COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE WILLIAMSVILLE QUADRANGLE VIRGINIA

KENNETH F. BICK

REPORT OF INVESTIGATIONS 2

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

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GEOLOGY OF THE WILLIAMSVILLE QUADRANGLE, VIRGINIA

By

KENNETH F. BICK

ABSTRACT

The rocks of the Williamsville quadrangle, Virginia (bounded by parallels 38°00′ and 38°15′ and meridians 79°30′ and 79°45′) range in age from Early Ordovician to Late Devonian. Ordovician rocks outcrop only in the northwest part of the quadrangle in the center of a large anticline that has been breached by erosion; in ascending order, the Ordovician formations present are the Beekmantown formation, Lurich formation, Lincolnshire limestone, Big Valley formation (new name), McGlone formation, Moccasin formation, Edinburg formation, Martinsburg formation, and Juniata formation. The Ordovician rocks aggregate about 2100 feet in thickness. The remainder of the quadrangle is underlain by Silurian and Devonian clastic rocks, with the exception of approximately 500 feet of dominantly carbonate rocks of Late Silurian and Early Devonian age; the total thickness of Silurian and Devonian is about 8000 feet.

Deformation of the rocks of the Williamsville quadrangle occurred during the Appalachian orogeny of Permian age. The structure is characterized by folds, with minor associated faults. The major fold pattern of the area consists of anticlinoria on the southeast and northwest, separated by a synclinorium; many smaller folds are superimposed, in a complicated pattern, on the major folds. The northwest limbs of the anticlinoria dip more steeply than the southeast limbs, and many of the smaller folds are locally overturned to the northwest. Evidence suggests that this picture of a relatively simple folded terrain may be in error; the quadrangle may be underlain by one or more subsurface thrust faults, and the folds observed at the surface may continue downward only to the uppermost thrust plane.

The Williamsville quadrangle contains large reserves of impure limestones and high-calcium limestones that are suitable for many industrial purposes. Sands of ceramic quality are also probably present in the Ridgeley and Clinch sandstones.

INTRODUCTION

Location and Access

The Williamsville quadrangle, in west-central Virginia, is an area of 235 square miles bounded by parallels 38°00′ and 38° 15′ and meridians 79°30′ and 79°45′. Slightly more than the southern three-fourths of the quadrangle is in Bath County, and the remainder is in Highland and Rockbridge counties. The only communities in the area are Bath Alum, in the southwest, and Bolar, Burnsville, and Williamsville in the northern quarter of the quadrangle. The nearest towns are Warm Springs, 4.5 miles west of the area; Monterey, 13.5 miles north; and Goshen, 2 miles southwest.

The major highways in the quadrangle are U. S. Highway 220 across the northwest corner of the area, State Highway 39 across the southern part of the area, and State Road 629, which trends in a northerly direction through the central part of the area. Various roads, paved and unpaved, connect with these highways, but access to much of the quadrangle is difficult by road.

Geography

The Williamsville quadrangle lies wholly within the Valley and Ridge province of the Appalachian Highlands, and is characterized by northeast-trending mountain ridges and intervening valleys. The dominant elements of the topography are four complex ridges and four large valleys, although there are numerous minor ridges and valleys within these major elements. The valleys, from southeast to northwest, are the valleys of the Calfpasture River, Cowpasture River, Dry Run-Bullpasture River, and Jackson River; the valley of the Cowpasture River is the largest, but is bifurcated by Shenandoah Mountain in the east-central part of the quadrangle. The major ridge complexes are, from southeast to northwest, Mill Mountain-Sideling Hill-Walker Mountain, Warm Springs Mountain-Tower Hill Mountain-Bullpasture Mountain, Wilson Mountain-Little Mountain-Jack Mountain, and Back Creek Mountain. The ridges and valleys correspond closely with the geologic structure; ridges are anticlines and valleys are synclines. Shenandoah Mountain, which is comprised of resistant rocks in a synclinal trough, and

Back Creek Mountain, Little Mountain, and Jack Mountain, which are the resistant flanks of breached anticlines, are the only major exceptions to the above generalization. The crest of Back Creek Mountain, approximately 3940 feet in elevation, is the highest point in the quadrangle. Ridge crests range from 2600 feet to 3600 feet and valley elevations range from 1500 feet to 2200 feet; in both cases, the higher elevations are chiefly confined to the northwest half of the quadrangle. Total relief in the area is about 2600 feet.

The quadrangle is drained by four major rivers, the Calfpasture River, the Cowpasture River and its tributary the Bullpasture River, and the Jackson River. The rivers flow southwesterly and eventually join the James River. These major streams have entrenched meandering channel patterns. Each has numerous tributaries, of which Dry Run, Stuart Run, and Mill Creek are the most important. The quadrangle has a trellis drainage pattern.

ACKNOWLEDGEMENTS

The field work for this report was done in the summers of 1960 and 1961. The writer gratefully acknowledges the aid given by numerous residents of the area and by the Virginia Division of Mineral Resources. Special thanks are due Charles L. Campbell who was field assistant during the summer of 1961.

GEOLOGIC FORMATIONS

INTRODUCTION

In the following sections are described in chronologic order the 18 geologic formations shown on the geologic map (Plate 1, in pocket). These formations range in age from Early Ordovician to Late Devonian and all are comprised of sedimentary rocks.

ORDOVICIAN SYSTEM

BEEKMANTOWN FORMATION

The Beekmantown formation outcrops in Big Valley in the northwestern part of the quadrangle where erosion has breached a large anticline; only the upper few tens of feet of the formation are exposed. The contact with the overlying Lurich formation is difficult to locate because of extensive cover, and because the basal Lurich rocks are variable and in many places similar to the Beekmantown. At one good series of exposures, the contact was noted to be at a change from thick-bedded to thin-bedded rocks, coinciding with a change in lithology from dolomite to limestone. Thickness of bedding does not seem to be an unequivocal criterion of the contact, but the lithologic change from dolomite to limestone can be used in the Williamsville quadrangle. The contact is a disconformity in many parts of Virginia, but direct evidence of this is lacking in Big Valley; the basal part of the Lurich formation is variable in thickness and contains much limestone conglomerate suggesting the contact is disconformable in Big Valley.

The Beekmantown formation is comprised of fine-grained dolomite in beds 1 to 3 feet thick. The rock is light to medium gray on fresh fracture and weathers medium gray to yellowish-gray. Two distinctive features of the formation are abundant dark gray chert nodules and stringers, and a distinctive pattern of intersecting furrows on weathered surfaces. The Beekmantown is Early Ordovician in age (Butts, 1940).

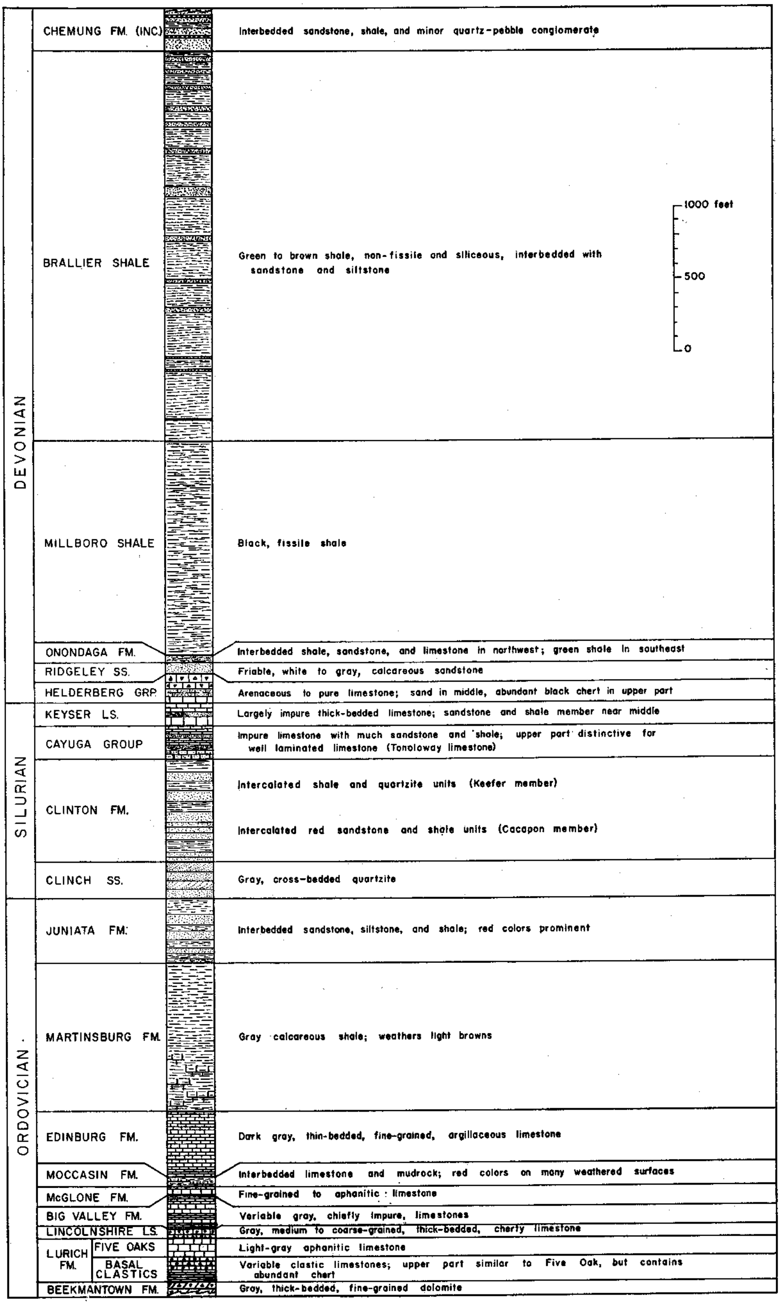

Figure 1—Stratigraphic section of the formations exposed in the Williamsville quadrangle, Virginia.

NOMENCLATURE OF MIDDLE ORDOVICIAN ROCKS

Middle Ordovician rocks are confined to Big Valley and to Hightown Valley; Hightown Valley is west of Back Creek Mountain in the extreme northwest part of the quadrangle. The Middle Ordovician sequence is comprised of limestone units of various types, with the exception of the upper few hundred feet which is calcareous shale, and is generally similar to the Middle Ordovician rocks described by Cooper and Prouty (1943) in Tazewell County, Virginia, 150 miles southwest. Exposures of the Middle Ordovician rocks are essentially continuous northeastward from Tazewell County into southern Allegheny County, a distance of 70 miles; between the latter point and Big Valley, the only complete exposures are in southern Warm Springs Valley, 35 miles southwest of Big Valley.

Kay (1956) has traced these rocks from Pennsylvania to southwest Virginia and has subdivided the section into formations. As to the relations of the Big Valley and southwest Virginia sections, the writer has studied the Middle Ordovician rocks between Bluegrass in the northern part of Hightown Valley and Sweet Chalybeate Springs in southern Allegheny County. The writer is in essential agreement with Kay as to the sequence present, and as to correlations, but cannot agree with all of the formations as he delineates them. Figure 2 contains the terminology of Kay and the writer, with southwest Virginia and Shenandoah Valley nomenclature included for comparison. Figure 2 is *not* a correlation chart, but is intended to contain only the relations between the terminology of the various workers; however, the dashed line across the chart represents one very distinctive faunal assemblage, probably indicating contemporaneity of that part of the section. The reasons for altering Kay's terminology will be presented below with the descriptions of the formations.

Southwest Virginia (Generalized section for Tazewell and western Giles counties) (Cooper and Prouty, 1943; Cooper, 1944; Twenhofel, et al, 1954)	Western Giles County Virginia (Kay, 1956, p. 60)	Big Valley (section measured 2.1 miles north of Bolar) (Kay, 1956, p. 68)	Big Valley (this report)	Shenandoah Valley, Lexington area (Cooper and Cooper, 1946)
Martinsburg fm.	Martinsburg fm.	Not measured	Martinsburg sh.	Martinsburg fm.
Eggleston fm.	Eggleston fm.	Onego member of the Salona fm.	Edinburg fm.	Collierstown ls.
— — — — —	— — — — —	— — — — —	— — — — —	— — — — —
Moccasin fm.	Moccasin fm.	Nealmont-Moccasin fm.	(Lantz Mills facies) Moccasin fm.	St. Luke mem.
Witten ls.	McGraw fm.	McGraw fm.	McGlone fm.	— — — — —
Bowen fm. / Wardell fm. — Gratton ls.	McGlone fm.	McGlone fm.		Edinburg fm. (Liberty Hall facies)
Benbolt ls.	Benbolt fm.	Benbolt fm.	Big Valley fm.	
Peery ls.	Peery fm.	Peery fm.		— — — — —
Ward Cove ls.	Ward Cove fm.	Ward Cove fm.		Botetourt mem.
Lincolnshire ls.	Lincolnshire fm.	Lincolnshire fm.	Lincolnshire ls.	Lincolnshire ls.
Five Oaks ls.	Five Oaks mem. (Lurich fm.)	Lurich fm.	Five Oaks mem. (Lurich fm.)	Whistle Creek ls.
Elway ls.	Elway mem. (Not everywhere present) (Lurich fm.)		Basal clastics (Lurich fm.)	New Market ls.
Blackford fm.	Blkfd. mem. (Not everywhere present) (Lurich fm.)			

Figure 2—Formation nomenclature used by Kay (1956) and this report for the Middle Ordovician rocks of Big Valley. Southwest Virginia and Shenandoah Valley nomenclature included for comparison. THIS IS NOT A CORRELATION CHART, (The dashed line represents the horizon of one distinct fauna, see Figure 3).

LURICH FORMATION

The Lurich formation disconformably overlies the Beekmantown formation and is disconformably overlain by the Lincolnshire limestone. The lower contact is not well exposed, but is known to be a disconformity in Hightown Valley and other parts of western Virginia (Kay, 1956); in Big Valley, the lower beds of the Lurich are variable in thickness and contain abundant limestone conglomerate, tending to indicate the presence of an unconformity at the base of the formation. The contact is at the change from dolomite to limestone, a position that commonly, but not always, corresponds to a change from thick-bedded to thin-bedded rocks. The upper contact is also disconformable and is at the change from aphanitic limestone to medium-grained, chert-bearing limestone. This contact exhibits a few inches of relief and the first bed overlying the contact is a limestone breccia containing fragments of calcite up to 1 inch in diameter.

The Lurich formation in its best development contains three distinct members (Kay, 1956), the Blackford member, the Elway member, and the Five Oaks member. The Blackford is a clastic unit containing limestone conglomerate, some shale, and characteristically some red rocks; the Five Oaks is a distinctive calcilutite with an almost glassy appearance; the Elway is similar to the Five Oaks, but contains abundant black chert. Only the Five Oaks is present in many places in Allegheny, Bath, and Highland counties, but rocks showing some similarity to the Blackford and Elway are locally present in Big Valley. The following section of the Lurich shows a very complete develop-

SECTION—1.6 MILES NORTH OF BOLAR, VIRGINIA, ON EAST SIDE OF BOLAR RUN

LINCOLNSHIRE LIMESTONE

LURICH FORMATION (285 feet)

FIVE OAKS MEMBER

1. Limestone (calcilutite, so fine-grained as to warrant the term aphanitic); interbedded olive gray and medium gray, weathers medium-light gray to light gray; regular 6 inch to 3 foot beds; scattered large, clear calcite grains; breaks with conchoidal fracture; abundant gastropod and Tetradium (?) sections on weathered surfaces of many beds; uppermost bed shows several inches of relief on upper surface. 116′

BASAL CLASTICS (BLACKFORD AND ELWAY EQUIVALENTS)

4. Limestone, interbedded aphanitic and very fine-grained; regular beds 6 inches to 2½ feet thick; aphanitic limestone dark gray to olive gray, weathers medium gray; fine-grained limestone dark gray, weathers to mottled grays; abundant black chert nodules and stringers.	53′
3. Limestone, very fine-grained; medium dark gray, weathers yellow-gray; laminated; yellow shaly partings.	11′
2. Limestone, interbedded aphanitic and very fine-grained; aphanitic limestone olive gray, weathers medium gray and smooth, ½ inch to 2 foot beds; very fine-grained limestone dark gray, weathers mottled and with ridges and pitted surfaces, 1 to 3 foot beds commonly laminated; abundant chert as nodules, stringers, and pebbles; limestone conglomerate beds scattered throughout lower 40 feet; 2 foot dolomitic limestone weathering yellow-gray at 29 feet.	72′
1. Limestone, fine-grained; various shades of gray, weathers shades of gray; 2 inch to 3 foot beds, many laminated; beds of limestone conglomerate throughout; dolomite beds weathering yellow-gray at 15 feet and 20 feet.	33′

BEEKMANTOWN FORMATION

The Five Oaks is persistent in lithology and thickness in Big Valley, but the lower part of the Lurich is subject to rapid variations; these variations probably indicate that the basal clastics were deposited in low spots on an erosion surface, a characteristic the writer has seen well displayed in the same part of the section in Warm Springs Valley. The Lurich formation is early Middle Ordovician (Chazyan) in age (Kay, 1956; Twenhofel, et al, 1954).

LINCOLNSHIRE LIMESTONE

The Lincolnshire limestone disconformably overlies the Lurich formation and is conformably overlain by the Big Valley formation. The lower contact is at the change from aphanitic limestone to medium-grained, chert-bearing limestone; this contact is irregular and the basal bed of the Lincolnshire is a limestone breccia. The upper contact is at a change from medium-bedded, coarse-grained limestone to thin-bedded, fine-grained limestone.

The Lincolnshire limestone is a distinctive unit comprised of dark gray, medium to coarse-grained, cherty limestone. The bedding appears massive in fresh outcrops, but often is nodular and only 2 inches to 10 inches thick in well weathered outcrops. The two most striking features of the formation are abundant black chert nodules, and intercalations of medium gray, thick-bedded calcarenites that weather to a pitted surface; these calcarenites thicken up to form "reef-like" masses and locally comprise over half of the formation. The Lincolnshire is 50 to 75 feet thick in Big Valley, and is Middle Ordovician (late Chazyan) in age (Twenhofel, et al, 1954).

BIG VALLEY FORMATION

The Big Valley formation is a new unit that includes the Ward Cove, Peery, and Benbolt formations of Kay (1956). In the Williamsville quadrangle, the Perry formation is not a mappable unit, and seldom outcrops; the Ward Cove and Benbolt contain wide covered areas and are variable in lithology. For these reasons, the formations as defined by Kay are difficult to use as mapping units. On the other hand, the base of the Ward Cove and the top of the Benbolt are at distinctive and easily traced lithologic changes, and the writer introduces the new name, Big Valley formation, to replace the previously used three formations of Kay (1956). One type section is insufficient to fully describe the characteristics of the Big Valley formation, so the writer herein designates 3 sections, one in Big Valley, one near Bluegrass in Hightown Valley, and one near Sinking Springs Church in southern Warm Springs Valley; each of these is described below.

The Big Valley formation conformably overlies the Lincolnshire limestone and is conformably overlain by the McGlone formation. The lower contact is at a change from thick-bedded, coarse-grained, chert-bearing limestone to thin-bedded, fine-grained, cherty limestone; in some outcrops, the difference in bedding thickness on either side of the contact is slight, but the difference in grain size is a usable criterion of the contact. The upper contact is at the base of a sequence of aphanitic limestone resembling the Five Oaks member of the Lurich formation. Although Kay (1956) reports the lower contact to be a disconformity in Big Valley and Hightown Valley, the writer could find no physical evidence of a disconformity. The formation is Middle Ordovician (Black River) in age (Twenhofel, et al, 1954).

The following sections illustrate the range of rocks within the Big Valley formation; the designated units are not continuous for great distances along strike.

BIG VALLEY SECTION—1.6 MILES NORTH OF BOLAR, VIRGINIA, EAST OF BOLAR RUN. THE SAME SECTION, WITH MINOR VARIATIONS, IS EXPOSED 2.1 MILES NORTH OF BOLAR ON THE WEST SIDE OF BOLAR RUN AND WAS MEASURED BY KAY (1956).

McGLONE FORMATION

BIG VALLEY FORMATION (232 feet)

8. Covered; appears similar to basal 3 feet which is limestone, very fine-grained, dark gray, weathering to medium dark gray, in 2 foot beds; weathered surfaces show 1 to 2 inches of gray limestone and 1 to 2 inches of yellow-brown argillaceous material in regular bands that are not visible on fresh surfaces	36′
7. Limestone; dark gray, weathers blue-gray; coarse-grained; 2 foot beds that weather to irregular, nodular, thin beds with yellow-brown argillaceous partings; fragmental fossils and pebbles abundant	21′
6. Limestone; medium dark gray, weathers medium gray; medium-grained; 1 to 3 foot beds irregularly parted; minor chert near middle; cliff former	55′
5. Covered; probably similar to unit below	57′
4. Limestone; gray-black, weathers medium gray; 1 to 3 inch beds, cobbly; fine-grained; argillaceous	33′
3. Limestone; medium gray, weathers medium gray; coarse-grained, thick beds	3′
2. Limestone; dark gray, weathers medium light gray; medium-grained; 4 inch to 2 foot beds	10′
1. Limestone; gray-black, weathers medium gray; fine-grained; 1 inch to 3 inch beds, cobbly; argillaceous; chert in lower part	17′

LINCONSHIRE LIMESTONE

Units 1 and 4 are noteworthy because of their strong resemblance to the Lantz Mills facies of the Edinburg formation; the units probably indicate intertonguing of the Edinburg and Big Valley formations.

HIGHTOWN VALLEY SECTION—¼ MILE NORTH OF BLUEGRASS, VIRGINIA, ALONG HIGHWAY AND ON HILL IMMEDIATELY EAST OF HIGHWAY.

McGLONE FORMATION

BIG VALLEY FORMATION (187 feet)

12. Limestone; medium to dark gray, weathers medium dark gray; medium-grained; well laminated; black chert nodules	3′
11. Covered; outcrop at 9 feet of limestone, dark gray, weathers medium gray; medium-grained; thick-beds	33′
10. Limestone; brownish-gray, weathers medium gray; coarse-grained; thin beds with abundant tan shale blebs; occasional layer of very coarse-grained, light gray limestone	12′
9. Limestone; dark gray, weathers medium gray; medium-grained; thin-bedded	3′
8. Limestone; olive gray, weathers medium gray with rough surface; very fine-grained, conchoidal fracture; medium-bedded, tan argillaceous material on bedding planes	11′
7. Limestone; brownish-gray, weathers medium gray, pitted and furrowed; coarse-grained; thin beds	26′
6. Covered	24′
5. Limestone; dark gray, weathers medium gray; fine-grained; thick-bedded and massive	18′
4. Limestone; gray-black, weathers medium gray; fine-grained; thick-bedded, weathers cobbly; black chert nodules	36′
3. Limestone; dark gray, weathers medium gray; medium-grained; thin-bedded	3′
2. Covered; probably similar to units 1 and 3	16′
1. Limestone; extremely argillaceous; dark gray, weathers to light gray shaly mass; 1 to 3 inch beds; highly fossiliferous	2′

LINCOLNSHIRE LIMESTONE

WARM SPRINGS VALLEY SECTION—HOLLOWROCK FARM, ¾ MILES SOUTH OF SINKING SPRINGS CHURCH ON EAST SIDE OF U.S. HIGHWAY 220, ALLEGHENY COUNTY. STARTING IN FIELD ¼ MILE EAST OF FARMHOUSE AND MEASURING WEST THROUGH FARMYARD AND TO TOP OF SMALL HILL 200 YARDS SOUTH OF FARMHOUSE. SECTION IS ALSO WELL EXPOSED FOR ¾ MILES ALONG WEST SIDE OF U.S. HIGHWAY 220, STARTING ½ MILE SOUTH OF HOLLOWROCK FARM.

McGLONE FORMATION

BIG VALLEY FORMATION (204 feet)

5. Limestone; gray-black, weathers medium light gray; very fine-grained; 1 to 3 inch beds, cobbly, irregular yellow-brown partings; much of this unit is replaced by thick-bedded, coarse-grained light gray limestone 1 mile south	80′

4. Limestone; dark gray, weathers medium gray; coarse-grained; 6 inch to 2 foot beds	4′
3. Limestone; gray-black, weathers medium light gray to light gray; fine-grained; thick-bedded; some chert; becomes thinner bedded upward and ¼ inch shaly partings at 6 to 8 inch intervals appear in upper 20 feet	53′
2. Limestone; dark gray; weathers medium gray; medium and fine-grained; cobbly 2 inch to 1 foot beds; abundant chert	17′
1. Limestone; dark gray, weathers medium gray to medium light gray; fine-grained; lower 22 feet in cobbly 6 inch to 2 foot beds containing abundant chert; upper 28 feet in 2 to 3 foot beds without chert	50′

LINCOLNSHIRE LIMESTONE

Much of this section, especially unit 5, is very similar to the Edinburg formation and probably indicates intertonguing of the Edinburg and Big Valley formations.

MCGLONE FORMATION

The McGlone formation conformably overlies the Big Valley formation and is conformably overlain by the Moccasin formation. The lower contact is at the base of a sequence of olive gray to dark gray aphanitic limestone. The upper contact is at the base of a unit of interbedded mudrock and limestone that is mottled with red argillaceous material on weathered surfaces. Kay (1956) considered the upper contact to be a disconformity, but the writer could not substantiate this.

The McGlone formation is a distinctive unit comprised chiefly of olive gray, medium gray, and dark gray aphanitic limestone that weathers light gray. The rock breaks with conchoidal fracture because of the extremely small size of its constituent grains. The beds are 2 to 3 feet thick and usually well laminated. The upper 12 feet of the formation is comprised of fine-grained, gray limestone with yellow-brown argillaceous partings; this is the McGraw formation of Kay (1956). The McGlone is about 50 feet thick in Big Valley, and is Middle Ordovician (Black River) in age (Twenhofel, et al, 1954).

MOCCASIN FORMATION

The Moccasin formation of the writer represents the lower part of the Nealmont-Moccasin formation of Kay (1956). The lower part of the Nealmont-Moccasin formation is distinctly different from the upper part and is easily separable from it as the Moccasin formation. The Moccasin overlies the McGlone formation and is conformably overlain by the Edinburg formation. The lower contact is at the base of a unit of limestone and mudstone which contains red layers and mottled areas on weathered surfaces. The upper contact is at the base of a sequence of very fine-grained, thin-bedded, dark gray limestone that weathers medium gray.

The lower half of the Moccasin formation is comprised of various types of limestone ranging from coarse-grained to aphanitic, chiefly dark gray, in thin to thick beds. Many of the beds have yellow-brown and red argillaceous partings and blebs. The upper half of the formation contains argillaceous aphanitic limestone and abundant tan mudstone showing occasional red colors. The Moccasin is approximately 60 feet thick in Big Valley.

The age of the Moccasin formation has been a matter of dispute. The formation is correlative with part of the Lebanon limestone of Tennessee (Byron Cooper in Twenhofel, et al, 1954, pp. 273 and 277) and with part of the Nealmont formation of Pennsylvania (Kay, 1956). Cooper believes the Lebanon is late Black River is age and Kay believes the Nealmont is early Trenton in age. Until this problem is resolved, the Moccasin cannot be dated more closely than either late Black River or early Trenton.

EDINBURG FORMATION

The Edinburg formation includes the upper part of the Nealmont-Moccasin formation and the Salona formation of Kay (1956) in Big Valley. Nealmont and Salona are Pennsylvania names that Kay has applied to rocks in western Virginia. The writer does not doubt the validity of the names, but the part of the section included in these formations is lithologically similar to the Edinburg formation of the Shenandoah Valley of Virginia, and occupies the same stratigraphic position below the Martinsburg formation as the Edinburg. The writer wishes to emphasize this similarity and therefore has adopted Edinburg formation in place of the Pennsylvania names.

The Edinburg formation conformably overlies the Moccasin formation and is conformably overlain by the Martinsburg formation. The lower contact is at the base of a sequence of thin-bedded, fine-grained, dark gray limestone. The upper contact is at the base of a thick unit of calcareous shale. The Edinburg formation is exposed in Hightown Valley, west of Back Creek Mountain, as well as in Big Valley.

The Edinburg formation is comprised of argillaceous limestone. The rock is medium gray to gray-black on fresh fracture and weathers to medium and medium light gray. Most of the beds are very fine-grained limestone and are about 2 inches to 6 inches thick; argillaceous partings are common between the beds. The formation is approximately 450 feet thick and is Middle Ordovician (Trenton) in age (Twenhofel, et al, 1954).

STRATIGRAPHIC RELATIONS OF THE MIDDLE ORDOVICIAN ROCKS OF WESTERN BATH AND HIGHLAND COUNTIES WITH THOSE OF THE SHENANDOAH VALLEY

Kay (1956) has deciphered the stratigraphic relations of the Middle Ordovician rocks of southwest Virginia and central Pennsylvania by tracing the units along strike. Figure 3 is the writer's interpretation of the relations across strike, between the Shenandoah Valley and western Bath and Highland counties; this interpretation can hardly be considered a final one because there is a 25 mile gap in outcrops between the Shenandoah Valley and Big Valley, a distance that might be increased to 30 or 40 miles if a palinspastic reconstruction were made. Figure 3 is based on three important assumptions, all of which have reasonable evidence to support them: (1) the distinctive fauna present in the Collierstown limestone, Onego member of the Salona formation, and Eggleston formation represents a time line (see Figure 2); (2) the Lincolnshire limestone is everywhere the same age; (3) the Edinburg-like limestones present in parts of the Big Valley formation in various areas represent intertonguing of the Edinburg formation and the Big Valley formation (see stratigraphic sections, pp. 12 and 13).

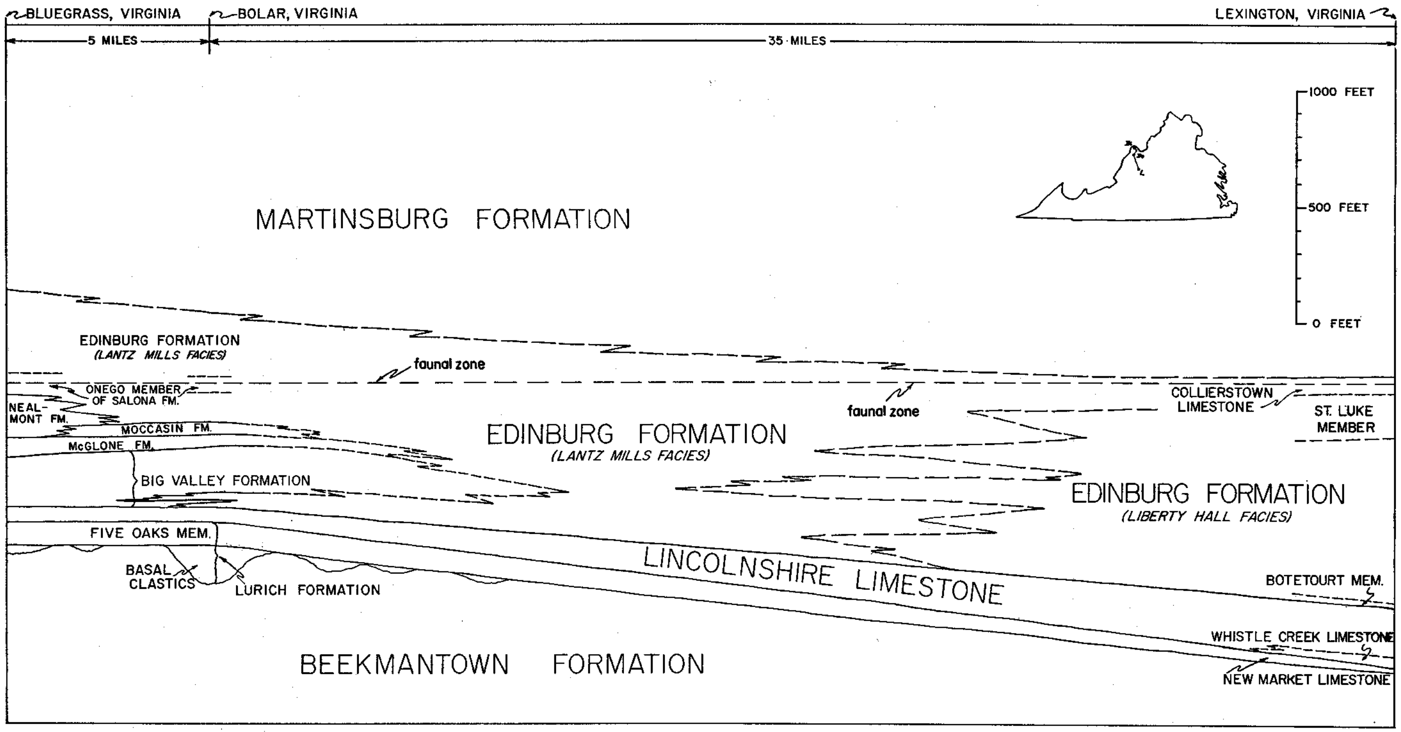

Figure 3—Stratigraphic diagram showing the relations of the Middle Ordovician rocks of western Bath and Highland counties with those of the Shenandoah Valley. The dashed line represents the distinctive faunal zone found in the Collierstown limestone and the Onego member of the Salona formation (Kay, 1956). Notice the section is offset between Bolar and Bluegrass.

MARTINSBURG FORMATION

The Martinsburg formation is conformable with the underlying Edinburg formation and is conformably overlain by the Juniata formation. The lower contact is at the base of a thick unit of yellow to brown weathering limy shale; the upper contact is gradational with the Juniata and is placed at the occurrence of abundant sand beds 1 inch or more in thickness. Neither contact is well exposed and the limits of the formation are difficult to define exactly. The Martinsburg is exposed only in Big Valley and Hightown Valley.

The Martinsburg formation is a distinctive unit and a good mapping guide even though its exact limits are difficult to determine. The major constituent of the formation is gray, highly calcareous, shale that weathers yellow to light brown; in fresh exposures this rock type resembles limestone much more than shale. Parts of the Martinsburg are more limy, and parts more sandy, than the bulk of the formation. Because the formation is largely covered and the ground strewn with shale chips, one tends to regard the Martinsburg as a shale; this leads to difficulty of recognition in fresh outcrops.

The thickness of the Martinsburg formation is estimated at 1000 feet. The formation is of Middle and Late Ordovician age; an undetermined lower part is Trentonian and the remainder is Edenian and Maysvillian (Butts, 1940; Twenhofel, et al, 1954).

JUNIATA FORMATION

The Juniata formation conformably overlies the Martinsburg formation and is conformably overlain by the Clinch sandstone. The lower contact is gradational and is placed at the base of the first abundant sandstone beds one inch, or greater, in thickness. The upper contact is sharply defined and is at the base of a sequence of thick-bedded gray quartzite. The outcrop of the formation is limited to Back Creek Mountain, Little Mountain, and Jack Mountain in the northwestern part of the quadrangle.

The Juniata formation is a heterogeneous unit of sandstone, siltstone, mudrock, and shale which is distinctive for its red color; in fact, the redness is nearly confined to mudrock and shale and comprises no more than 25 percent of the total formation, but weathering and mass-wasting have spread the reddish material over large parts of the remainder of the Juniata. The following section shows the general characteristics of the formation.

JUNIATA FORMATION—ALONG STATE HIGHWAY 39, TOP OF WARM SPRINGS MOUNTAIN.

CLINCH SANDSTONE

JUNIATA FORMATION (367 feet)

10. Covered	90′
9. Red mudrock with minor sandstone	20′
8. Yellow-brown, cross-bedded sandstone; red mudstone and shale	15′
7. Gray sandstone, cross-bedded; minor red sandstone; greenish-gray shale	6′
6. Yellow-brown sandstone; red mudstone and shale	10′
5. Yellow-brown and medium gray sandstone, thin beds, well laminated; greenish-gray shale	6′
4. Yellow-brown sandstone; red mudstone and shale	20′
3. Yellow-brown and medium gray sandstone, thin to thick beds, well laminated; greenish-gray shale	50′
2. Yellow-brown sandstone, thin to thick beds; abundant red shale	25′
1. Dark gray, medium-grained sandstone, ½ inch to 6 inch beds, well laminated; dark gray shale; much yellow-brown sandstone toward top; the whole weathers brown and dark yellow-brown	125′

MARTINSBURG FORMATION

The Juniata formation in the northwestern part of the quadrangle has the same general characteristics as shown in the above section. The thickness, however, appears to be closer to 600 feet on Back Creek Mountain and 450 feet on Jack Mountain, indicating southeastward thinning of the Juniata; this is further supported by absence of the formation in the Lexington quadrangle (Bick, 1960) about 20 miles to the southeast, and the nearest area where this part of the section is again exposed. The formation is largely unfossiliferous, but is believed Late Ordovician (Richmondian) in age (Butts, 1940; Twenhofel, et al, 1954).

SILURIAN SYSTEM

CLINCH SANDSTONE

The Clinch sandstone conformably overlies the Juniata formation and is conformably overlain by the Clinton formation. The lower contact is at the base of a sequence of thick-bedded gray quartzite, and the upper contact is at the base of a unit of thin-to-thick-bedded red sandstone. Both contacts are seen to be sharp where well exposed, and the Clinch is easily identified by its position between two units of red rock. The formation is very resistant to erosion and underlies most of the high ridges in the quadrangle except Shenandoah Mountain and Tower Hill Mountain.

The Clinch sandstone is composed of quartz grains cemented by quartz. The color is variable, ranging from white to yellow-brown to reddish, but shades of gray and yellow-gray predominate; the red color is confined to cross-beds and is not common enough to cause any confusion with the red beds above and below. The beds range from 1 to 5 feet in thickness and most display prominent cross-bedding. The Clinch can be confused on isolated outcrops with quartzites in the upper part of the Clinton formation, but can usually be recognized by its relation to the red rocks and lack of accompanying shale units. The formation is about 250 feet thick. Although fossils are scarce in the Clinch, the formation is believed to be of Early Silurian age (Butts, 1940; Swartz, et al, 1942).

CLINTON FORMATION

The Clinton formation is conformable with the underlying Clinch sandstone and is conformably overlain by the McKensie limestone of the Cayuga group. The lower contact is at the base of a unit of red sandstone, siltstone, and shale; the upper contact is at the base of the limestones of the McKensie. The Clinton outcrops on the flanks of all the high ridges in the quadrangle and the upper part of the formation is largely covered by slope wash from the Clinch sandstone and lower Clinton.

The Clinton formation is a heterogeneous unit of sandstone, siltstone, and shale that may be conveniently divided into 2 members, the Cacapon and the Keefer. The Cacapon member overlies the Clinch sandstone and is distinctive for the deep red, and red-brown, color of most of its beds. The member is comprised of sandstones, siltstones, and shale in distinct units; the red color is imparted by hematite, and sandstone beds of this member have been mined as iron ore in other Virginia localities, but the writer has seen nothing to warrant mining operations anywhere in the Williamsville quadrangle. The Keefer member forms approximately the upper 2/3 of the formation and is characterized by thick-bedded, gray, yellow-brown weathering quartzite and green to brown shale. The quartzite and shale occur in discrete units, although outcrops are scarce and a complete picture of this member could not be gained. In general terms, shale is more abundant than sandstone in the northwestern part of the quadrangle; the two rock types are in about equal amount in the central and southeastern areas; and seven miles southeast of the quadrangle, in Goshen Pass, the sandstone forms the bulk of the Keefer member (Bick, 1960).

The following sections indicate the general nature of the Clinton formation; the writer did not find any complete sections in the quadrangle. Estimated thicknesses should not be considered very accurate.

SECTION—SOUTHEAST FLANK OF WARM SPRINGS MOUNTAIN, ALONG STATE HIGHWAY 39.

CAYUGA GROUP

CLINTON FORMATION (330+ feet)

KEEFER MEMBER (INCOMPLETE)

3. Quartzite, gray, weathers yellow-brown, thick beds	25′
2. Shale, greenish-gray, weathers yellow-brown; minor thin sandstones, occasional red shale layer	30′
1. Covered	150′?

CACAPON MEMBER

3. Sandstone, red, thick-bedded	40′
2. Shale, red to yellow-brown; minor red sandstone, more abundant near base	70′
1. Sandstone and siltstone chiefly, red, thick beds	15′

CLINCH SANDSTONE

SECTION—SOUTHEAST FLANK OF PINEY MOUNTAIN, ALONG STATE HIGHWAY 39.

CAYUGA GROUP

CLINTON FORMATION (275+ feet)

KEEFER MEMBER (INCOMPLETE)

6.	Quartzite, gray, weathers yellow-brown; structural complications near top	20′
5.	Shale, greenish-gray, weathers yellow-brown, minor red layers	30′
4.	Quartzite, gray, weathers yellow-brown	30′
3.	Shale, greenish-gray, weathers yellow-brown, minor red layers	30′
2.	Quartzite, gray, weathers yellow-brown	30′
1.	Shale, greenish-gray, weathers yellow-brown, minor red layers	30′

CACAPON MEMBER

2.	Sandstone, red, thick-bedded	45′
1.	Shale, red to yellow-brown; minor red sandstone more abundant near base	60′
	(base not exposed)	

CLINCH SANDSTONE

SECTION—PANTHER GAP, NORTH SIDE ALONG STATE HIGHWAY 39.

CLINTON FORMATION (440+ feet)

KEEFER MEMBER (INCOMPLETE)

3.	Quartzite, thick- to thin-bedded, cross-bedded, gray, weathers yellow-brown	60′
2.	Covered bench, shale?	20′
1.	Quartzite, thin- to thick-bedded, cross-bedded, gray, weathers yellow-brown	80′

CACAPON MEMBER

4.	Shale, siltstone, and sandstone alteration; red, brown shale predominant toward top	100′?
3.	Sandstone and siltstone, red	100′?
2.	Shale, red	50′?
1.	Sandstone, thin- to thick-bedded, red	30′?

CLINCH SANDSTONE

The total thickness of the Clinton formation is estimated to be 500 to 800 feet. The Clinton is early Middle Silurian in age (Butts, 1940; Swartz, et al, 1942).

CAYUGA GROUP

The Cayuga group conformably overlies the Clinton formation and is conformably overlain by the Keyser limestone. The Cayuga is comprised of 3 formations, the McKensie limestone, Wills Creek formation, and Tonoloway limestone; these formations could not be conveniently distinguished on the present mapping scale in most of the quadrangle. The lower contact is distinct and is placed at the base of the McKensie limestone, the first carbonate unit above the thick Ordovician and Silurian clastic rocks described above. The upper contact is at the point where well laminated limestone gives way to a unit of medium-bedded, nodular limestone. The Cayuga group is usually poorly exposed because it is covered by slope wash from the Clinton formation.

The McKensie limestone is comprised largely of arenaceous limestone, calcareous sandstone, and thin sandstone interbeds. Cross-bedding is prominent, and much of the formation exhibits irregular bedding; in some outcrops laminated beds and massive beds are present. On the whole, the formation is characterized by its variability. The Wills Creek formation is divisible into 2 parts; a lower unit of interbedded sandstone, arenaceous limestone, and shale which has the overall appearance of shale in weathered outcrops, and an upper unit of light colored, yellow-brown weathering, calcareous sandstone which approaches quartzite in some outcrops. The Tonoloway limestone, the most widely exposed member of the group, is distinctive for its fine-grained, dark gray, well laminated limestone, although the formation contains limestones of other types and significant amounts of sandstone. The following sections indicate the nature and thickness (estimated by pacing) of the formations comprising the Cayuga group.

SECTION—ONE MILE NORTHWEST OF WILLIAMSVILLE ALONG STATE ROAD 629.

KEYSER LIMESTONE

TONOLOWAY LIMESTONE (170+ feet)

2. Sandstone and shale interbedded; weathers yellow-brown; 4 foot limestone at 20 feet	70′
1. Limestone; laminated; dark gray, weathers blue-gray; interbeds of shaly limestone; basal 2 feet is sandy, coarse-grained limestone; whole unit increasingly shaly toward top	100′

WILLS CREEK FORMATION (55 feet)

2.	Sandstone; calcareous, light gray to brownish-gray, weathers yellow-brown	20′
1.	Interbedded shale, sandstone, and limestone; beds ½ inch to 1 foot thick, thin beds predominate; unit has overall appearance of shale; weathers dark brown	35′

McKENSIE LIMESTONE (38 feet)

3.	Interbedded limestone and calcareous sandstone, minor shale; thin to thick beds, cross-laminated; weathers brown; basal 2 feet is limestone conglomerate with very well rounded limestone clasts up to 6 inches in diameter	20′
2.	Limestone predominant; dark gray to medium gray, weathers brown to brownish-gray; 1 inch sandstone beds in base, diminishing upward	10′
1.	Arenaceous limestone; lenticular beds; brownish-gray; weathers dark yellow-brown; strongly ribbed appearance on weathered surface, ribs are sandstone which enclose the lenticular beds, not apparent on fresh surface; lenses cross-laminated	8′

CLINTON FORMATION

SECTION—ALONG ROAD AT NORTHEAST END OF CHESTNUT RIDGE.

KEYSER LIMESTONE

TONOLOWAY LIMESTONE (135 feet)

6.	Limestone; laminated shaly	50′
5.	Sandstone	5′
4.	Limestone; fine-grained; medium to dark gray; laminated; shaly and sandy limestone beds common	35′
3.	Limestone; dark gray; fine- to coarse-grained; thick beds, crudely laminated and cross-laminated; occasional chert nodule; some beds of silicified shell hash	25′
2.	Limestone; fine- to medium-grained; dark gray; very cherty	5′
1.	Limestone; fine-grained; olive gray; thick-bedded, abundant silicified crinoid stems and bryozoans impart crude lamination	15′

WILLS CREEK FORMATION (15 feet)

1.	Largely covered; lower part very shaly; few sandstone beds in upper part	15′

McKENSIE LIMESTONE (20 feet)

2.	Limestone; thin to thick beds, irregular bedding; sandy, silty	15′
1.	Limestone; dark gray; thin-bedded; sandy and shaly	5′

CLINTON FORMATION

SECTION—WEST END OF PANTHER GAP ALONG STATE HIGHWAY 39.

KEYSER LIMESTONE

TONOLOWAY LIMESTONE (115 feet)

5. Covered	20′
4. Limestone; dark gray; fine-grained; well laminated; arenaceous	5′
3. Covered; upper 15 feet shaly and sandy	40′
2. Limestone; dark gray; fine-grained; laminated, nodular beds	35′
1. Covered	15′

WILLS CREEK FORMATION (23 feet)

3. Quartzite; massive; medium gray	3′
2. Sandstone; yellow-brown; friable	5′
1. Shale; yellow to red; silty	15′

McKENSIE LIMESTONE (20+ feet)

4. Limestone; fine-grained; dark gray; nodular beds	3′
3. Covered	8′
2. Limestone; fine-grained; dark gray; poorly laminated, sandy streaks	2′
1. Covered interval 45 feet; contact with Clinton formation somewhere in this interval	?

CLINTON FORMATION

The Cayuga group, and each of its constituent formations, thins in a southeasterly direction. The Tonoloway limestone thins from approximately 200 feet to 100 feet, the Wills Creek formation from 55 feet to 20 feet, and the McKensie limestone from 40 feet to 15 or 20 feet. The Cayuga group is Late Silurian in age (Butts, 1940; Swartz, et al, 1942).

KEYSER LIMESTONE

The Keyser limestone conformably overlies the Cayuga group and is conformably overlain by the Helderberg group. The lower contact is at the base of a sequence of medium-bedded, nodular limestone that contrasts sharply with the laminated beds of the underlying Tonoloway limestone. The upper contact is at the base of a thick-bedded, very coarse-grained limestone that usually contains irregular lenses of red limestone. The Keyser is exposed in a few natural outcrops and in several roadcuts, but is mostly covered.

The Keyser limestone is a heterogeneous unit containing various types of limestone, sandstone, and shale. The formation is characterized by 3 members; a lower limestone member, a middle sandstone and shale member, and an upper limestone member. A facies change occurs in the middle member, which is chiefly shale in the northwest and entirely sandstone in the southeast; this member is distinctive enough that it has been named (Swartz, 1929) the Big Mountain shale member or the Clifton Forge sandstone member, depending on the facies present. The limestone members are generally medium to thick-bedded, nodular, medium gray to blue-gray, medium to coarse-grained limestone. Many of the beds are arenaceous, and black chert nodules are present in the lower member in the southeast. The lower member may be easily mistaken in southeastern areas for the upper part of the Helderberg group because of the thick beds, the black chert, and the overlying sandstone that resembles the Ridgeley sandstone. The following section illustrates the formation as it occurs in the southeastern part of the quadrangle.

SECTION—PANTHER GAP, NORTH SIDE, ALONG STATE HIGHWAY 39 (ADDITIONAL DETAILS FROM SOUTH END OF SIDELING HILL ALONG STATE HIGHWAY 39, ¼ MILE SOUTH OF QUADRANGLE)

HELDERBERG GROUP (COEYMANS LIMESTONE)

KEYSER LIMESTONE (90 feet)

UPPER LIMESTONE MEMBER	
1. Limestone; largely covered; apparently generally similar to lower member, no chert	25′
CLIFTON FORGE MEMBER	
2. Sandstone; thin to thick-bedded, calcareous; friable; nearly white fresh, weathers deep yellow-browns and red-browns	20′
1. Sandstone and siltstone; thin-bedded; friable; weathers yellow-brown	10′
LOWER LIMESTONE MEMBER	
2. Limestone; thick-bedded; coarse-grained; medium gray fresh and weathered; contains abundant irregular black chert nodules	20′
1. Limestone; nodular; medium to thin beds; minor chert; dark gray fresh and weathered; many beds arenaceous, a few thin sandstone interbeds	15′

CAYUGA GROUP (TONOLOWAY LIMESTONE)

As the Keyser is traced northwestward, the limestone members do not exhibit much change in character, although both thicken; the Clifton Forge member gradually becomes more shaly, but retains approximately the same thickness. East of the bridge across Jackson River, on U. S. Highway 220, the Keyser is well exposed and Swartz (1929) has measured the section. Here, the lower member is about 50 feet thick, and is overlain by 30 feet to 40 feet of greenish shale, the Big Mountain shale member. A three foot bed of calcareous sandstone, the northernmost tongue of the Clifton Forge member, overlies the shale and in turn is overlain by 120 to 130 feet of limestone belonging to the upper member. The Keyser limestone is Late Silurian in age (Swartz, et al, 1942).

DEVONIAN SYSTEM

HELDERBERG GROUP

The Helderberg group conformably overlies the Keyser limestone and is conformably overlain by the Ridgeley sandstone. The group is comprised of three formations, the Coeymans limestone, the New Scotland limestone, and the Licking Creek limestone; the formations could not be conveniently distinguished over most of the quadrangle on the present mapping scale. The lower contact is at the base of a sequence of very coarse-grained, thick-bedded limestone that usually shows some red limestone layers. The upper contact is at the base of a unit of thick-bedded brown-weathering sandstone. The Helderberg is well exposed in a few outcrops and quarries, but is mostly covered.

The basal formation of the Helderberg group, the Coeymans limestone, is a very distinctive unit. The Coeymans is thick-bedded and extremely coarse-grained, containing crinoid columnals up to ½ inch in diameter. A striking feature of the formation, although not everywhere present, are lenticular beds of red limestone. The Coeymans is variable in thickness, ranging from 20 feet to 50 feet. The New Scotland limestone is a heterogeneous unit of limestone, arenaceous limestone, and sandstone; where well developed, the sandstone is named the Healing Springs sandstone member (Swartz, 1929). The formation is about 20 feet thick throughout the quadrangle. In the northwest, the lower 2/3 of the formation is calcareous sandstone, the Healing Springs member, and the upper 1/3 is gray arenaceous limestone containing white chert nodules. The formation is essentially of this same lithology in the south-central part of the area as shown by outcrops along Dry Run where the stream cuts through McClung Ridge. As the formation is traced further southeastward, the sandstone is much reduced; in the southeast, the New Scotland is thick-bedded, coarse-grained, medium gray arenaceous limestone containing many one inch sandstone beds that stand out as ribs on weathered surfaces. The Licking Creek limestone is medium to dark gray, medium to fine-grained, thick-bedded, and distinctive for abundant black chert nodules and stringers. The Licking Creek thins from approximately 200 feet in the northwest to 85 feet in the southeast. An excellent exposure of the entire group, in its southeastern development, may be seen in a roadcut and abandoned quarry along State Highway 39, ¼ mile northwest of the junction of State Highways 39 and 629. The group is Early Devonian (Ulsterian) in age (Cooper, G. A., et al, 1942).

RIDGELEY SANDSTONE

The Ridgeley sandstone conformably overlies the Helderberg group and is conformably overlain by the Onondaga formation. The Onondaga formation is included with the Ridgeley in the northwestern half of the quadrangle, however; the Onondaga changes facies from shale to abundant sandstone as traced northwestward and cannot be readily separated from the Ridgeley because of extensive cover. The lower contact of the Ridgeley is at the base of a sequence of brown-weathering sandstone and the upper contact is at the base of a sandy, cherty, gray to green shale unit which is the basal part of the Onondaga formation; as mapped, however, the upper contact is at the base of a thick sequence of black fissile shale that comprises the Millboro shale. The Ridgeley is one of the best mapping units in the area, although the contact zones are not usually well exposed.

The Ridgeley sandstone is comprised of medium to coarse-grained, thick-bedded, red-brown weathering sandstone. The sandstone is nearly white on fresh fracture and is commonly calcareous; the calcareous parts weather to a friable mass which is often nothing more than a pile of loose sand. The Ridgeley thins from approximately 120 feet in the northwest to 20 feet in the southeast.

The Onondaga formation, included with the Ridgeley in the northwestern half of the map, was clearly seen in only one section which is described below.

SECTION — ROADCUT AT BRIDGE IMMEDIATELY EAST OF WILLIAMSVILLE

MILLBORO SHALE

ONONDAGA FORMATION (107 feet)

4. Sandstone; thick-bedded, cross-bedded; nearly white, weathers yellow-brown; friable; shale layers near top	45′
3. Limestone; dark gray; weathers brown; medium to fine-grained; cherty and sandy	12′
2. Sandstone; yellow-brown, weathers same; friable; chert	10′
1. Shale; gray to green, minor red; sandy, cherty	40′

RIDGELEY SANDSTONE

The Ridgeley and Onondaga are Early Devonian (Ulsterian) in age (Cooper, G. A., et al, 1942).

MILLBORO SHALE

The Millboro shale conformably overlies the Onondaga formation and is conformably overlain by the Brallier shale; the Onondaga is included with the Millboro in the southeastern half of the quadrangle because it is impossible to separate the two except where outcrops are perfect. The actual lower contact of the Millboro is at the base of a thick sequence of black, fissile shale; the rocks underlying this contact are green, non-fissile shale in the southeast and sandstone in the northwest due to the facies change in the Onondaga. For practical purposes, because the contact is seldom exposed, the contact has been mapped at the top of a sandstone sequence; as explained, this means that the Onondaga is included with the underlying Ridgeley sandstone in the northwest, but is included with the Millboro in the southeast. The upper contact of the Millboro is at the base of a thick sequence of brown and green shale and siltstone that contrasts sharply with the black shale of the Millboro.

The Millboro shale is a fissile black shale that weathers light gray to gray-brown; where extensively weathered, the outcrops take on a yellow-brown color. Outcrops, and covered areas, typically are strewn with thin slivers and flakes of shale. The formation contains abundant carbonate concretions that are up to 3 feet in diameter and 1 foot thick; the concretions are of secondary origin and the bedding of the shale passes through them without interruption. The thickness of the Millboro is difficult to determine because of internal deformation, but appears to be well in excess of 1000 feet. The formation is Middle Devonian (Erian and Senecan) in age (Cooper, G. A., et al, 1942).

Two good outcrops of the Onondaga formation were seen in the southeastern part of the quadrangle. In both the formation was about 15 feet thick and comprised of dark green, nonfissile, brown weathering shale.

BRALLIER SHALE

The Brallier shale conformably overlies the Millboro shale and is conformably overlain by the Chemung formation. The lower contact is at the base of a thick sequence of brown and green shale and siltstone that contrasts sharply with the underlying fissile black shale. The upper contact is gradational and has been taken at the lowest locally exposed sandstone units greater than 6 feet in thickness; the Brallier becomes increasingly sandy upward and an exact contact is difficult to draw, although the zone of change from typical Brallier to typical Chemung is apparent. The Brallier outcrops in a wide belt occupying the central part of the quadrangle.

The Brallier shale is a distinctive unit comprised of nonfissile shale, siltstone, and sandstone. The shale and siltstone are dark gray to green, weather shades of brown, and are noticeably siliceous. Sandstone beds are grayish and greenish and weather dark yellow-brown; the lower part of the formation is sparingly sandy, but the sands increase upward and toward the top many evenly stratified beds up to 4 and 5 feet thick are interlayered with the shale. The formation appears to be about 3000 feet thick. The Brallier is Middle Devonian (Senecan) in age (Cooper, G. A., et al, 1942).

CHEMUNG FORMATION

The Chemung formation conformably overlies the Brallier shale and is conformably overlain by the Hampshire formation

(Butts, 1940) ; the top of the Chemung is not present in the Williamsville quadrangle, owing to recent erosion. There is possibly one exception to this last statement in the area immediately surrounding the Wallace Peak Lookout Tower on Shenandoah Mountain. Red rocks, perhaps of the Hampshire formation, are exposed on the upper few tens of feet of Wallace Peak, but red rocks are also known from the Chemung and the writer could not determine positively which formation these rocks belonged to; the thickness is slight and the rocks have been included with the Chemung. The Chemung formation is gradational with the underlying Brallier shale, and the contact was taken at the lowest locally exposed sandstone units 6 feet or more in thickness. The outcrop area of the formation is confined to Shenandoah Mountain in the east-central part of the quadrangle.

The Chemung formation is comprised of sandstone, shale, and minor conglomerate. The bulk of the formation is sandstone of varied types and colors. Bedding ranges from thin to thick, and color from nearly white to red, usually weathering shades of yellow-brown and red-brown. Conglomerate beds about 1 foot thick, containing well-rounded pebbles of white quartz up to ½ inch in diameter, are present throughout the formation. These conglomerates are a small part of the Chemung in a quantitative sense, but are striking to the eye and a positive criterion for identification of the formation. The shale is largely covered by slope wash on the flanks of Shenandoah Mountain, but appears to be chiefly green and poorly fissile. The Chemung formation is probably about 2000 feet thick and is Middle and Late Devonian (Senecan and Chatauquan) in age (Cooper, G. A., et al, 1942).

GEOLOGIC STRUCTURE

The structural geology of the Williamsville quadrangle, as seen from surface exposures, appears simple in its broad aspects. The area is one of predominantly folded rocks, with minor associated faults. As best shown in cross-section BB' (Plate 1, in pocket), the structure is comprised of two anticlinoria, one on the southeast and one on the northwest, separated by a synclinorium. Many smaller folds are superimposed on these major structures, as are several faults of small displacement. The structure is locally quite complex, but this does not obscure the basic simplicity of the overall pattern. Butts (1933, 1940) recognized the fold pattern of the quadrangle, and his map shows that the three major folds extend many miles northeast and southwest of the Williamsville area; the southeastern anticlinorium is part of what Butts called the Deerfield anticline, the synclinorium is part of the McClung syncline, and the northwestern anticlinorium is part of the Hot Springs anticline. The anticlinoria are asymmetric with northwestern limbs steeper than southeastern; the smaller folds are often more sharply asymmetric and are locally overturned to the northwest. Viewed in its entirely, the synclinorium is remarkably flat-bottomed as the steep northwest dips of the Deerfield anticline flatten abruptly into the down-folded area.

The most important of the faults in the Williamsville quadrangle extends from the northeastern part of the area to the southwestern part, and is herein named the Tower Hill fault (Plate 1, in pocket); the area traversed by the southern 2/3 of the fault is heavily covered, but scattered outcrops suggest the location and continuity of the break. The dip of the fault ranges from 30° to 50° in the few good outcrops. The fault appears to be a rupture of small displacement along the northwest limb of a complex anticline. The Mill Mountain fault, west of Mill Mountain in the southeast corner of the quadrangle, is similar to the Tower Hill fault in its general relations and is a minor overthrust of the northwest limb of an overturned anticline. The fault on McClung ridge, in the southwestern part of the area, has normal relations and may also be regarded as a minor rupture accompanying folding of the rocks.

The preponderance of folds, with only minor associated faults, and the lack of overthrust faults of great displacement such as are present in the Shenandoah Valley to the east, suggest that the Williamsville quadrangle occupies an area marginal to the main locus of the orogenic forces causing the deformation. The structural geology of the area conforms to the generally accepted interpretation of Central Appalachian structure; that is, a westward diminuation in intensity of deformation, with severe deformation on the southeast grading northwestward into folded rocks and finally into nearly flay-lying rocks of the Appalachian Plateau province. The time of deformation can be established only as post-Late Devonian in the quadrangle, but in light of the regional geology of the Appalachian Highlands (King, 1950), it appears probable that the deformation is part of the Appalachian orogeny of Permian (?) age.

Recent evidence suggests that this general picture of the structure of the Williamsville quadrangle deduced from surface outcrops may be greatly in error. A well drilled in West Virginia in 1960 by the United Fuel Gas Company encountered a pronounced discontinuity in the stratigraphic section at 10,035 feet beneath the surface. The well is located in Pendleton County, about 5 miles northeast of Bluegrass, Virginia and about 25 miles north of the Williamsville quadrangle, on the same anticline that underlies Hightown Valley. The drilling started in limestones of Middle Ordovician (Trenton) age, continued through the Ordovician and Cambrian rocks into the Elbrook dolomite of Middle Cambrian age, and then passed back into Trenton limestones at a depth of 10,035 feet. Apparently an overthrust fault is present in the subsurface in the general area of the Williamsville quadrangle, although to the writer's knowledge the surface outcrop of the fault has not been located.

The structural geology of the Williamsville quadrangle has many of the same characteristics as the Southern Appalachians. For instance, in the Athens, Tennessee quadrangle, Rodgers (1952) notes that the beds dip steadily southeastward between outcrop traces of adjacent thrust faults, and that the higher formations dip more gently than the lower; this suggests that the dips of the faults flatten with depth. Rodgers further notes that anticline and syncline pairs have steep to overturned dips on the common northwest limb of the anticline; the geometry is such that the thrust faults visible at the surface could not have developed out of these steep limbs, but the anticlines may well mark positions at which thrust planes step up from lower to higher incompetant layers in the section. In the Williamsville quadrangle, the formations clearly dip at progressively lower angles as one traces them from anticlinal crests into synclines, and the northwest limbs of all the major anticlines are steeply dipping to overturned, although the dips flatten abruptly into the synclines (this is also true of the Hightown Valley anticline and the Warm Springs Valley anticline, neither of which is completely shown on the map).

Rodgers believes the structural evidence in the Athens quadrangle indicates the probable presence of a sole-thrust fault from which the observed surface faults have branched. The general similarity of the Williamsville quadrangle structure, in addition to the probable presence of at least one subsurface thrust fault, suggests that the basic structure is like that of the Athens area. The great difference is that relatively many thrust faults and few folds characterize the Tennessee structure, while the obverse is true in the Williamsville area. This has been explained as a basic difference in the structure of the Southern and Central Appalachians, but it may be largely a difference in the depth of erosion. If the Williamsville quadrangle were eroded another 2500 feet to 3000 feet, the structure might have much greater similarity than is now apparent to that of Tennessee, and the long-held distinction between the thrust-faulted Southern Appalachians and the folded Central Appalachians would become rather obscure.

ECONOMIC GEOLOGY

Introduction

The only operation utilizing the rock and mineral resources of the Williamsville quadrangle is the State Highway Department quarry in the south-central part of the area. Other, smaller, abandoned quarries are present in the quadrangle, and apparently furnished local needs for road metal, but no other materials have been produced in the area to date. Some of the formations present in the quadrangle have been utilized elsewhere in Virginia, however, and development possibilities do exist for the rocks of the Williamsville area.

Iron Ore

Iron ore deposits associated with the Helderberg group, and overlying formations, have been an important economic resource in parts of Virginia in the past. These deposits are the so-called "Oriskany ores" which are really replacement deposits in the upper part of the Helderberg; iron-bearing solutions, derived from weathering of the overlying rocks, circulated downward and replaced some of the limestones. These deposits have been rarely found in the Ridgeley sandstone and overlying shales. This part of the stratigraphic section is largely covered, and the writer did not observe any ores in the Helderberg where exposures were good. Such deposits may well exist in the quadrangle, but in light of experience elsewhere, they are likely to be small and difficult to locate.

The Cacapon member of the Clinton formation contains mineable iron ore in some parts of Virginia, but the writer did not see any outcrops of the Clinton that show promise of development in the Williamsville quadrangle.

Manganese Ore

Minor manganese ore deposits have been found in conjunction with the "Oriskany" iron ores in parts of Virginia. There is no indication that such deposits exist in the Williamsville area, and those that may be present are likely to be very small.

CARBONATE ROCKS

The Middle Ordovician carbonate rocks, present in Big and Hightown Valleys, and the Siluro-Devonian carbonates, distributed widely over the quadrangle, offer good possibilities for development. Most of these rocks are classed as *impure limestone* (more than 5 percent non-carbonate material) and can be utilized for the manufacture of agricultural limestone, explosives, natural cement, hydraulic lime, and many other products.

The Siluro-Devonian carbonates are less desirable for high-purity lime uses than the Middle Ordovician rocks because of their generally high silica content; the basal part of the Keyser limestone is locally relatively free of impurities, however, and the Coeymans limestone is locally nearly pure calcium carbonate. These formations are suitably thick for extensive quarry operations in the northwestern half of the quadrangle, but are too thin for extensive development in the southeast.

The Five Oaks member of the Lurich formation is worthy of special mention. The Five Oaks is *high-calcium limestone* (over 95 percent calcium carbonate) which may be utilized for the manufacture of fertilizers, dye, fluxes, glass, lime, mineral feeds, paper, Portland cement, and many other products. The Five Oaks outcrops widely in Big Valley and is about 100 feet thick, promising abundant reserves. The rock type is virtually identical to the "cement rock", or New Market limestone, so extensively quarried in the northern part of the Shenandoah Valley.

The limestones have been quarried in at least four localities in the quadrangle, probably for road metal, and these are marked on the map; all quarries are in the Helderberg group. One quarry, operated by the State Highway Department is presently in operation. There are many possible quarry sites in the area; the most desirable sites are areas of either steeply dipping or nearly flat-lying rocks. Especially good are those places where streams have cut relatively deep valleys across rocks of favorable structure, forming ready-made quarry faces that can be worked with a minimum of effort. Two such localities, although others exist, are in the valley of Dry Run across McClung Ridge and the gorge of the Bullpasture River north of Williamsville.

SANDSTONES

The principal use of sandstones, outside of building stone, is in the ceramic industry. The major requirement is that the sandstone must contain only a minute percentage of impurities such as iron. Both the Clinch sandstone and the Ridgeley sandstone meet these requirements in various parts of Virginia, and it appears probable that such is also the case in the Williamsville quadrangle.

The Ridgeley sandstone is usually rather strongly iron-stained, but the stain is prominent only when the Ridgeley is covered by mantle derived from other formations. In many areas where the cover has been stripped from the Ridgeley, the formation weathers shades of gray and there is no evidence of iron compounds; one such area of exposure is along State Highway 629 north of Fort Lewis. Parts of the Ridgeley sandstone in the Williamsville quadrangle probably have the composition of "glass sand."

The Clinch sandstone is also a relatively pure silica rock. Some parts of the formation contain red cross-beds, but most of the Clinch is white to gray quartzite. Excellent natural exposures of the Clinch, weathering medium gray without iron stain, may be seen along the crests of Mill Mountain and Warm Springs Mountain; road cut exposures of the formation usually give the appearance of an impure rock. The Clinch is firmly cemented, in contrast to the Ridgeley, and would need more extensive preparation than the Ridgeley.

SUMMARY

The Williamsville quadrangle contains abundant reserves of impure limestone and high-calcium limestone that can be utilized in many industrial processes. It is probable that sands of ceramic quality are also present in the area. The major obstacle to development of these resources at present is distance from a market and lack of transportational facilities.

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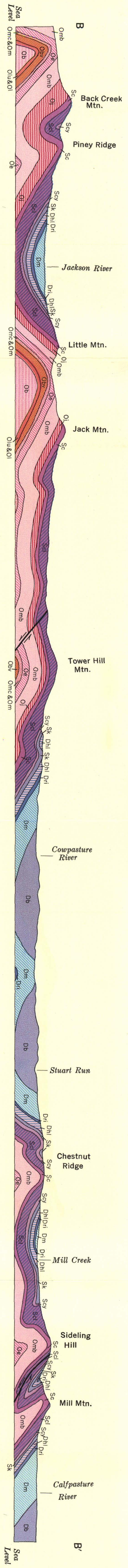
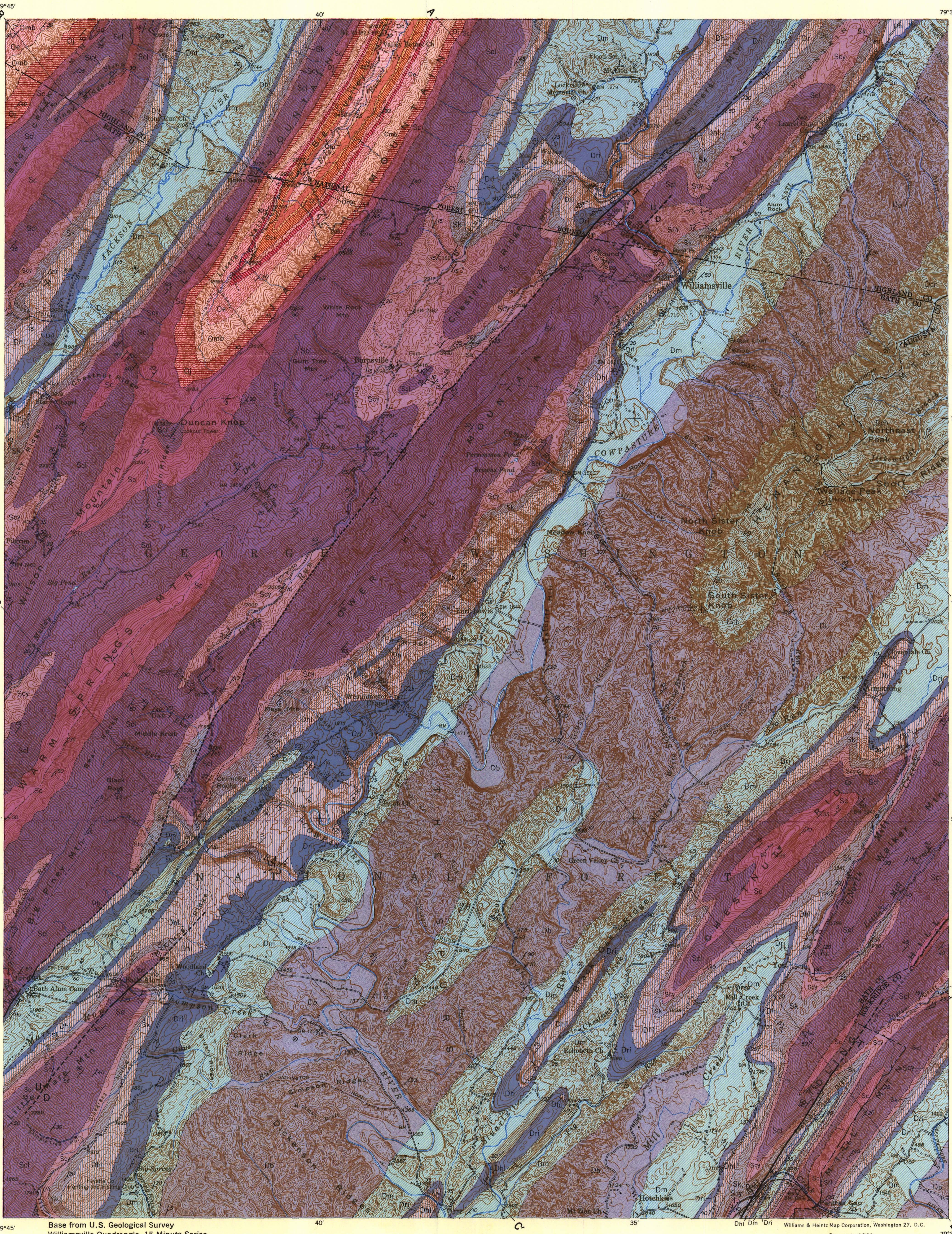
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

REPORT OF INVESTIGATIONS 2
PLATE 1





Base from U.S. Geological Survey
Williamsville Quadrangle, 15 Minute Series.

Williams & Heintz Map Corporation, Washington 27, D.C.

EXPLANATION

DEVONIAN

Upper Devonian
- Dch — Chemung formation

Middle Devonian
- Db — Brallier shale
- Dm — Millboro shale (*including Onondaga fm. in southeast*)

Lower Devonian
- Drl — Ridgeley sandstone (*including Onondaga fm. in northwest*)
- Dhl — Helderberg group (*Coeymans ls.; New Scotland ls.; Licking Creek ls.*)

SILURIAN

Upper Silurian
- Sk — Keyser limestone
- Scy — Cayuga group (*McKenzie ls.; Wills Creek fm.; Tonoloway ls.*)

Middle Silurian
- Scl — Clinton formation

Lower Silurian
- Sc — Clinch sandstone

ORDOVICIAN

Upper Ordovician
- Oj — Juniata formation
- Omb — Martinsburg formation

Middle Ordovician
- Oe — Edinburg formation (*Lantz Mill facies*)
- Om — Moccasin formation
- Omc — McGlone formation
- Obv — Big Valley formation
- Ol — Lincolnshire limestone
- Olu — Lurich formation (*Basal clastics; Five Oaks mem.*)

Lower Ord.
- Ob — Beekmantown dolomite

CONTACTS
- exposed
- approximate
- covered

FAULTS
NORMAL AND REVERSE
- exposed
- approximate

U - *upthrown side*
D - *downthrown side*

THRUST
- exposed
- approximate

T overthrust side

ATTITUDE OF ROCKS
- Strike and dip of beds
- Strike and dip of overturned beds
- Strike of vertical beds
- Horizontal beds

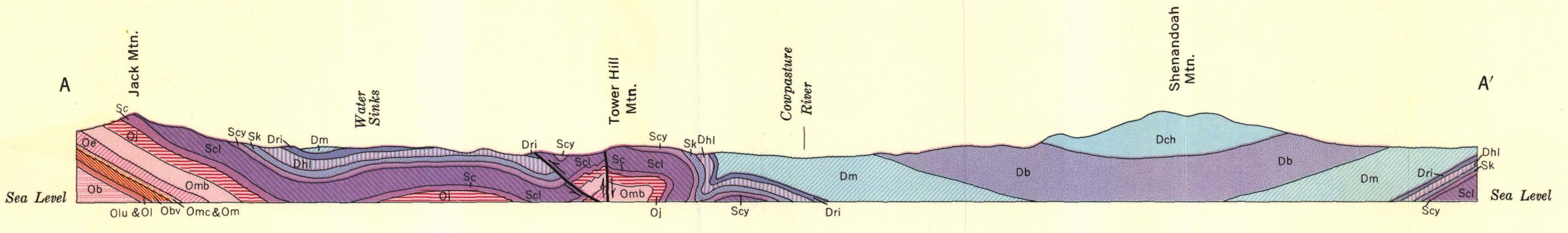
GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE WILLIAMSVILLE QUADRANGLE, VIRGINIA

Geology by K. F. Bick

SCALE 1:62500

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

APPROXIMATE MEAN DECLINATION, 1946



No vertical exaggeration