebble conglomerate.
20.0	Dark-greenish-gray to medium-dark-gray, thin- to medium-bedded quartzite.

LOCALITY 7

Section along Pennsylvania Route 16 east of Rouzerville, Franklin County, Pennsylvania. Section begins behind retaining fence along bend in highway, within the upper part of the Montalto Member of the Harpers Formation and ends in the Antietam Formation.

Thickness (feet)

Harpers Formation

Montalto Member

10.0	Grayish-olive, very-fine-grained sandstone.
5.0	Light-olive-gray to olive-gray, sandy siltstone.
12.0	Brownish-gray, medium-bedded, cross-bedded, coarse-grained sandstone.
2.0	Olive-gray, to dark-greenish-gray, phyllitic shale.
5.0	Medium-gray, cross-bedded, medium-grained sandstone.
3.0	Dark-greenish-gray, phyllitic shale.
10.0	Interbedded, dark-greenish-gray, sandy siltstone and light-gray, medium-grained sandstone.
6.0	Light- to medium-light-gray sandstone.
3.0	Olive-gray, sandy shale to siltstone.
70.0	Grayish-olive-green, very thick-bedded, fine-grained sandstone with thin (0.5-1.0 inch) white to light-gray sandstone interbeds.
25.0	Olive-gray, massive, fine-grained argillaceous sandstone.
30.0	Dark-greenish-gray to greenish-black, very fine-grained sandstone with few 0.5- to 1.5-inch thick light-gray, fine-grained sandstone beds containing *Skolithos* burrows.
60.0	Interbedded, dark-greenish-gray, fine-grained, clayey sandstone with laminations and cross-laminations and light-gray, medium-grained sandstone containing *Skolithos* burrows.
14.0	Light-gray, medium-grained sandstone with few greenish-gray laminations and cross-lamination at base.
41.0	Covered.
55.0	Interbedded, dark-greenish-gray, sandy siltstone and light-gray, medium-grained, quartz sandstone with beds 1-4 inches thick containing *Skolithos* burrows. Sandstone beds become progressively thicker upsection.
3.0	Dark-greenish-gray siltstone.
5.0	Dark-greenish-gray, massive, fine-grained sandstone.
7.0	Interbedded, olive-gray, medium-grained sandstone and light-gray, sandstone with *Skolithos* burrows.
37.0	Dark-greenish-gray, fine- to medium-grained sandstone and siltstone with a few light-gray, laterally discontinuous sandstone beds.
45.0	Interbedded, olive-gray, sandy siltstone and light-gray, medium-grained, bioturbated sandstone.
16.0	Olive-gray, silty sandstone.
53.0	Dark-greenish-gray, fine-grained, sandy siltstone with lenses of pink to light-olive-gray sandstone containing abundant *Skolithos* burrows.
18.0	Light-olive-gray to olive-gray, medium-grained, micaceous sandstone with few light-gray sandstone bed containing *Skolithos* burrows.
20.0	Greenish-black, medium-grained, silty sandstone with a few light-gray sandstone beds.
105.0	Interbedded, dark-greenish-gray siltstone and light-gray sandstone with *Skolithos* burrows, light-gray beds 1-6 inches thick. Olive-gray at top.

Antietam Formation

31.0	Tan to light-olive gray, fine-grained sandstone with thin 0.5-2.0 inches white sandstone beds

containing *Skolithos* burrows.
37.0 Covered.
12.0 Light-olive-gray to very-light brown, medium-grained, cross-bedded sandstone.
3.0 Reddish, thin-bedded sandstone.
11.0 Light-gray, medium-bedded, medium-grained sandstone, with *Skolithos* burrows, and interbedded siltstone beds.
13.0 Covered.
22.0 Light-brown, medium-bedded, cross-bedded, sandstone with *Skolithos* burrows.
30.0 Covered.
18.0 Pale-yellowish-brown, fine-grained sandstone; highly bioturbated.
16.0 Covered.
14.0 Pale-yellowish-brown, iron-stained, medium-grained sandstone.
12.0 Covered.
27.0 Pale-yellowish-brown, knobbly weathering, cross-bedded sandstone with *Skolithos* burrows.
95.0 Covered.
15.0 Light-gray, medium-grained sandstone with *Skolithos* burrows.
11.0 Light-gray, massive, pure, sandstone with *Skolithos* burrows.

LOCALITY 8

Section along east side of Shenandoah River 2 miles south of Shannondale, Jefferson County, West Virginia. Section exposes contact of Antietam and Tomstown Formations.

Thickness (feet)

Antietam Formation
45.0 Interbedded, medium-light-gray, medium-bedded, coarse-grained sandstone, and dusky-yellow, fine-grained, bioturbated sandstone.
10.0 Covered.
3.0 Dusky-yellow to grayish-orange, ripple-laminated, fine-grained sandstone.
23.0 Interbedded, dark-gray, vuggy, coarse-grained sandstone, grayish-orange, medium-grained, hematitic sandstone and greenish-gray siltstone.

Tomstown Formation

Bolivar Heights Member
1.0 White, medium-bedded, saccharoidal, sandy dolomite.
15.0 Very light-gray, vuggy weathering, sandy dolomite.
25.0 Very light-gray, dusky-yellow weathering, saccharoidal dolomite.

Section moved north 150 yards.

35.0 Very light-gray, laminated marble (Keedysville marble bed).
20.0 Covered.
50.0 Dark-gray limestone.

LOCALITY 9

Section along north side of Shenandoah River, 1 mile southeast of Shannondale, Jefferson County, West Virginia. Section begins near base of Tomstown Formation and end in the Elbrook Formation.

Thickness (feet)

Tomstown Formation

Bolivar Heights Member
15.0 Light-brown, knotty, sandy dolomite.
30.0 Very light-gray, lineated marble (Keedysville marble bed).
22.0 Grayish-brown to olive-black, bioturbated limestone, with thin discontinuous dolomitic burrows.
56.0 Olive-black, flow-folded, dolomitic limestone.
27.0 Covered, tributary valley.

Fort Duncan Member
24.0 Dark-gray to olive-black, bioturbated, massive dolomite.
3.0 Dark-gray, bioturbated dolomite.
65.0 Dark-gray to olive-black, thick-bedded, bioturbated dolomite.
75.0 Dark-gray, medium- to thick-bedded, bioturbated dolomite.
35.0 Dark-gray, thick-bedded, bioturbated dolomite.

Benevola Member
37.0 Medium-light-gray, thick-bedded dolomite.
45.0 Light-gray, massive dolomite with ghosts of cross-bedding locally evident.
30.0 Covered.
23.0 Light-gray, cross-bedded, coarse-grained dolomite.
15.0 Covered.

Dargan Member
7.0 Light-gray dolomite.
4.5 Medium-gray, laminated dolomite.
15.0 Covered.
2.0 Medium-gray, laminated dolomite.

2.0 Medium-gray, cross-bedded dolomite.
40.0 Interbedded, medium-gray, bioturbated dolomite and medium-gray, laminated dolomite.
5.0 Medium-gray, laminated limestone containing cryptalgal stromatolites.
4.5 Medium-gray, thin-bedded, bioturbated dolomite.
19.0 Covered.
25.0 Interbedded, medium-gray, bioturbated and laminated dolomite.
20.0 Covered.
23.0 Interbedded, medium-gray, bioturbated and laminated dolomite.
15.0 Medium-gray, thick-bedded, laminated dolomite.
3.0 Dark-gray, ribbony dolomite.
7.0 Covered.
15.0 Interbedded, medium-gray, medium-bedded, laminated and bioturbated dolomite.
6.0 Dark-gray, stromatolitic dolomite, limestone at top.
12.0 Medium-gray, laminated, cryptalgal dolomite.
10.0 Medium-gray, ribbony and laminated dolomite.
3.0 Covered.
3.0 Medium-gray, ribbony dolomite, with black chert lenses.
5.0 Medium-gray, medium-bedded, laminated dolomite.
3.0 Medium-gray, laminated limestone.
2.0 Moderate-yellowish-brown dolomite.
10.0 Dark-gray, stromatolitic and laminated dolomite.
10.0 Medium-gray, thin-bedded, bioturbated dolomite.
27.0 Covered.
23.0 Medium-gray, medium-bedded, laminated dolomite.
11.0 Covered.
5.0 Medium-gray dolomite.
23.0 Covered.
15.0 Medium-gray, medium-bedded, bioturbated dolomite.
30.0 Medium-gray, interbedded bioturbated and laminated dolomite.
12.0 Covered.
7.0 Medium-gray, medium-bedded dolomite.
14.0 Interbedded, dark-gray, bioturbated and laminated dolomite.
8.0 Medium-gray dolomite.
5.0 Medium-gray, stromatolitic dolomite.
7.0 Covered.
12.0 Black, crinkle-laminated limestone.
10.0 Dark-gray, laminated dolomite with ooid ghosts, and chert lenses and nodules.
5.0 Black, laminated, stromalolitic limestone.
2.0 Dark-gray dolomite.
1.0 Black, laminated limestone.
2.0 Light-brown dolomite with chert nodules.
7.0 Black, crinkle-laminated limestone.
34.0 Interbedded, dark-gray, laminated dolomite and stromatolitic limestone.
2.0 Black, calcareous shale.
3.0 Black, sandy dolomite.
5.0 Dark-gray, laminated limestone.
16.0 Dark-gray, laminated dolomite.
3.0 Dark-gray, laminated limestone.
6.0 Medium-gray, bioturbated dolomite.
12.0 Covered.
2.5 Dark-gray, crinkle-laminated limestone.
3.2 Light-brown dolomite.
6.0 Covered.
14.0 Interbedded, dark-gray, laminated limestone and laminated dolomite.

— Highly Folded strata at contact interval — possible fault. Interval thickness in question.

Waynesboro Formation

Red Run Member
5.0 Light-olive-gray, sandy shale.
2.0 Dusky-yellow, fine-grained sandstone.
15.0 Light-olive-gray, laminated, shaly dolomite.
3.0 Black, shaly limestone.
15.0 Medium-gray, laminated dolomite.
27.0 Covered.
5.0 Grayish-red, sandy siltstone.
6.0 Grayish-brown, fine-grained sandstone.
2.0 Light-olive-gray, shale.
2.0 Dusky-yellow dolomite.
4.0 Olive-gray, sandy dolomite.
3.0 Olive-gray, calcareous shale.
3.0 Olive-gray shale.
2.0 Medium-gray, laminated dolomite.
5.0 Interbedded, olive-gray, sandstone and siltstone.

Cavetown Member
50.0 Covered (thickness estimated).
10.0 Medium-gray, shaly dolomite.
45.0 Covered (thickness estimated).
23.0 Interbedded, medium-gray, stromalolitic, dolomitic limestone, and dolomite.
40.0 Covered (thickness estimated).
21.0 Interbedded, medium-gray limestone and bioturbated and laminated dolomite.
10.0 Dusky-yellow and olive-gray, sandy dolomite.
30.0 Covered.
42.0 Interbedded, laminated limestone and biotur-

bated dolomite.

3.0 Moderate-olive-gray, calcareous shale.
9.0 Medium-gray, bioturbated dolomite.
5.0 Dusky-yellow dolomite.
35.0 Covered (thickness estimated).
15.0 Medium-gray, laminated limestone and bioturbated dolomite.

5.0 Medium-gray, argillaceous dolomite.
45.0 Covered (thickness estimated).

Chewsville Member

10.0 Interbedded, dark-reddish-brown siltstone, and medium-light-gray, calcareous, medium-grained sandstone.
5.0 Dusky-yellow, dolomite.
11.0 Grayish-red, sandy siltstone.
6.0 Dusky-yellow dolomite.
7.0 Interbedded, medium-gray and tan, sandy dolomite with thin (1-3 inches) sandstone beds.
1.0 Medium-gray limestone.
1.0 Dusky-yellow, laminated limestone.
10.0 Dusky-yellow dolomite with medium-gray sandstone interbeds.
5.0 Dark-reddish-brown, sandy shale to siltstone.
10.0 Dusky-yellow dolomite with sandstone stringers.
3.0 Medium-gray, laminated dolomite.
4.0 Medium-gray, ribbony, sandy dolomite with thin (1-2 inches) sandstone interbeds.
7.0 Interbedded, dark-reddish-brown siltstone and tan calcareous sandstone.
12.0 Interbedded, tan, sandy dolomite and medium-gray, shaly, laminated dolomite.
6.0 Medium-gray, bioturbated dolomite.
4.0 Medium-gray, laminated limestone.
2.0 Tan, laminated dolomite.
2.0 Light-olive-gray, calcareous shale.
6.0 Dusky-yellow, dolomitic limestone.
4.0 Olive-gray, sandy shale with sandstone nodules.
6.0 Olive-gray, argillaceous sandstone with dolomite stringers.

Elbrook Formation

2.0 Tan, laminated dolomite.
6.0 Medium-gray, thin-bedded, argillaceous dolomite.
5.0 Light-gray, shaly limestone.

LOCALITY 10

Section along CSX railroad tracks, and Potomac River at northern end of Bolivar Heights, Jefferson County, West Virginia. Section begins near the base of the Tomstown Formation, and is the type section of the Bolivar Heights Member.

Thickness (feet)

Tomstown Formation

Bolivar Heights Member

45.0 Dark-yellowish-orange, to white laminated marble with tan dolomitic laminae (Keedyville marble bed).
2.0 Medium-gray, platy limestone.
19.0 Interbedded, laminated, dark-gray limestone and dark-yellowish-orange dolomite.
12.0 Dark-gray, platy limestone.
3.0 Medium-gray, shaly limestone.
8.0 Dark-gray, laminated limestone with continuous beds.
0.8 Dark-gray dolomite.
12.0 Medium- to dark-gray, laminated limestone.
2.0 Medium-gray, platy limestone (sheared).
31.0 Dark-gray, laminated to ribbony limestone with a few rounded dolomitic burrows.
24.0 Dark-gray, very thinly bedded limestone with distorted brownish-gray burrows.
5.0 Dark-gray, thin-bedded limestone.
7.0 Dark-gray, thin-bedded, bioturbated limestone.
8.0 Dark-gray, laminated limestone with a few dolomitic burrows.
4.0 Dark-gray, very thinly bedded limestone with abundant dolomitic burrows.
6.0 Dark-gray, moderate-yellowish-brown weathering, dolomitic bioturbated limestone.
3.0 Dark-gray, laminated, burrowed limestone.
27.0 Dark-gray, burrow-mottled limestone with tan laminations.

Fort Duncan Member

20.0 Dark-gray, thick-bedded, bioturbated dolomite.
5.0 Covered.
147.0 Dark-gray, thick-bedded, bioturbated, coarse-grained dolomite.
55.0 Covered.

Benevola Member

20.0 Light-gray, fractured, aphanitic dolomite.
65.0 Covered, section moved to riverbank.
40.0 Light-gray, massive dolomite.

Dargan Member

250.0 Covered.
25.0 Light to medium-gray, medium-bedded, bioturbated dolomite.
10.0 Light-gray, coarse-grained dolomite.

45.0 Covered.
9.0 Dark-gray, bioturbated dolomite.
10.0 Covered.
47.0 Medium to dark-gray, coarse-grained, ribbony dolomite with numerous bioturbated beds.
23.0 Covered.
50.0 Dark-gray, medium-bedded, coarse-grained, bioturbated dolomite with numerous laminated, rippled and ribbony beds.
3.0 Dark-gray, laminated dolomite.
9.0 Medium-gray, coarse-grained, bioturbated dolomite.
2.0 Dark-gray, ripple-laminated dolomite.
5.0 Medium-gray, bioturbated dolomite.
12.0 Covered.
3.0 Medium-gray, cross-bedded, oolitic dolomite.
16.0 Dark-gray, bioturbated dolomite.
7.0 Covered.
5.0 Dark-gray, laminated dolomite with sharp (hard ground) upper surface.
14.0 Interbedded, dark-gray, laminated, and bioturbated dolomite. Contains several oolitic beds.
15.0 Dark-gray, medium-bedded, bioturbated dolomite.
10.0 Interbedded, dark-gray, laminated limestone and dolomite.
27.0 Interbedded, dark-gray, laminated limestone and bioturbated dolomite.

LOCALITY 11

Section along C & O Canal along north side of first meander bend northwest of Harpers Ferry, Washington County, Maryland. Section begins in lower strata of Bolivar Heights Member of the Tomstown Formation. Section is the type locality of the Fort Duncan Member.

Thickness (feet)

Tomstown Formation

Bolivar Heights Member
18.0 Medium-gray, with tan streaks, sheared, platy limestone and marble (Keedysville marble bed).
110.0 Medium-gray, weathering white, limestone with stringers, blebs and nodules of tan dolomite, especially at top.
10.0 Dark-gray, sheared, platy limestone.
12.0 Covered.

Fort Duncan Member
5.0 Dark-gray, bioturbated dolomite.
6.0 Covered.
25.0 Dark-gray, coarse-grained, brown-weathering, thick-bedded, bioturbated dolomite.
7.0 Covered.
105.0 Dark-gray, very thick-bedded, bioturbated dolomite.
4.0 Covered.
74.0 Dark-gray, thick-bedded to massive, highly burrowed dolomite.
14.0 Covered.
45.0 Dark-gray, medium-bedded, coarse-grained bioturbated dolomite; thinner bedded, less bioturbated at top.

Benevola Member
27.0 Medium-gray, fractured crystalline dolomite.
24.0 Covered.
55.0 Medium- to light-gray, massive, dolomite, with faint cross-bedding.

LOCALITY 12

Section located in Martin Marrietta's Benevola Quarry. Section begin in southwest corner of quarry within the uppermost part of the Fort Duncan Member. This is the type section of the Benevola Member.

Thickness (feet)

Tomstown Formation

Fort Duncan Member
10.0 Dark-gray, thick- to medium-bedded, bioturbated dolomite.
7.0 Very dark-gray, medium-bedded, bioturbated dolomite.
32.0 Dark-gray, dense, medium-bedded, dolomite.

Benevola Member
53.0 Very light-gray to light-gray and brownish-gray, massive dolomite, highly fractured.
6.0 Medium-gray laminated dolomite.
5.0 Medium-gray, medium-bedded dolomite.
4.0 Black, coarse-grained, bioturbated dolomite.
2.0 Dark-gray, vuggy dolomite.
1.0 Black, vuggy dolomite.
20.0 Medium-gray, massive dolomite.
5.0 Light-gray, laminated dolomite.
40.0 Light-gray, mottled massive dolomite.

Dargan Member
11.0 Very light-gray, massive dolomite.
2.0 Medium-gray, laminated dolomite.
6.0 Dark-gray, rippled dolomite.
3.0 Tan, laminated dolomite.
2.0 Dark-gray, thin-bedded, shaly dolomite.

5.0 Medium-gray, bioturbated dolomite.
11.0 Light-gray, cross-bedded dolomite.
5.0 Medium-gray, tan weathering, massive dolomite.
10.0 Covered (may be fault zone).
3.0 Black, dense, fractured dolomite.
4.0 Black, laminated dolomite.
5.0 Dark-gray, laminated dolomite, weathers tan.
3.0 Dark-gray, ribbony dolomite.
2.0 Medium-gray, medium-bedded dolomite.
10.0 Dark-gray, massive dolomite.
3.0 Medium-gray, laminated dolomite.
10.0 Black, ribbony dolomite with thin interbeds of laminated dolomite.
20.0 Dark-gray, medium-bedded dolomite.
30.0 Medium-gray, thick-bedded, fractured dolomite.
22.0 Interbedded, dark-gray, laminated and bioturbated dolomite.

LOCALITY 13

Section along C & O Canal and Lime Kiln Road, 1 mile northwest of Dargan, Washington County, Maryland. Section begins along canal in fold that exposes upper strata of Bolivar Heights Member of the Tomstown Formation. This is the type section of the Dargan Member.

Thickness (feet)

Tomstown Formation

Bolivar Heights Member
48.0 Dark-gray, impure limestone with tan dolomitic stringers.
6.0 Covered.
16.0 Dark-gray, burrowed limestone with dolomitic stringers.
3.0 Covered.

Fort Duncan Member
7.0 Dark-gray, thick-bedded, bioturbated dolomite.
11.0 Covered.
10.0 Dark-gray, bioturbated dolomite.
4.0 Medium-gray limestone.
7.0 Olive-black, bioturbated dolomite.
2.0 Dark-gray, bioturbated dolomite with limestone interbeds.
210.0 Dark-gray, medium- to thick-bedded, coarsed-grained, bioturbated dolomite. Less burrowed at top.

Benevola Member
10.0 Covered (continued on Lime Kiln Road).
45.0 Medium- to light-gray, granular, massive dolomite.
37.0 Very light-gray, massive dolomite.
1.0 Brownish-gray, bioturbated dolomite.
6.0 Brownish-gray, laminated dolomite.
5.0 Covered.
6.0 Dark-gray, bioturbated dolomite, thick-bedded at top.
2.0 Dark-gray, ribbony dolomite.
25.0 Medium-gray, medium-bedded dolomite, locally bioturbated.
3.0 Covered.
55.0 Very light-gray, massive to thick-bedded dolomite; some indications of cross-bedding.

Dargan Member
1.0 Medium-gray, laminated dolomite.
3.0 Light-gray, coarse-grained dolomite.
4.0 Dark-gray, laminated, stromatolitic dolomite.
3.0 Dark-gray dolomite.
7.0 Dark-gray, stromatolitic dolomite.
3.0 Dark-gray, thin-bedded dolomite.
5.0 Medium-gray, laminated dolomite.
5.5 Medium-gray, bioturbated dolomite.
3.0 Dark-gray, laminated, algal dolomite.
1.0 Medium-gray dolomite.
1.0 Medium-gray, bioturbated dolomite.
3.0 Medium-gray, laminated dolomite.
17.0 Medium-gray, medium-bedded, bioturbated dolomite.
1.0 Dark-gray, laminated dolomite.
3.0 Dark-gray, dolomite.
3.5 Dark-gray, bioturbated dolomite.
4.0 Medium-gray, bioturbated dolomite.
6.0 Medium-gray, stromatolitic dolomite.
3.0 Medium-gray, medium-bedded dolomite.
2.0 Medium-gray, stromatolitic dolomite.

3.0 Medium-gray, medium-bedded, bioturbated dolomite.
5.0 Covered.
4.0 Medium-gray, laminated dolomite.
3.0 Covered.
15.0 Dark-gray, laminated dolomite.
12.0 Dark-gray, medium-bedded, bioturbated dolomite.
3.0 Dark-gray, laminated dolomite.
3.0 Covered.
11.0 Dark-gray, massive, coarse-grained, bioturbated dolomite.
25.0 Covered.
4.0 Medium-gray, laminated dolomite.
10.0 Covered.
3.0 Medium-gray dolomite.
5.5 Dark-gray, laminated vuggy, dolomite.

6.0	Medium-gray, thin-bedded, stylolitic limestone.
5.0	Very light-gray, coarse-grained dolomite.
3.0	Light-gray, laminated dolomite.
3.0	Medium-gray, medium-bedded, bioturbated dolomite.
2.0	Covered.
10.0	Medium-gray, laminated dolomite.
3.0	Medium-gray, bioturbated dolomite.
2.0	Medium-gray dolomite.
1.5	Dark-gray, bioturbated dolomite.
1.0	Medium-gray, laminated dolomite.
2.0	Dark-gray, bioturbated dolomite.
12.0	Interbedded, medium-gray, tan-weathering dolomite, and dark gray, laminated, stromatolitic limestone.
5.0	Dark-gray, laminated limestone.
3.0	Medium-gray, dense limestone.
2.5	Medium-gray, laminated limestone.
10.0	Interbedded, dark-gray, ribbony limestone, and algal laminated dolomite.
2.0	Tan, argillaceous dolomite.
4.0	Medium-gray, laminated limestone.
1.0	Tan, laminated dolomite.
7.0	Dark-gray, laminated limestone, with grainstone interbeds.
3.0	Dark-gray, sheared limestone.
4.0	Covered.
3.0	Dark-gray, laminated limestone.
4.0	Covered.
1.5	Tan, laminated dolomite.
5.0	Dark-gray, crinkle-laminated limestone.
2.0	Tan, argillaceous dolomite.
1.0	Dark-gray, stromatolitic limestone.
2.0	Tan dolomite.
10.0	Dark-gray, laminated dolomite.
25.0	Covered.
2.0	Tan dolomite.
7.0	Dark-gray, laminated limestone.
2.0	Tan dolomite.
13.0	Dark-gray, cherty limestone; chert black in color.
17.0	Interbedded, medium-gray limestone with thin, black chert beds, and tan, laminated dolomite and dolomitic limestone.

LOCALITY 14

Section along abandoned Western Maryland railroad grade and Red Run Creek south of Wayne Heights, Franklin County, Pennsylvania. Section begins in the Dargan Member, Tomstown Formation, and is the type section of the Red Run Member of the Waynesboro Formation.

Thickness (feet)

Tomstown Formation

Dargan Member

20.0	Dark-gray, bioturbated dolomite.
7.0	Tan, laminated dolomite.
3.0	Tan, shaly dolomite.
7.0	Medium-gray, ribbony dolomite.
15.0	Dark-gray, silty limestone.
7.0	Covered.
5.0	Dark-gray, dolomite.
3.0	Tan, laminated dolomite.

Waynesboro Formation

Red Run Member

3.0	Olive-gray, calcareous shale.
10.0	Medium-gray, laminated, sandy dolomite.
3.0	Dark-gray dolomite.
11.0	Dark-gray, medium-bedded dolomite with sandy stringers.
12.0	Covered.
4.0	Medium-gray, medium-bedded, sandy dolomite, weathering tan.
2.0	Covered.
2.0	Medium-gray, sandy dolomite.
4.0	Olive-gray, calcareous shale.
7.0	Light-gray, calcareous, medium-bedded sandstone with purple laminations at top.
4.0	Interbedded, medium-gray and tan dolomite.
6.0	Covered.
5.0	Medium-gray, tan weathering, dolomitic sandstone.
3.0	Tan, sandy, ribbony dolomite.
3.0	Covered.
15.0	Interbedded, tan, dolomitic sandstone, sandy, ribbony dolomite and very dark-red shale.
3.0	Medium-gray, medium-bedded, medium-grained calcareous sandstone.
5.0	Tan, laminated, medium-grained sandstone.
7.0	Covered.
25.0	Interbedded, medium-gray, sandy limestone, and olive-gray, calcareous, sandy shale.

Cavetown Member

30.0	Dark-gray, folded, sandy limestone.
10.0	Dark-gray, massive limestone.
15.0	Covered.
21.0	Dark-gray, massive, dolomitic limestone.
350.0	Covered (thickness estimated by pacing).
17.0	Dark-gray, bioturbated, massive dolomite.
120.0	Covered (thickness estimated by pacing).

Chewsville Member

15.0	Dusky-red, silty shale and sandy siltstone.
50.0	Covered.

3.0 Interbedded, dusky-red shale, and grayish-pink sandstone.
2.0 Covered.
6.0 Interbedded, white to grayish-pink, medium-grained, cross-laminated sandstone, and very dark-red, silty shale.
3.0 Covered.
2.0 Very light-gray, medium-grained, flaser-bedded sandstone.
7.0 Interbedded, olive-gray, shaly limestone and shaly sandy limestone.
3.0 Brown, calcareous sandstone.
11.0 Medium-gray, oolitic limestone.

LOCALITY 15

Section along CSX railroad tracks at Halltown, beneath the U.S. Route 340 bridges, Jefferson County, West Virginia. Section begins in the uppermost part of the Tomstown Formation.

Thickness (feet)

Tomstown Formation

Dargan Member
2.0 Medium-gray, laminated dolomite.
3.0 Medium-gray, bioturbated dolomite.
5.0 Medium-gray, laminated to ribbony dolomite.
20.0 Interbedded, medium-gray bioturbated dolomite and laminated limestone.
1.0 Light-brown, laminated dolomite.
15.0 Covered.

Waynesboro Formation

Red Run Member
9.0 Medium-gray, ribbony dolomite with thin sandstone stringers and interbeds.
21.0 Covered.
16.0 Medium-gray, sandy limestone to calcareous sandstone; weathers light-brown.
6.0 Covered.
24.0 Interbedded, medium-gray, laminated dolomite shaly dolomite.
10.0 Olive-gray to medium-gray, shaly dolomite.
5.0 Light-brown, punky sandstone.
5.0 Interbedded, olive-gray shale and shaly limestone.
27.0 Medium-gray, sandy dolomite and thin sandstone stringers, and interbedded with thin shaly layers.
10.0 Medium-gray, sandy dolomite.
5.0 Medium-gray, shaly dolomite to dolomitic shale.
7.0 Olive-gray, calcareous shale.

LOCALITY 16

Section exposed along north and east wall of Beaver Creek Quarry, 1 mile south of Mt. Aetna, Washington County, Maryland. Section begins in the Cavetown Member on the northwest corner of quarry.

Thickness (feet)

Waynesboro Formation

Cavetown Member
0.5 Olive-gray, calcareous shale.
1.0 Tan, argillaceous dolomite.
13.0 Interbedded, olive, calcareous shale and laminated dolomitic limestone.
5.0 Dark-gray, bioturbated dolomite.
6.0 Medium-gray, laminated, dolomitic marble.
6.0 Medium-gray, dolomite.
19.0 Dark-gray, massive, bioturbated dolomite.
3.0 Dark-gray, laminated limestone.
12.0 Medium-dark-gray, medium-bedded limestone with thin shaly interbeds.
7.0 Medium-gray, bioturbated dolomite.
1.0 Thin-bedded, limestone.
15.0 Dark-gray, thick-bedded, bioturbated, dolomitic limestone.
2.0 Dark-gray, thin-bedded limestone.
3.0 Light-gray, cross-bedded dolomite.
5.0 Interbedded, light-gray dolomite and black, siliceous dolomite.
1.0 Dark-gray, laminated limestone.
12.0 Dark-gray, thin-bedded, ribbony dolomite.
2.0 Light-gray, dolomite.
6.0 Dark-gray, thin-bedded dolomite.
4.0 Thinly interbedded, dark-gray limestone and olive calcareous shale.
5.0 Dark-gray, medium-bedded limestone.
2.0 Interbedded, dark-gray limestone and shale.
5.0 Medium-gray, medium-bedded dolomite.
6.0 Dark-gray, thin-bedded limestone and olive shale.
24.0 Medium- to dark-gray, thin- to medium-bedded dolomite with thin shaly partings.
1.5 Olive, calcareous shale.
3.0 Very light-gray, bioturbated dolomite.
4.0 Medium-gray, bioturbated dolomite.
14.0 Medium- to dark-gray, laminated to thin-bedded limestone to dolomitic limestone.
4.0 Tan, laminated dolomite.
10.0 Tan to light-gray, thin-bedded, argillaceous

limestone.

11.0 Dark-gray, medium-bedded dolomite to dolomitic limestone.
3.0 Thinly interbedded, dark-gray limestone and calcareous shale.
5.0 Dark-gray, argillaceous limestone.
2.0 Dark-gray, shaly, laminated limestone.
10.0 Dark-gray, massive, bioturbated dolomite.
15.0 Dark-gray, thin-bedded dolomite.
50.0 Fractured, dark-gray dolomite (probable fault zone, thickness in question).
7.0 Dark-gray, thin- to medium-bedded limestone.

Chewsville Member
5.0 Tan to medium-gray, dolomitic shale.
2.0 Tan, argillaceous dolomite.
10.0 Olive-gray shale with tan dolomitic interbeds and red-brown siltstone at top.
3.0 Tan, argillaceous dolomite.
5.0 Medium-gray, argillaceous limestone.
10.0 Olive-gray shale with tan dolomite interbeds.
6.0 Interbedded, tan dolomite and gray, sandy limestone.
3.0 Interbedded, red-brown, sandy siltstone and fine-grained sandstone.

LOCALITY 17

Section along north and west faces of quarry in Cavetown, Washington County, Maryland. Section begins within Cavetown Member of Waynesboro Formation. This is the type section of the Cavetown Member of the Waynesboro Formation.

Thickness (feet)

Waynesboro Formation

Cavetown Member
55.0 Medium- to dark-gray, medium- to thick-bedded, bioturbated dolomite and ribbony dolomitic limestone.
20.0 Covered.
35.0 Medium- to dark-gray, intraclastic dolomite; cross-bedded, sandy, massive.
20.0 Medium-gray, massive dolomite.
15.0 Medium- to dark-gray, medium-bedded, laminated, algal limestone and ribbony, sandy, dolomitic limestone.

Chewsville Member
25.0 Interbedded, red-brown siltstone, shale, sandstone and tan mudcracked dolomite.

LOCALITY 18

Section along CSX railroad tracks (formerly Western Maryland) approximately 1.0 mile east of Chewsville, Washington County, Maryland. Section begins near the base of the Chewsville Member of the Waynesboro. This is the type section of the Chewsville Member.

Thickness (feet)

Waynesboro Formation

Chewsville Member
5.0 Interbedded, dusky-red, sandy siltstone and grayish-pink to light-gray, medium-grained, sandstone with *Skolithos* burrows.
2.0 Dark-reddish-brown, sandy siltstone.
6.0 Covered.
3.2 Moderate-reddish-brown, silty, calcareous, fine-grained sandstone.
16.0 Covered.
4.0 Dusky-red, silty shale to mudstone.
4.0 Light-brown, laminated to thinly cross-laminated, sandy dolomitic limestone.
2.0 Moderate-red, sandy siltstone with *Rusophycus* burrows.
2.0 moderate-reddish-brown, sandy dolomite.
2.3 Pale-reddish-brown, very fine-grained, calcareous sandstone.
6.0 Covered.
2.5 Interbedded, moderate-red, cross-bedded sandstone, and dusky-red, and olive-gray shale.
2.0 Interlaminated, olive-gray and dusky-red, sandy siltstone with fine-grained sandstone lenses.
1.5 Olive-gray shale.
6.2 Interbedded, pale-red to moderate-reddish-brown laminated, sandy dolomite and laminated, calcareous sandstone.
2.0 Very light-gray, medium-grained, well-sorted, platy sandstone.
5.0 Interbedded, dusky-red, sandy siltstone and cross-laminated grayish-pink sandstone.
1.0 Grayish-red sandstone.
7.0 Olive-gray to medium-gray, shaly limestone to calcareous shale.
1.0 Medium-gray, shaly dolomite.
1.0 Tan weathering, laminated, silty dolomite.
5.0 Tan-weathering, medium-gray, medium-bedded, fine-grained sandstone with reddish shale partings.
2.0 Interbedded, dusky-red and olive-gray, calcareous shale.
5.0 Interbedded, dusky-red siltstone to mudstone and grayish-pink, medium-grained sandstone.
9.0 Covered.

7.0 Olive-gray to medium-gray, laminated to ribbony, sandy limestone and dolomite limestone.
5.0 Covered.
6.0 Medium-gray, tan-weathering, stromatolitic dolomite.
5.0 Olive-gray shale with dusky-red siltstone interbeds.
6.0 Medium-gray, silty sandstone.
3.0 Light-gray, tan-weathering, cross-bedded sandstone.
4.0 Covered.
1.5 Tan, sandy dolomite.
2.0 Olive-gray, dolomitic, medium-grained sandstone.
10.0 Thinly interbedded, dusky-red and olive-gray siltstone and grayish-pink sandstone.

LOCALITY 19

Section along Alternate U.S. 40 near junction of Cool Hollow Road and near Antietam Creek. Section begins in Elbrook Formation on bend in highway near house.

Thickness (feet)

Elbrook Formation
5.0 Light-brown dolomite (in core of small anticline).
5.5 Light-gray, ribbony limestone and dolomite.
2.0 Olive-gray shale.
4.0 Light-brown, argillaceous limestone.
3.0 Light-gray, ribbony limestone.
5.0 Tan, ribbony dolomite.
6.0 Tan, shaly dolomite.
2.0 Light-gray limestone.
10.0 Tan, shaly, platy dolomite.
3.0 Medium-gray, argillaceous limestone.
3.0 Tan dolomite, shaly at top.
2.0 Tan, calcareous shale.
5.0 Light-gray, bioturbated limestone, laminated at top.
2.0 Tan, shaly dolomite.
3.0 Light-gray limestone with tan wispy laminae at top.
6.0 Tan, shaly dolomite, ribbony and laminated at top.
2.0 Light-gray limestone.
0.5 White marble.
4.0 Light-gray, intraclastic, ribbony limestone.
1.5 Olive-gray shale.
5.0 Interbedded, light-gray, stromatolitic limestone and tan dolomite.
1.0 Olive-gray shale.
3.0 Tan, ribbony dolomite.
2.0 Medium-gray, algal limestone.
3.0 Tan, ribbony dolomite.
2.0 Light-gray, algal limestone.
11.0 Tan, shaly dolomite, ribbony at top.
20.0 Interbedded, light- to medium-gray, thrombolitic limestone, and tan to light-brown, ribbony dolomite with thin shale beds <1.0 foot thick.
7.0 Tan, shaly dolomite, ribbony at top.
15.0 Interbedded, light-gray, algal limestone and tan dolomite.
2.0 Red, sandy siltstone.
2.0 Light-brown, ribbony dolomite.
3.0 Light-gray, shaly, dolomite limestone.
1.0 Olive-gray shale.
2.0 Light-gray, dolomitic limestone.
5.0 Covered.
3.0 Red and olive, calcareous, dolomitic shale.
34.0 Interbedded, light-gray-brown, argillaceous limestone with algal beds and tan ribbony dolomite. Weathers platy.
26.0 Covered.
5.0 Light-grayish-brown, argillaceous limestone with shaly partings.
7.0 Medium-gray, massive, algal limestone.
0.8 Light- to medium-gray limestone with tan laminae.
2.0 Tan dolomite.
5.0 Light-gray, bioturbated, dolomitic limestone.
5.0 Interbedded, tan, argillaceous limestone and dolomite.
8.0 Medium-gray, ribbony limestone and tan to light-gray dolomite.
13.0 Medium- to dark-gray, bioturbated limestone with grainstone beds; intraclastic with trilobites and few tan dolomite layers.
2.0 Light-brown dolomite.
47.0 Interbedded, medium-gray, platy, dolomitic limestone and ribbony, and algal (thrombolitic) dolomite.
32.5 Interbedded, light-gray-brown and gray, dolomitic limestone and dolomite and tan, platy, shaly dolomite, and laminated and ribbony dolomite. Few red and olive-gray siltstone interbeds.
10.0 Tan, massive dolomite.
7.0 Medium-gray, medium-bedded limestone.

LOCALITY 20

Section of Elbrook Formation along railroad tracks near Altenwald, Franklin County, Pennsylvania. Section begins and ends within the Elbrook.

Thickness (feet)

Elbrook Formation

3.0	Medium-gray, bioturbated limestone.
14.0	Tan, shaly, silty dolomite.
3.0	Light-gray, thin-bedded limestone.
2.0	Covered.
3.0	Tan, dolomitic shale.
3.0	Covered.
4.0	Greenish-gray, calcareous shale.
2.0	Interbedded, tan, silty sandstone and shale.
5.0	Tan dolomite.
4.0	Light-gray, platy limestone.
2.0	Covered.
5.0	Light-gray, argillaceous limestone.
20.0	Covered.
4.0	Light-gray, ribbony limestone.
4.0	Tan, argillaceous limestone.
2.0	Medium-gray limestone.
5.0	Medium-gray, argillaceous, dolomitic limestone.
5.0	Covered.
2.0	Ribbony limestone.
7.0	Covered.
32.0	Interbedded, light-gray limestone and tan dolomite.
5.0	Medium-gray limestone.
6.0	Interbedded, tan dolomite and medium-gray limestone.
5.0	Tan, argillaceous limestone.
14.0	Medium-gray, thin-bedded limestone.
2.0	Tan, shaly dolomite.
3.0	Tan, laminated dolomite.
3.5	Tan, shaly, laminated dolomite.
5.0	Tan, shaly dolomite.
2.0	Light-gray marble.
5.0	Tan, shaly dolomite.
4.0	Light-gray marble.
7.0	Covered.
3.0	Tan, ribbony dolomite.
2.0	White, laminated marble.
2.0	Medium-gray, ribbony limestone and dolomite.
10.0	Interbedded, tan, shaly dolomite and gray dolomitic limestone.
3.0	Light-gray marble.
10.0	Interbedded, tan, shaly dolomite and ribbony dolomite.
2.0	Medium-gray, bioturbated limestone.
2.0	Medium-gray, argillaceous limestone.
5.0	Covered.
3.0	Tan, dolomitic shale.
2.0	Medium-gray limestone.
12.0	Covered.
34.0	Interbedded, tan, ribbony dolomite, massive dolomite, and medium-light-gray limestone.

LOCALITY 21

Section at Roadside, Franklin County, Pennsylvania. Section begins in the upper Dargan Member of the Tomstown Formation, and ends in the lower Red Run Member of the Waynesboro Formation.

Thickness (feet)

Tomstown Formation

Dargan Member

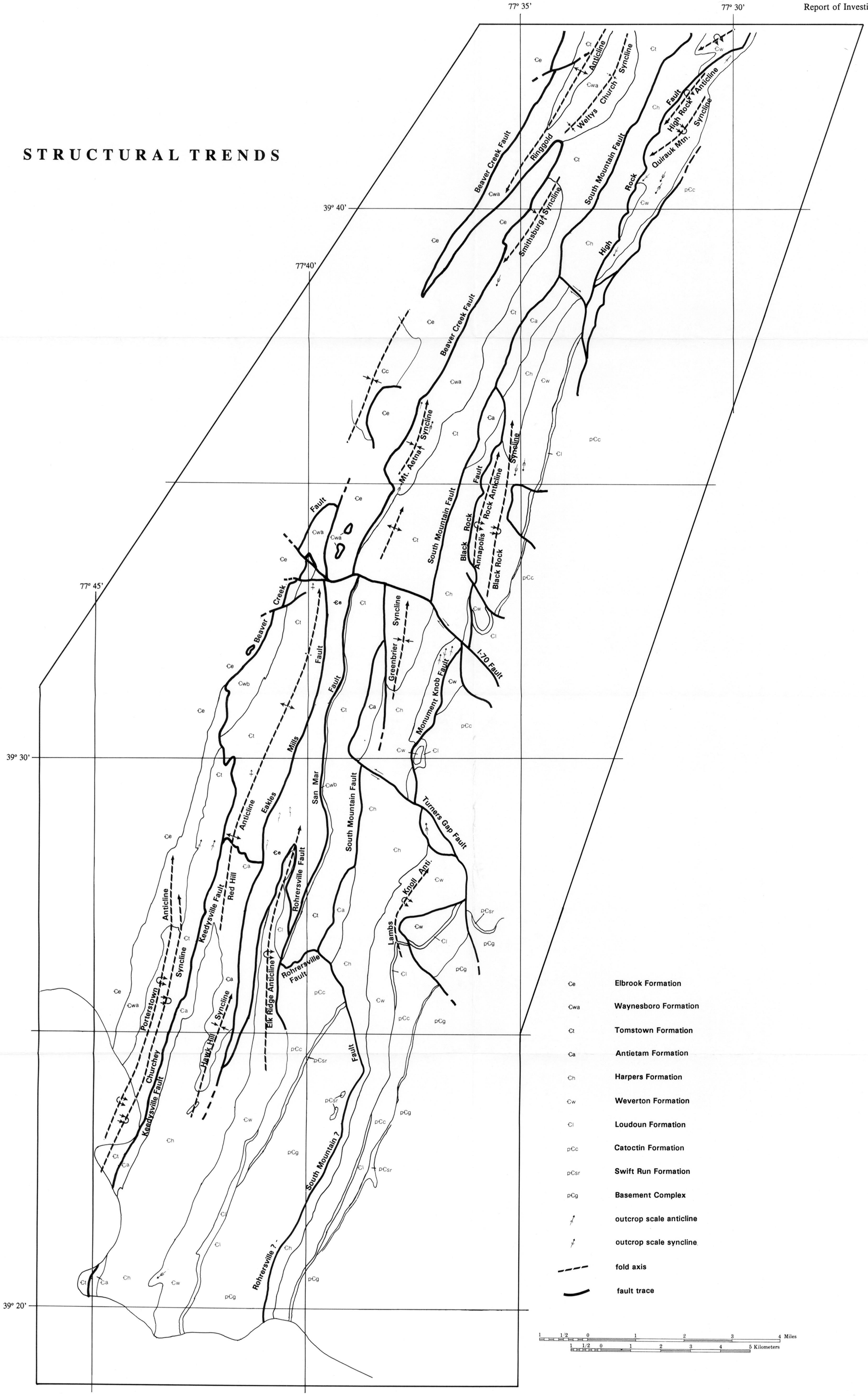
35.0	Interbeded medium-gray laminated limestone and tan laminated dolomite
15.0	Tan, laminated, silty dolomite.

Waynesboro Formation

Red Run Member

28.0	Interbedded, tan to white, fine-grained, calcareous sandstone and tan laminated dolomite.
10.0	covered.
3.0	Light-gray, laminated limestone. .
15.0	Covered.
9.0	Interbedded, tan, sandy limestone, and green-gray, calcareous shale.

STRUCTURAL TRENDS

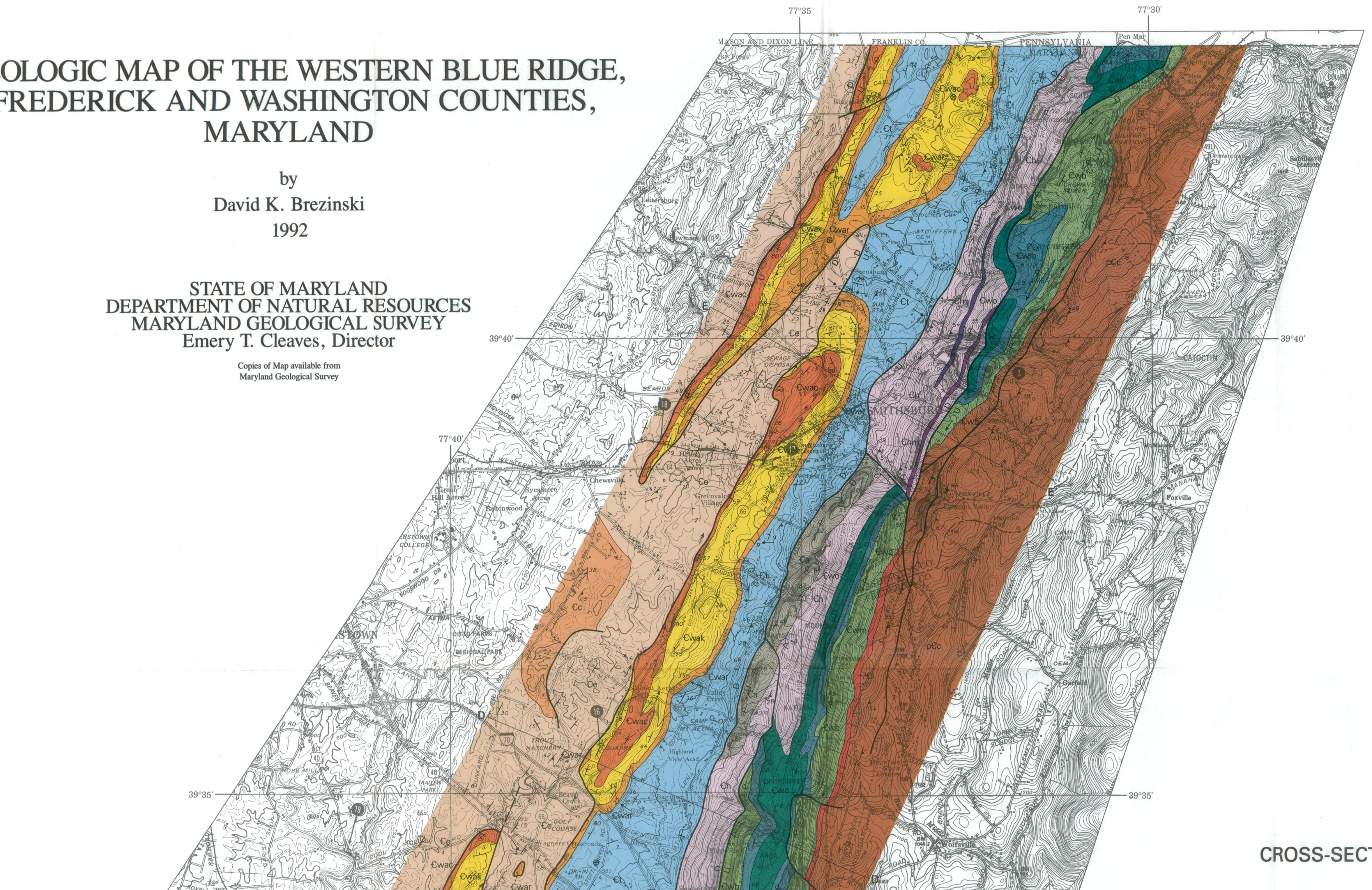
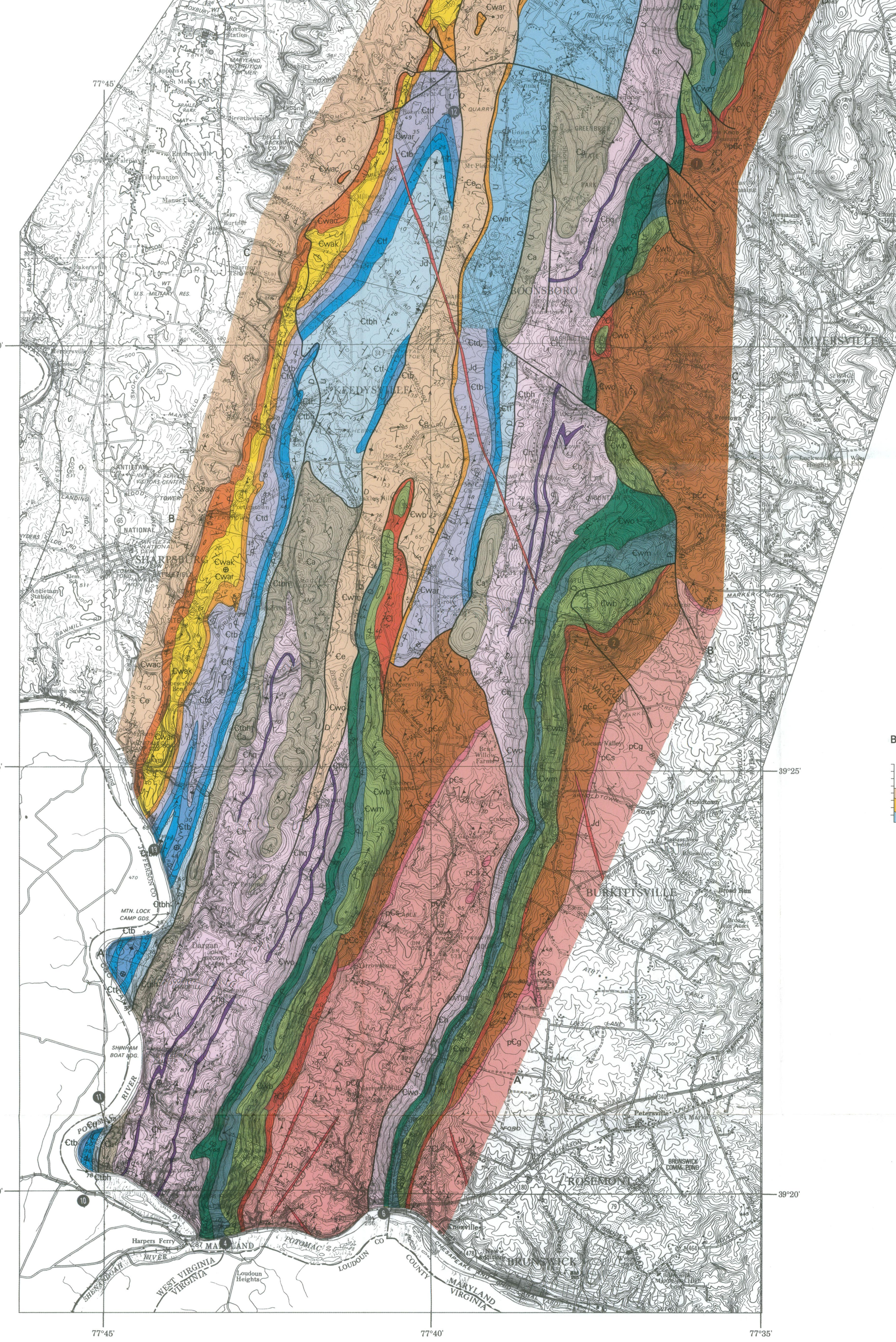


GEOLOGIC MAP OF THE WESTERN BLUE RIDGE, FREDERICK AND WASHINGTON COUNTIES, MARYLAND

by
David K. Brezinski
1992

STATE OF MARYLAND
DEPARTMENT OF NATURAL RESOURCES
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

Copies of Map available from
Maryland Geological Survey

EXPLANATION

JURASSIC

Jd — DIABASE DIKE—Dark-gray, fine-grained metabasalt, weathering to a yellowish-brown color.

UPPER CAMBRIAN

€c — CONOCOCHEAGUE FORMATION—Interbedded, dark-gray, algal limestone, laminated, dolomitic limestone, and tan dolomite. Thickness: 2000–2500 feet

MIDDLE CAMBRIAN

€e — ELBROOK FORMATION—Interbedded, medium-gray, thinly-bedded limestone, white, mylonitic marble, tan, laminated dolomite, and thin, calcareous shale to shaly dolomite. Thickness: 2000–2500 feet.

LOWER CAMBRIAN

€wa — WAYNESBORO FORMATION (undivided in cross sections only)

- €wac — CHEWSVILLE MEMBER—Interbedded, maroon shale, mudstone and argillaceous sandstone, light-gray sandstone, and tan, sandy, dolomitic limestone and dolomite. Thickness: 100–150 feet.
- €wak — CAVETOWN MEMBER—Interbedded, medium- to dark-gray, bioturbated dolomite, dolomitic limestone and laminated limestone, with a few thin siliciclastic interval near the middle. Thickness: 500–600 feet.
- €war — RED RUN MEMBER—Interbedded, light-olive-gray shale, light-gray, fine-grained sandstone, and medium- to dark-gray, sandy, dolomitic limestone. Thickness: 100–125 feet.

€t — TOMSTOWN FORMATION (where not divided into members)

- €td — DARGAN MEMBER—Interbedded, dark-gray, bioturbated dolomite, medium- to dark-gray, laminated dolomite, and dark-gray limestone. Thickness: 600–700 feet.
- €tb — BENEVOLA MEMBER—Light-gray, massive, coarse-grained dolomite. Thickness: 60–150 feet.
- €tf — FORT DUNCAN MEMBER—Dark-gray, medium- to thick-bedded, bioturbated dolomite. Thickness: 175–250 feet.
- €tbh — BOLIVAR HEIGHTS MEMBER—Predominately dark-gray, bioturbated and sheared limestone with white, mylonitic marble (Keedysville marble bed) near the base. Thickness: 200–250 feet.

€a — ANTIETAM FORMATION—Interbedded, greenish-black, sandy siltstone and light-brown, fine-grained sandstone in the lower part; medium-bedded, light-brown, fine-grained sandstone in the middle; and medium-gray, vuggy, cross-bedded, coarse-grained sandstone at the top. Thickness: 500–600 feet.

€hq, €h, €hm — HARPERS FORMATION—Interbedded, dark-greenish-gray to dark-gray, sandy metasiltstone, dark-gray metagraywacke, and thinly bedded, light-gray, quartzose sandstones containing *Skolithos* burrows near the top. Medium-gray, coarse-grained, ferruginous quartzites (€hq) present in middle of formation and light-gray Montalto Member (€hm) in the lower part of the formation near the Pennsylvania State line. Thickness: 2000–3000 feet.

€w — WEVERTON FORMATION—(undivided in cross section only)

- €wo — OWENS CREEK MEMBER—Medium- to dark-gray, medium-bedded, coarse-grained to conglomeratic metagraywacke. Thickness: 100–150 feet.
- €wm — MARYLAND HEIGHTS MEMBER—Interbedded, dark-greenish-gray, sandy metasiltstone, medium-gray, coarse-grained metagraywacke, and medium-light-gray quartzite. Thickness: 300–500 feet.
- €wb — BUZZARD KNOB MEMBER—Medium-light-gray to light-gray, medium- to coarse-grained, medium-bedded quartzite. Thickness: 125–175 feet.

LOWER CAMBRIAN OR PROTEROZOIC

?€l — LOUDOUN FORMATION—Dark-gray to grayish-black phyllite, locally containing amygdules, and medium-gray, cross-bedded to massive, polymictic conglomerate. Thickness: 20–100 feet.

PROTEROZOIC

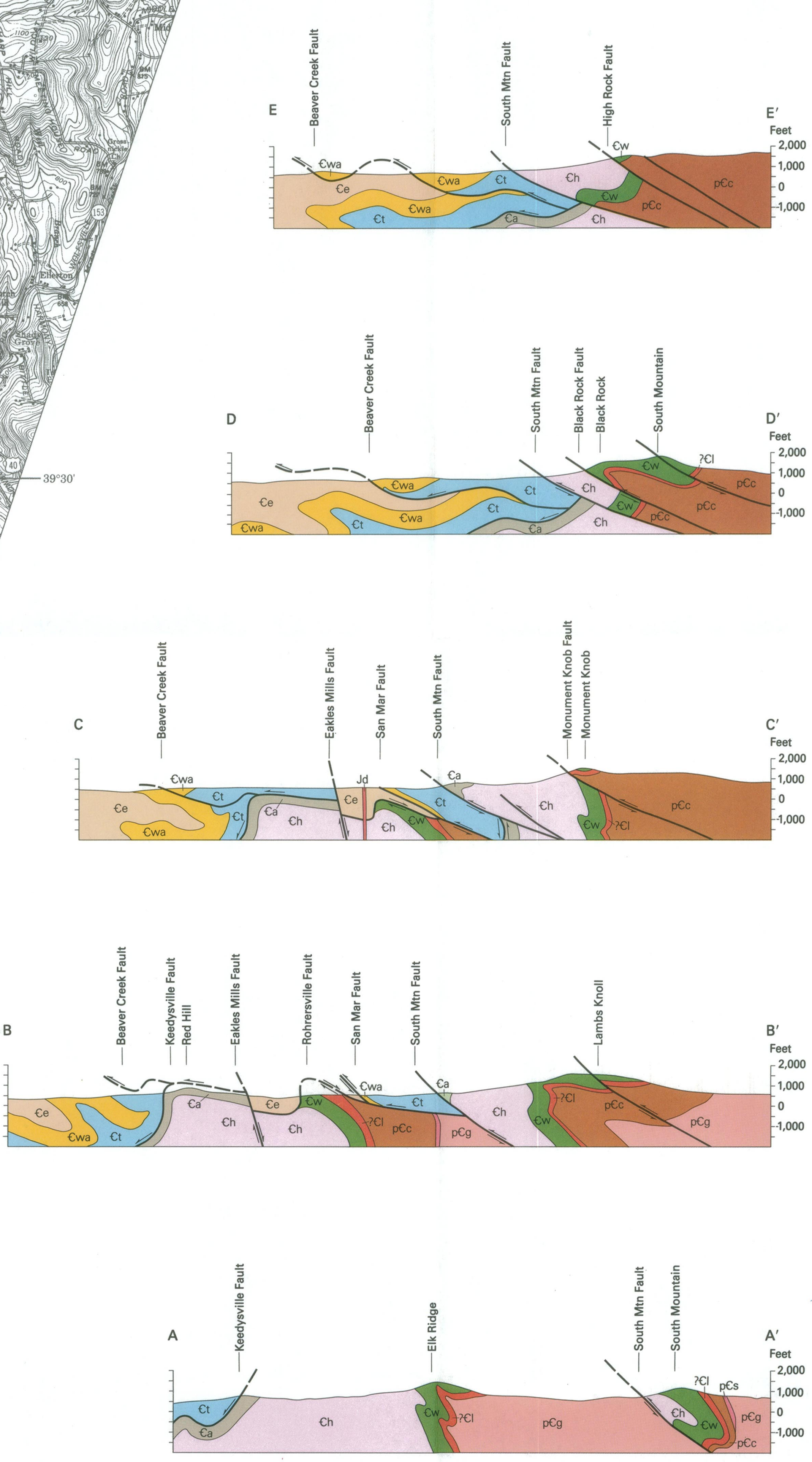
p€c — CATOCTIN FORMATION—Predominately dark-greenish- gray, to greenish-black, fine-grained metabasalt, locally with beds of amygdaloidal basalt, and greenish-gray tuffs. Less commonly medium-gray to moderate-red, porphyritic and flow-banded metarhyolite.

p€s — SWIFT RUN FORMATION—Light-bluish-gray phyllite, light-gray, sandy siltstone, and light-olive-gray, coarse- to very-coarse-grained, arkosic sandstone.

p€g — BASEMENT GNEISS—Massive, light-brownish-gray, to white, coarse-grained, garnet-bearing, granite gneiss, locally mylonitic, and pale pink, very-coarse-grained, augen gneiss. Pervasively cross-cut by dark-greenish-gray, highly cleaved, metabasalt dikes.

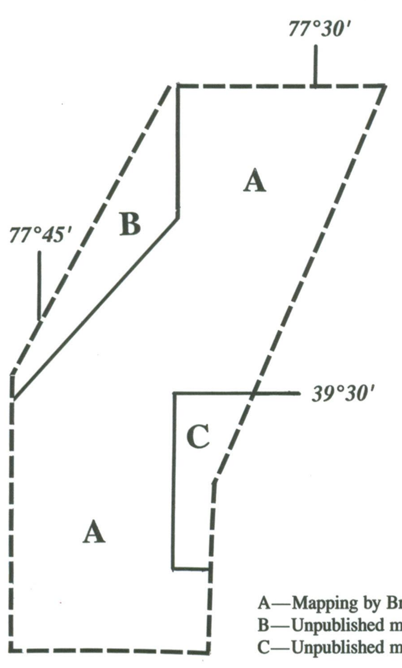
(55) Circled numbers are locations of sections described in Appendix.

CROSS-SECTIONS

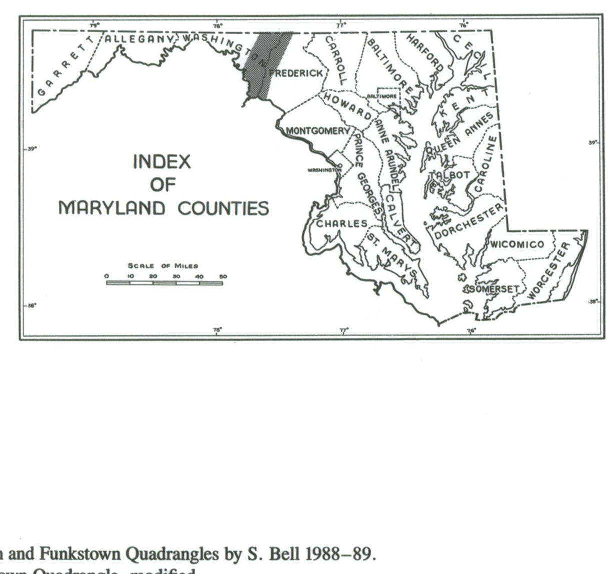


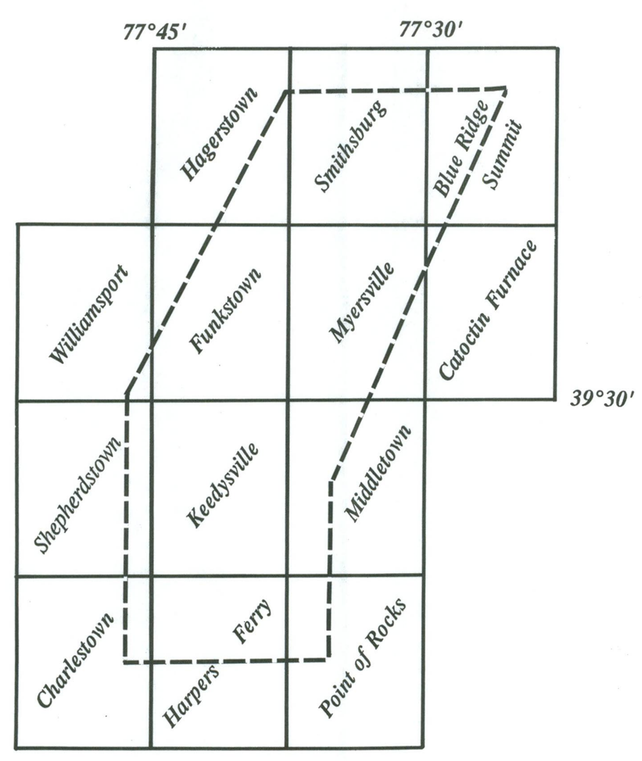
SYMBOLS

- contact
- strike and dip of bedding
- strike of vertical bedding
- horizontal bedding
- strike and dip of overturned bedding
- bedding rotated more than 180°
- strike and dip of cleavage
- strike of vertical cleavage
- strike and dip of compositional banding in Proterozoic rocks
- bearing and plunge of lineation
- direction of plunge of minor fold
- fault (U and D on the upthrown and downthrown sides).
- fault (showing relative directions of motion).



A—Mapping by Brezinski 1986–1992
B—Unpublished mapping of parts of the Hagerstown and Funkstown Quadrangles by S. Bell 1988–89.
C—Unpublished mapping by J. Fauth of the Middletown Quadrangle, modified.





Scale 1:62500

0 1/2 1 2 3 4 Miles

1 1/2 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level

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