Honors Thesis

Geology 295-6

DEVELOPMENT OF THE NOMENCLATURE OF ORDOVICIAN STRATIGRAPHY IN VIRGINIA.

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PREFACE

This paper is a bare outline of the development of the Ordovician nomenclature in Virginia. The emphasis has been on the nomenclature as such and paleontologic relations which are so important to the stratigrapher have only received passing mention. The Ordovician nomenclature has had a long history in Virginia and new developments are continually made. The major development over the years has been to divide the larger formational units into smaller ones as paleontology and more detailed field work have allowed it. With increasingly detailed work has come better correlations over regional areas. Virginia has developed as a key spot in the overall picture of the relation of the New York type sections to the long defined Tennessee formations. This paper has been liberally footnoted and numerous papers are listed in the bibliography to which one may go for the original sources of the stratigraphic nomenclature listed herein. This paper is offered in the hope that it will prove useful for a fuller study of the development of the Ordovician nomenclature in Virginia which will make use of the paleontologic literature on the subject.

In 1809 William Maclure (1763-1840) read a paper before the American Philosophical Society in which he described some of the geology of the eastern United States. Many references are made to Virginia and the ones with which this paper is concerned are his comments about rocks in Wythe County and along the New River in Virginia as being Transition rocks. This is probably the first attempt to define the rocks of the Appalachian Valley in Virginia. Maclure was using the Wernerian stratigraphic system, developed by the German geologist Werner (1750-1817) which consisted of the following classification in descending order.

Alluvial rocks
Flötz or Secondary rocks
Transition rocks
Primary rocks

The Transition rocks in the eastern United States consisted of limestones, traprocks, graywackes, flinty slates and gypsum which Maclure had correlated in a general way from New York to the Southern States. The Wernerian classification and Maclure's work are only of historic interest today but Maclure's interest opened the way for others.[1]

The next piece of geologic work concerning the Great Valley in Virginia was done by William Barton Rogers (1804-1882) who spent the years 1835-42 as geologist for the State of Virginia. His principle job was to find rocks and minerals of economic importance. His Geology of the Virginias published posthusmously in 1884 was primarily a series of notes on the economic possibilities of the rocks in Virginia. Rogers, however, wrote a section of one of his geologic reports on the formations in the Appalachian Valley in Virginia. No names were given to the divisions into which he divided the Appalachian Valley rocks. Rogers gave his formational divisions numbers and his divisions of Virginia formations

remained as a standard naming of Appalachian rocks in Virginia until the United States Geological Survey began publishing its geologic folios on parts of the Appalachian Valley and Ridge in Virginia in the eighteen nineties.

Rogers No. I formation consists of what is now the Cambrian of the Appalachian Valley in Virginia. His No. II and No. III corresponded to what is now the Ordovician in the Appalachian Valley in Virginia. On his No. II Rogers writes the following:

> The second member of our series, is the valley limestone with its associated slaty and siliceous bands . . . Varying in colour from the deepest blue, approaching black, to a light grey, and sometimes an almost pure white, presenting every modification of texture from the uniform and compact grain of a marble susceptible of the highest polish, to the soft, slaty, or harsh arenaceous structure, and exhibiting a composition equally diversified, varying from the pure calcareous spar, to the siliceous, the aluminous, and the magnesian limestone, it is obvious, that no one general description will be applicable to its numerous modifications.[2]

No. II is in general referred to as the "valley limestone" by Rogers and he gives the composition by weight and a description of a number of specimens of this limestone. Rogers did not define any smaller units within this formation or list such units in any sequence although he recognized that such units existed over a wide area. While Rogers is hazy on the sequence of beds in his formations he lists for industrial purposes two beds of No. II with a high lime content.[3] One is a dark blue limestone with a fine grain and smooth fracture and the other is a dun-colored limestone of a very close grain, semi-conchoidal and somewhat rounded fracture.[4] In addition Rogers lists six bands of marble (limestone) within this formation because the various limestone colors were in demand for decorative purposes. In only one case are we given a clue as to its sequence in No. II. A gray marble is said to lay very close to the bottom of the formation. A band of magnesian limestone is noted which

probably corresponds to the Beekmantown dolomite of today.[5] On a map showing a geologic cross-section from Waynesboro to Staunton, Virginia, Rogers has noted the following sequence of rocks without regard to faults. Limestone, shale and then eight beds of alternating siliceous limestones and shales and nine beds of alternating limestones and sandstones are noted as occurring.[6] The fossils in No. II of Rogers is described by him as follows:

> Organic remains, though not in general abundant in the valley limestone, may be discovered sparsely distributed in many of the beds of which it is composed, and are found in particular layers or bands in the greatest profusion. It would appear that they become more numerous as we approach the upper limit of the limestone, where it adjoins the third or next superior member of our series. In these positions the rock is frequently crowded with impressions and remains of Encrinites, Spirifers, Productas, Terebrantulas, Orthoceratites, etc. In some of the slaty bands, and in the cherty beds so largely interstratified with the limestone of the valley, Goniatites, Ammonites, and other remains, are by no means unfrequent, and when found are generally in a beautiful state of preservation.[7]

No. III is described by Rogers as follows:

> This member of the series consists of slates and slaty sandstones, or various shades of bluish black, lead colour, and yellowish brown, the dark varieties in general predominating. Their structure is laminated and fissile, not unfrequently evincing the presence of a small quantity of mica. When weathered they in most cases assume a yellowish or dingy brown appearance. Usually, this slate is devoid of carbonate of lime, though bands are occasionally met with, containing organic impressions, and of a composition more or less calcareous.[8]

This is the only description given by Rogers of No. III. It probably corresponds to the Martinsburg shale of today's nomenclature. Rogers lists a number of mountains and ridges in which the formations present are listed but no further description of the rocks is given.[9] On the geologic map of Virginia published in 1884 to accompany <u>The Geology of the Virginias</u> by Rogers the

Appalachian Valley is shown to be wholly of Formations I - III except where the sandstones of older formations cap a few of the Valley ridges.[10] A list of fossils from parts of Rogers' manuscript notebooks published by Jed Hotchkiss in The Virginias suggests that Rogers recognized subdivisions of his formations which he never formally described.[11] Elsewhere Rogers' notebooks are quoted as saying that No. II is a carbonate of lime 10,000 feet thick of which the upper part is a very pure carbonate of lime. Chert or hornstone appears in this formation more in the southwest than in the northeast parts of the state. No. III is a slate 1500 feet thick in the northeast but less in the southwest. No. III is very calcareous in the southwest and beds of limestone are separated by fissile calcareous slate.[12]

It was early recognized that faulting and folding had complicated the stratigraphy of the Appalachian Valley in Virginia[13] but the process of unraveling this was a long slow one. It was late in the nineteenth century before detailed work was done on this problem in Virginia. Rogers' nomenclature continued to be used especially in central Virginia. As late as 1899 Rogers' formations were shown side by side with newer systems of classification in the Monterey Folio published by the United States Geologic Survey. Remarkably little work was done on Virginia stratigraphy from the time of Rogers last report in 1842 until the eighteen eighties. However, work was being done elsewhere which was to influence Virginia stratigraphy.

In England Roderick Impey Murchison published a book in 1837 on the formations beneath the Old Red Sandstone, which, before Murchison, was the lowest series of rocks that the geologists of England had interpreted. He called this system of rocks the Silurian and the lowest members of this system represent what is today called the Ordovician period.[14] The Silurian beds showed a distinct fossil fauna composed largely of trilobites. The English names for geologic periods but not

for geologic epochs was adopted in this country and type localities were described here and have been constantly re-defined and revised to the present day. The type locality for what is now called the Ordovician strata in this country was in New York State. A group of very capable geologists working for the New York Geological Survey between 1836 and 1842 defined the type sections for what was then called the Lower Silurian or Cambro-Silurian. Vanuxem, whose grouping is typical, placed the Potsdam sandstone which is now called Cambrian in a group which the New York State geologists called the Champlainian Division of the New York System. In todays terms all the rocks between

New York System	Ontario Division	Medina sandstone
		Gray sandstone of Oswego
	Champlain Division	Hudson River group
		Utica slate
		Trenton limestone
		Black River limestone
		Calciferous sandstone
		Potsdam sandstone

TABLE 1 [15]

the Potsdam sandstone and the Medina sandstone belong to the Ordovician period.

Between 1851 and 1900 James M. Safford wrote by himself or with J. B. Killebrew five major papers or books relating to the geology and nomenclature of the rocks in Tennessee. Safford's 1869 grouping is compared below with that of J. D. Dana (see Table 2). His other papers will be discussed elsewhere.

Safford 1869 [16]		Dana 1865 [17]	
Upper Silurian	5a. Clinch Mountain sandstone (Medina)	Upper Silurian	Niagara
Lower Silurian	4. Nashville or Nash		Hudson
	3. Trenton or Lebanon	Lower Silurian	Trenton
	2. Potsdam		Potsdam
	2c. Knox or Knoxville		
	2c''' Knox dolomite		

TABLE 2

Dana in the 1865 edition of his text had made the time divisions shown above. His Hudson epoch included the Hudson River group and the Utica slate of Vanuxem and his Trenton included the Trenton, Black River and Calciferous formations of Vanuxem. Safford's Knox dolomite overlapped into the Ordovician period from the Cambrian period as the terms are now used by the United States Geological Survey. Safford called the Knox dolomite a "massive formation of calcareous strata . . . the formation of many ridges and valleys."[18] Safford gave a section of this formation between Webb's Ridge and Knoxville as follows:

(a) Limestone and Dolomite, mostly blue, but some of the upper strata dark gray and sparry; the blue is partly compact and partly oolitic; the lower part is interstratified with shale, thus running into the shale division below; fossiliferous; entire thickness 650 feet

(b) Dolomite, mostly dark gray and sparry, heavy bedded; contains more or less chert throughout, some of which approaches sandstone; upper part includes gray dolomite; thickness 1,870 feet

(c) Chert 4 feet

(d) Dolomite and Limestone, mostly light gray sparry dolomite with more or less chert throughout; upper part interstratified with blue layers which are fossiliferous; thickness[19] 980 feet

In the uppermost beds fossils were noted by Safford of which three species of gastropods were identified.[20] Above the Knoxville dolomite Safford described a series of beds belonging to the Trenton and Nashville epochs. In East Tennessee he discussed both these groups together. A section is given below for the Trenton rocks which was taken a few miles northeast of Knoxville near the mouth of French Broad River.

(7) Calcareous Shale, with occasionally thin, flaggy limestones and a few layers of hard, sandy limestone; contains fossils. This and the shales below are sky-blue, weathering yellowish gray, or buff. Owing to folds thickness uncertain, say in feet 400? feet

(6) Red Marble, fossiliferous, variegated, mostly red marble, with gray and greenish layers; folded and thickness doubtful, say 300? feet

(5) Calcareous Shale, with more or less flaggy, fossiliferous limestone; thickness doubtful, as above, say 500? feet

(4) Iron-limestone, a hard, sandy, very ferruginous limestone, weathering to a porous, dark brown, sandy skeleton; fossiliferous . . . Thickness from 200 to 250 feet.

(3) Calcareous Shale containing interstratified beds of iron-limestones. (The division above (4) might be included in this, as the upper member.) 400 feet

(2) Red and Gray Marble, coralline, grayish white, and variegated 380 feet

(1) Blue Limestone, argillaceous, Fossiliferous; contains Maclurea magna and is followed below by rocks of the Knox group.[21] 500 feet

Fossils were found in all the beds of the Trenton and Nashville formations and Safford made lists of them.[22] The Maclurea magna bed was very prominent and from the fossil record in it Safford felt that this bed was the equivalent of the Chazy (Calciferous) and Black River beds of New York[23] (see Table 1). The Nashville series was noted as a shale in the southeast becoming mostly limestone in the northwest where it lay directly over the Maclurea magna bed.[24] A graptolite zone was very well marked in this Nashville series.[25]

In Pennsylvania in 1859 W. B. Rogers and his brother H. D. Rogers had named the beds that W. B. Rogers had previously only numbered in his work in Virginia. No. II became the Auroral and No. III the Matinal. These names were used to describe the beds as though they were periods in a long day. These names were inadequate in the face of earlier usage and they were abandoned although they were retained in the literature as late as 1899 for the purposes of comparison with newer work. A composite chart of the various names used in different areas by different men is given in Table 3.

Eastern Canada	New York	Virginia Rogers 1835-42	Pennsylvania Rogers Bros. 1859	Tennessee Safford 1869
Hudson River and Trenton groups probably wanting	Hudson River group: Hudson River shales or Lorraine shales; Utica shales; Trenton; Black River and Birdseye limestones	III	Matinal	Nashville
Quebec group	Chazy limestone; Calciferous sandstone	II	Auroral	Trenton
Potsdam group	Potsdam sandstone	I	Primal	Potsdam

TABLE 3 [26]

In 1880 J. D. Dana used the following time units and correlations with the Tennessee names:

	New York			Tennessee
Lower Silurian	Niagara	Medina		
	Trenton	Hudson River		Nashville group
		Utica shale		
		Trenton	Trenton Black River Birdseye	Trenton beds (beds 2-7 as listed on page 7 above)
	Canadian	Chazy		"Maclurea limestone" (bed 1 on page 7)
		Quebec	Sillery Levis	Knox shale and dolomite
		Calciferous		Knox sandstone
	Cambrian	Potsdam		

TABLE 4 [27]

Dana's Quebec group (see Table 4) was poorly defined or absent in New York but was well defined in Quebec Canada and Newfoundland. With the above background we are now ready to see what developments were taking place in Virginia.

In 1879 J. L. Campbell published a short paper describing the limestones in Rockbridge County and adjacent portions of Augusta and Botetourt Counties, Virginia, in the central part of the Great Valley.[28] The formations described extended from the Blue Ridge across the Great Valley to the first ridges of the Valley and Ridge Province. J. L. Campbell's divisions were numbered as W. B. Rogers had used them but Campbell had subdivided two of Rogers groups into smaller units which were recognized over wide areas in central Virginia. Campbell better defined the rock groups of Rogers and compared them with the rock-time units used by Dana in his Manual of Geology (1865?). It will be noted that Campbell divided Rogers No. II and III into three subdivisions (see Table 5). II (a) he describes as "several layers of very siliceous and argillareous limestones separated from one another by beds of brown bluish and purple shales, and some soft sandstones."[29] This suggests a similarity to the Elbrook formation of today (Butts, 1940). Group II (b) "embraces a series of heavy beds of dark blue limestones with some dark brown and yellow shales intervening. A large portion of the limestone is magnesian (dolomitic), and some beds hydraulic." This probably corresponds to the Copper Ridge, Conococheague, and Beekmantown formations of Butts (1933). Group II (c) "is characterized lithologically (1) by having the greater part composed of light blue and bluish drab colored limestones, with yellow shales interstratified, especially among the lower beds; (2) by one and some times two layers of light colored limestones, and (3) by a remarkable bed of chert near its upper limit."[30] The chert bed was said to vary

in thickness from one to ten feet. This chert bed suggests the Lenoir limestone of Butts (1940) which is prominent in the Lexington, Virginia, area. The Natural Bridge of Virginia is noted to occur in the beds of No. II (b) which was called by Butts (1933) the Stonehenge member of the Beekmantown formation.

Campbell notes considerable variation in No. III in the Great Valley and observes that the coralline limestones, III (a), (Butts Holston, 1933) seems to occur almost entirely in Rockbridge County and no farther north than Staunton, Virginia. The coralline limestone "has all the appearance of an old coral reef very much disintegrated, stratified, and subsequently solidified by the infiltrating of carbonate of lime which has given the mass a crystalline texture, and converted it into a gray limestone."[31] The Lexington limestones are composed of limestones and limy shales and are very fossiliferous. Campbell equates it with the Trenton limestone formation of New York. He notes, however, that there is no marked distinction between this formation and No. III (c), the House Mountain shales which he equates with the Hudson River shales in New York.[32] The House Mountain shales (Martinsburg shales, Butts 1933) are well exposed on House mountain west of Lexington, Virginia. No special fossils are noted for formations No. II and III. The divisions used by Campbell in 1879 are the same as those used in his book on the Geology and Mineral Resources of the James River Valley in 1882.[33]

From 1881 to 1886 The Virginias: A Mining, Industrial, and Scientific Journal ~~was~~ published by Jed. Hotchkiss ~~published~~ contained reprints of a number of geologic articles on Virginia especially those concerning the geology of mineral deposits. Hotchkiss also edited W. B. Rogers The Geology of the Virginias which was published in complete form in 1884. Many articles in The Virginias were reprints from Rogers book and from geologic journals which contained articles of interest on Virginia geology. Some of the articles were original ones from W. B. Rogers

manuscript notebooks. (See footnotes for the uses of such articles in this paper.)

	Dana 1865	Rogers 1837-42	J. L. Campbell 1879[34] Virginia subdivisions
Trenton	Medina	No. IV	conglomerate
	4(c) Hudson River	No. III	c) House Mountain shales
	4(b) Utica		b) Lexington limestones
	4(a) Trenton		a) Coralline limestones
	3(c) Chazy		c) cherty limestones
	3(b) Quebec	No. II	b) dolomitic limestones
	3(a) Calciferous		a) hydraulic limestones
Cambrian	2(b) Potsdam	No. I	Iron-bearing shales

TABLE 5

In 1881 C. R. Boyd published a book in which a large number of geologic sections across the counties of southwestern Virginia were drawn. The nomenclature of J. D. Dana rather than that of W. B. Rogers was used in describing the beds. Boyd was, however, aware of and favorable toward Rogers contributions to Virginia geology. Boyd's major interest was mineral deposits and many of the rocks which compose todays Ordovician were either described briefly or not at all by him although they occur in his structure sections. Six structural sections showing formation positions are of sufficient detail to be of note in this paper. In Wythe County the following section is given from a cross-section of the county:[35]

Medina sandstone	100 feet
Oneida (Oswego?)	180
Birdseye	500
Chazy	2,000
St. Peter sandstone and slate	380
Calciferous ophileta (a gastropod)	200
Calciferous Great Limestone	6,000
Calciferous slates	1,000
Potsdam	1,500

The Oneida probably refers to the Oswego sandstone (Butts 1933) or perhaps includes the Juniata formation which is considered at the top of the Ordovician by Butts (1940). The Birdseye is equivalent to the Trenton in New York but it is hard to tell exactly what is meant by it here. In a cross-section across Smyth County, Boyd uses in descending order the names Oneida, Hudson, Trenton, and Calciferous and notes that a commercial marble lies between the Trenton and the Hudson.[36] The Giles County cross-section uses the same formations as in Smyth County but a fine iron ore is noted near the base of the Trenton. The Hudson series is 1000 feet thick and the Trenton limestones are 850 feet thick in Giles County.[37] In Bland County the Hudson River group is described as 650 feet thick and the Trenton as 300 feet thick. The base of the Trenton is divided from the Upper Calciferous limestones here by a "felsphatic flint measure."[38] Russell, Tazewell, and Scott Counties have about the same geology in Boyd's book but on the Scott County cross-section Boyd has a Black River series labeled as the bottom of the Trenton.[39] In the Lee County cross-section there is listed 150 feet of reddish shales between the Oneida grit (sandstone) and the Hudson rocks.[40]

In 1881 J. J. Stevenson described a section of the Nashville and Knox groups of Safford (1869) in southwestern Virginia. Stevenson described the beds with an eye to their economic usages. He notes that beds two and eight, in a section he describes, are fossiliferous. Bed eight is said to contain reddish marbles similar to those found in Tennessee.[41] The section is as follows:[42]

Trenton and Nashville group

1.	Shale and thin limestone	600 feet
2.	Limestone and calcareous shale	25
3.	Calcareous shale	130
4.	Limestone	70
5.	Shale	65
6.	Limestone	45
7.	Shale	50
8.	Massive limestones	200
		1,185

Knox Group

9.	Cherty rock and limestone	160 feet
10.	Limestone and shale	120
11.	Concealed	60
12.	Cherty rock	165
13.	Light blue limestone	55
14.	Concealed	15
15.	Limestone, shale and chert beds	300
16.	Variegated shale	70
17.	Limestone	250
18.	Shale	60
19.	Limestone	260
20.	Shale	30
21.	Siliceous limestone	200
		1,745

In 1885 Stevenson described briefly the formations in southwest Virginia using the New York nomenclature as Boyd had done. The Cambro-Silurian or Lower Silurian including the Hudson, Trenton, Knox or Calciferous formations are noted. The Utica is said to be either absent or so changed that it cannot be separated from the Hudson or the Trenton. His description is as follows:

> The Hudson consists of red to yellow sandy shales and the passage to lower Medina is wholly imperceptible. The yellow shales below become calcareous and the passage to the Trenton is equally gradual. The upper beds of the latter group are very argillaceous, but the marbles are reached near the bottom of the group. They are thoroughly characteristic. Toward the bottom of the marbles some massive limestones occur containing much black chert; these mark the passage to the siliceous Knox group in which are several beds of white chert and many beds of very hard and slightly calcareous sandstones. This is merely the Calciferous of New York, vastly increased in thickness. No detailed section of any portion of the Cambro-Silurian was attempted, but enough was observed to show that the writer's estimate of 3,250 feet for the thickness of the Knox group is materially below the truth.[43]

In 1885 the Second Geological Survey of Pennsylvania was formed which discarded the nomenclature of the Rogers' and began using the New York nomenclature. In addition, the previous broad classifications were broken down so that fourteen mappable units were formed from the Rogers' No. II or Matinal in

Pennsylvania.[44] In MacFarlane's Geological Railway Guide the nomenclature used is the same as that in Table 5, page 11, above. Levis was used for the term Quebec. It might be noted that some geologists merged the Levis with the Calciferous group and called both groups the Calciferous.[45] MacFarlane's book consisted of the comments of various geologists on the geology along the railroads in the area with which they were familiar. W. B. Rogers wrote the section on Virginia before he died in 1884 but in the 1890 edition of the book J. L. and H. D. Campbell wrote an additional geologic section. The nomenclature used was that of Rogers No. II and III with the subdivisions that J. L. Campbell had recognized and proposed in 1879. The Chazy was noted in many places as containing beds of chert that contain characteristic fossils. The caverns at Luray, Virginia, were said to be in both the Chazy and Levis groups.[46]

~~It might be noted that some geologists merged the Levis with the Calciferous group and called both groups the Calciferous. MacFarlane's book consisted of the comments of various geologists on the railroads in the area with which they were familiar. W. B. Rogers had written the section on Virginia before he died in 1884. In the 1890 edition of the book J. L. and H. D. Campbell wrote an additional section for the newer railroad routes. This new section used stratigraphic divisions of Rogers No. II and III which J. L. Campbell (1879) had previously used.~~

In the same year that J. L. Campbell (1879) subdivided W. B. Rogers formations in central Virginia, C. Lapworth in England proposed to call the lower Silurian rocks described by Murchison in 1837 the Ordovician system.[47] This name was not fully adopted in this country until about 1900. Between 1890 and 1900 the United States Geologic Survey began an intensive period of geologic work in the Great Valley of Tennessee, Virginia, and Pennsylvania which resulted in a number of geologic folios describing the geology of various

quadrangles in Virginia. Since little previous intensive work had been done on the Great Valley geology in Virginia it was necessary either to invent a new nomenclature for subdivisions of older groups when such names became necessary or to use names which the geologists of neighboring states used for equivalent formations. Both steps were taken. The formation names of Tennessee were used in the description of the geology of the southwestern part of the Great Valley in Virginia and the nomenclature used by the Geological Survey of Pennsylvania since 1885 was adopted in some cases in the northern part of Virginia. In 1894 three United States Geologic Folios were issued which dealt with areas in Virginia. The Harpers Ferry Folio in northern Virginia called the upper Cambrian and Silurian formations the Shenandoah limestone and Martinsburg shale respectively. Both of these formations were first described as such by N. H. Darton in the vicinity of Staunton, Virginia.[48] At Harpers Ferry "the Shenandoah limestone differs strikingly from previously deposited formations, which were largely siliceous and composed of particles of appreciable size . . . In general it is a series of blue and gray limestones and dolomites, with occasional beds of mottled blue limestone . . . The prevailing calcareous character of the formation is locally modified by a series of slates and sandy shales interbedded with the limestone . . . Another exception to the usual character of the formation is a bed of white marble . . . It is pure, and of fine, even grain."[49] Fossils which were found indicated a Cambrian age for the lower part of the Shenandoah formation and a Silurian age for the upper part of the formation as these terms were used in 1894. The Martinsburg formation overlying the Shenandoah limestone was composed of black and gray argillaceous shales of a fine grain and showed no variations in the Harpers Ferry area.[50] Part of the Harpers Ferry columnar section and comparisons with other formations elsewhere are shown in Table 6. In the central part of the Great Valley in Virginia N. H. Darton in

the Staunton Folio described the Martinsburg shale as a "gray shale, with sandy beds above and calcareous beds below" and from 800 to 1400 feet thick. The Shenandoah limestone below the Martinsburg shale was recognized as a massive fossiliferous limestone with Trenton age fossils in its upper beds. The Shenandoah limestone was listed as about 1500 feet thick here.[51]

In southwestern Virginia M. R. Campbell in his description of the Estillville sheet (1894) used the Tennessee nomenclature for formations in the area. It was known that the Knox dolomite (Safford, 1869) straddled the Cambrian and Silurian periods. M. R. Campbell recognized three divisions of the formations between the Knox dolomite and the Bays (Medina) sandstone (Table 7). The Knox dolomite was described as a magnesian limestone the top of which was characterized by white, argillaceous limestone, below which the rock is generally gray and at certain horizons very cherty. The Chickamauga limestone was a blue, flaggy limestone, becoming more massive toward its base. In its lower portion occurred extensive lentils of red and gray marble, below which the rock generally contained black cherts. The Moccasin formation was a red argillaceous limestone and the Sevier shale was a sandy shale at the top and a yellow, calcareous shale at the bottom.[52]

In 1894 M. R. Campbell in the description of the Pocahontas sheet used the term Shenandoah limestone to apply to magnesian beds with the cherty horizons which he had called the Knox dolomite in his description of the Estillville sheet. The Chicamauga limestone, Moccasin limestone, Sevier shale, and Bays sandstone were used as they had been in the Estillville sheet.[53] Rocks of Trenton age were not thought to be in the Shenandoah limestone in the Estillville and Pocahontas sheets but in northern Virginia N. H. Darton in 1895 in his description of the Franklin Folio used the Shenandoah limestone to include Trenton rocks and the Martinsburg shale as equivalent to the Hudson River shales of

New York which lie above the Trenton rocks. The term Juniata was used for the brownish-red sandstones and red shales of the upper Martinsburg shale in the Franklin Folio.[54] In the Estillville Folio M. R. Campbell had thought that the Chicamauga limestone might be equivalent to the base of Rogers III. The description and nomenclature of formations in the Tazewell Folio is virtually the same as that of the Estillville Folio for the formations of the Lower Silurian (Ordovician).[55] The Monterey Folio has a description and nomenclature similar to that of the Franklin Folio.[56] In 1899 M. R. Campbell in the Bristol Folio recognized that the Knox dolomite to the southwest of Clinch Mountain in the center of the quadrangle merged with the Honaker limestone and Nolichucky shale, which were Cambrian formations below the Knox dolomite, and the Lower Silurian Chickamauga limestone above the Knox dolomite to become one indistinguishable series which Campbell called the Shenandoah limestone as equivalent to the term as it was used in the geologic folios in northern Virginia. In addition, the Chickamauga limestone, a blue flaggy limestone, was recognized to thin appreciably and virtually to disappear to the southwest of Clinch Mountain where it was replaced by the Athens shale. Above the Athens shale was a lenticular mass of thin-bedded sandstones and sandy shales called the Tellico sandstone. The Sevier shale, a sandy shale, was above the Tellico sandstone and the Bays sandstone was above the Sevier shale southwest of Clinch Mountain. To the northeast of Clinch Mountain the formations were the same as those used in the Estillville Folio for the Lower Silurian as mentioned above. The Moccasin limestone which lay between the Sevier shale and the Chickamauga limestone northwest of Clinch Mountain was believed to be a transition group which graded farther west into Chickamauga limestone.[57] The Athens shale--Tellico sandstone--Chickamauga limestone relationship was virtually the same as the conclusions reached by A. Keith in the Knoxville Folio in 1895. Campbell used Keith's Athens and Tellico nomenclature to describe the situation in the Bristol Folio.[58] The

Athens shale was named and given its relationship to the Chickamauga limestone by C. W. Hayes in the Kingston and Cleveland Folios in Tennessee.[59]

	Harpers Ferry Folio	J. M. Safford Tennessee	W. B. Rogers Geology of Va.	J. P. Lesley Geol. Sur. of Pa.
Ordovician	Martinsburg shale 700-1000 ft.	Nashville shale	III Hudson River III Utica	III Hudson River Utica
	Shenandoan limestone 2500 ft.	Knox dolomite	II Trenton Chazy Levis Calciferous	Trenton Chazy Calciferous

TABLE 6[60]

	Estillville Folio	Safford	Stevenson
Silurian	Bays sandstone 1-325 ft.	Clinch Mountain sandstone	Medina sandstone
Ordovician	Sevier shale 440-675 ft. Moccasin limestone 500 ft. Chickamauga limestone 1200-1300 ft.	Trenton and Nashville series	Trenton and Nashville group
Cambrian	Knox dolomite 2100-2900 ft.	Knox dolomite	Knox dolomite

TABLE 7[61]

As early as 1851 J. J. Safford had divided the rocks of the Nashville Basin in Tennessee into mappable units (see Table 8). He called the group of formations immediately over the Knox dolomite the Stones River Group. This was in turn divided into three units the lowest member of which was called the Stones River beds. The other members were the Upper and Lower Lebanon limestones. In

1869 Safford called the Stones River Group the Trenton or Lebanon Group in middle Tennessee. His description of this group is as follows:

> The Trenton Formation
>
> (5) Carter's Creek Limestone. (Topmost) A heavy-bedded, light blue, or dove colored, limestone, the upper part often gray; contains Stromatapora rugosa, Columnaria alveolate, Tetradium columnare, Petraia profunda . . . The thickness of the stratum is from 50 to 100 feet.
>
> (4) The Glade Limestone. A stratum of light blue, thin-bedded, or glaggy limestones. Pre-eminently the bed of the great "Cedar Glades" of the Central Basin . . . Maximum thickness 120 feet.
>
> (3) Ridley Limestone. Next below is this stratum -- a group of heavy-bedded, light blue, or dove colored, limestones . . . The maximum thickness observed is 95 feet.
>
> (2) Pierce Limestone. A group of thin-bedded, flaggy limestones, with generally a heavy-bedded layer near the base. These rocks are highly fossiliferous and abound in Bryazoa . . . The group has a maximum thickness of 27 feet.
>
> (1) Central Limestone. An important group of thick-bedded, cherty limestones, of a light blue, or dove color . . . and presents in its heaviest exposures a thickness of about 100 feet.62

In 1900 a newer nomenclature was proposed by Safford and Killebrew which changed the name of the Central limestone to Murfreesboro limestone, and the Glade limestone to the Lebanon limestone. The Ridley, Pierce, and Murfreesboro limestones were then recognized as the Stones River Group and were correlated with the Chazy of New York. The Carters limestone, the Orthis bed and another series of limestones were then called the Nashville Group which was correlated with the Trenton of New York. As will be shown elsewhere these are not the same Stones River beds as used by others in the upper middle Appalachian Valley. The Black River beds of New York which were recognized as occurring between the

Trenton and Stones River Group were said to be absent in the area of the Columbia (Tennessee) Folio by C. W. Hayes and E. O. Ulrich (1903).[63]

Generalized Time Scale for Central North America	Safford and Killebrew: 1900		Safford: 1869 Middle Tennessee		Safford 1851		
Richmond	Hudson. Includes Hudson phosphates	Nashville	Upper Nashville	Nashville	Upper Nashville	Nashville Group	Central limestone and shale group
Lorraine							
Frankfort	(f)(g) Cyrtodonta and Stromatopora beds (d)(e) Dove and Ward limestones (c) Capital limestone (b) Orthis bed		Middle Nashville		Lower Nashville		
Utica							
Trenton			Lower Nashville (Orthis bed)		Siliceous or sandy limestone		
Black River	(not classified)	Trenton		Trenton or Lebanon		Stones River Group	
Stones River	(a) Carters limestone		Carters Creek limestone		Upper Lebanon limestone		
	Lebanon limestone	Stones River (Clays)	Glade limestone		Lower Lebanon limestone		
	Ridley limestone		Ridley limestone		Stones River beds		
	Pierce limestone		Pierce limestone				
	Murfreesboro limestone		Central limestone				

Correlation Table Commbia (Tenn.) Folio

TABLE 8[64]

In 1900 C. S. Prosser wrote a short article on the Shenandoah limestone and Martinsburg shale. He listed a number of fossils in both formations and from these concluded that the upper part of the Shenandoah corresponds to the Trenton limestone of New York but that the lower part contains Cambrian fossils and there is no distinct line between the Cambrian and Lower Silurian (Ordovician) within the Shenandoah limestone. The Martinsburg shale is correlated with the Utica shale of New York and the sandy beds succeeding the Martinsburg were correlated with the Lorraine beds in New York.[65]

In 1905 T. L. Watson briefly summed up the work on the Shenandoah limestone in Virginia to that date. The division of such a large formation occupied Virginia geologists for a generation. As noted above N. H. Darton had named the Shenandoah limestone which was the equivalent of Rogers Valley limestone (No. II) and which had been equated in part with the Knox dolomite in Tennessee.[66] Fossil evidence indicated that the lower part of the Shenandoah limestone was Middle Cambrian in age.[67] It was felt that there was no physical break in the Shenandoah limestone to indicate the division between the Cambrian and the Ordovician periods. It was therefore regarded as a lithologic unit of Cambro-Ordovician age. In certain localities in southwest Virginia the extreme top of the formation is marked by a few feet of sparingly fossiliferous limestone. In other localities the top is marked by heavy beds of a limestone conglomerate. This was thought to represent the existence of overlaps in early Paleozoic time. The lower or basal portion of the Shenandoah limestone is somewhat shaly in places.[68] Watson described the Shenandoah limestone in southwest Virginia as follows:

> Throughout the zinc and lead area of southwest Virginia the Shenandoah limestone shows considerable variation in character; it usually contains much chert in the form of

> nodules and layers. The chert as a rule is not regularly distributed through the limestone, and in some beds it is entirely absent. It shows much variation in color and texture, varying from very dark, nearly black to very light in color; from compact texture and typically banded to porous or spongy and oolitic masses without banding . . . The limestone is very much folded and crushed, and is usually interlaced by innumerable vein-like lines and knife-edge stringers of which crystallized calcite and dolomite, which recement the limestone fragments . . . In places, there appear occasional bands of homogeneous, compact and dense textured, light gray limestone within the formation, which doubtless would prove to be a fair grade of lithographic limestone. The formation is still marked in other places by bands or streaks of a nearly pure limestone . . . for which it has been quarried at a number of points. The Shenandoah limestone . . . is generally a heavy bedded, dark blue to gray, dolomite, with an estimated thickness of not less than 4000 feet.[69]

In southwest Virginia the Chickamauga limestone succeeded the Shenandoah limestone which was a blue, flaggy, fossiliferous limestone more heavily bedded toward its base. C. W. Hayes correlated it with the Trenton and Chazy or Maclurea beds of New York. In Virginia, M. R. Campbell felt the Chickamauga was probably equivalent to the base of Rogers No. III. At Staunton, Virginia, the Chickamauga was absent and the Shenandoah limestone was succeeded by a series of shales which were called the Martinsburg shale. The Martinsburg had been correlated with the Utica and Hudson shales of New York.[70]

In 1905 H. D. Campbell without trying to correlate any formations divided the Shenandoah limestone in central Virginia in the Great Valley into five formations. The Natural Bridge limestone contained fossils of Cambrian age

Period	Name of Formation	Thickness in Feet
Ordovician	Liberty Hall limestone	1000±
	Murat limestone	100 - 150
Cambro-Ordovician	Natural Bridge limestone	3500+
Cambrian	Buena Vista shale	600 - 900
	Sherwood limestone	1600 -1800

TABLE 9[71]

in its lower beds and in its top beds fossils of Beekmantown (Calciferous) age indicating the Ordovician period. The Natural Bridge limestone was described as a heavy-bedded gray and light blue magnesian limestone with thin siliceous laminae conspicuous especially on the weathered surfaces. Black chert occurred in nodules more or less throughout the formation. The Murat limestone above the heavy chert beds of the Natural Bridge limestone was described as a massive gray crystalline limestone containing hydrozoa and other fossils in abundance. The Liberty Hall limestone was called the Lexington limestone by J. L. Campbell in 1879 but because this name was being applied to formations in Kentucky of a different age but within the Ordovician period H. D. Campbell changed the name to the Liberty Hall limestone. The Liberty Hall limestone was described as a succession of rather evenly banded beds of fine grained, dark blue limestone of which the more argillaceous limestone weathers shaly. Calcareous shale predominates in the higher sections of the formation. Brachiopods and trilobites of Mohawkian age were abundant in the lower beds.[72] In 1905 Bassler made the following statement on the Shenandoah limestone:

> The name Shenandoah limestone proposed by Darton for the Valley limestone of early geologists was made to include all the limestone in the Valley of Virginia occupying the interval between the Cambrian quartzites and the Upper Ordovician shales. The lower portion of the great limestone series had been found by Mr. Walcott to include Lower, Middle, and Upper Cambrian rocks, but the Ordovician portion had been determined to the extent that Trenton strata were supposed to occur at the top. The work of the writer in Virginia brought out the fact that the geologic succession of the Ordovician division was quite different in various parts of the Valley. In northwestern Virginia a great thickness of Beekmantown is overlaid by 1,000 feet of Stones River, and this in turn by 400 feet of Black River, while the strata bearing Trenton fossils from the lowest division of the overlying shales. In central western Virginia the Black River alone rests upon Beekmantown but in southwestern Virginia two distinct arrangements were noted. Along the western edge of the Valley the Beekmantown is followed by 1000 or more feet of Stones River but no Black River, while along the eastern side only the Black River

> occupies the interval between the overlying shales and the Beekmantown. In each case the Trenton does not form the upper part of the limestone, but is the basal member of the overlying shales. The Shenandoah limestone, therefore, is a broad term embracing strata of Cambrian and Ordovician age, the geologic succession of the latter varying in different parts of the type area.[73]

At this point in order to understand the relations of Virginia formations to the type sections of New York it will be necessary to pause to see how Ordovician nomenclatures and relationships were evolving. The divisions that J. D. Dana used in 1880 for the Lower Silurian rocks of New York have been noted above. Lapworth in England proposed the term Ordovician for the Lower Silurian rocks. The term Ordovician was not taken up immediately in this country although it was recognized in Europe. Americans preferred to use American terms so that J. M. Clarke and Charles Schuchert in 1899 proposed the name Champlainic for the Lower Silurian rocks. J. D. Dana had proposed the term Canadian for the earliest Lower Silurian rocks in 1875.[74] Mohawkian was a new term proposed by Clark and Schuchert to cover the lower part of what had previously been called the Trenton system by J. D. Dana. It was realized that the upper part of what had formerly been the Trenton was poorly developed in New York but was well developed around Cincinnati, Ohio. Hence, the name Cincinnatian for the upper series of rocks of the Champlainic of Clarke and Schuchert. The Birdseye limestone of Dana was changed to the name Lowville limestone by Clarke and Schuchert. Increasingly detailed fossil investigations showed that the Hudson River group was mostly of Trenton and Utica age so they abandoned this term and used the term Lorraine for the remaining beds. The Richmond beds were well developed in Ohio and Indiana but poorly developed in New York.[75] In 1906 T. C. Chamberlain and R. D. Salisbury concurred with Clarke and Schuchert but preferred the term Ordovician rather than a new name for the

former Lower Silurian rocks. They also preferred the terms Lower, Middle, and Upper to Canadian, Mohawkian, and Cincinnatian. Both of these usages have been adopted and modified by American geologists and are still in general use. The Chamberlain and Salisbury terms are more widely used however (see Tables 10 and 11).

Champlainic (Lower Silurian and Ordovician)	Cincinnatian (NeoChamplainic)	Richmond beds (Ohio and Indiana) Lorraine beds Utica shale
	Mohawkian (Meso-Champlainic	Trenton limestone Black River limestone Lowville limestone
	Canadian (Paleo-Champlainic)	Chazy limestone Beekmantown limestone

TABLE 10 [77]

	Upper Ordovician (or Cincinnatian)	Richmond beds (Ohio and Indiana) Lorraine beds Utica shales
Ordovician	Middle Ordovician (or Mohawkian)	Trenton limestone Black River limestone Lowville limestone
	Lower Ordovician (or Canadian)	Chazy limestone Beekmantown limestone (=Calciferous)

TABLE 11 [78]

In 1906 Stose divided the Shenandoah limestone in Pennsylvania into six formations (see Table 12). In 1908 he divided the Knox limestone which he called the Beekmantown into two members (see Table 13). Concerning the upper part of the Shenandoah Group and the Martinsburg Group Stose said this in 1906:

> The conglomerate zone . . . is followed by drab magnesian limestone with the same Saratogan fauna, grading upward into siliceous limestones containing occasional poorly preserved

Age		Name	Thickness	Character
		Eden sandstone	500 feet	Soft, buff to green sandstone.
	Martinsburg Group	Utica shale	1000 feet	Gray fissile shale, with black, carbonaceous and calcareous shale, probably of Trenton age at the base.
Ordovician		Chambersburg limestone	1000+feet	Fossiliferous, crystalline and thin shaly limestones of Chazy-Black River age.
	Shenandoah Group	Stones River limestone	400+feet	Homogeneous, dove-colored, pure limestones of Stones River age.
Cambrian		Knox limestone	2000± feet	Drab magnesian and siliceous limestones, in part cherty, with limestone conglomerate at the base.

TABLE 12[79]

	Martinsburg formation	Eden Utica Upper Trenton	
	Chambersburg limestone, 100-600 feet	Lower Trenton	Ordovician
Shenandoah Group	Stones River limestone, 800-1000 feet	Black River Lowville	
	Beekmantown limestone, 2250-2400 feet (including Stonehenge limestone member at the base) 500 feet	Lower and Middle Chazy Beekmantown	

TABLE 13[80]

gastropods of Beekmantown age . . . Ulrich, who has recently made a careful study of the rocks through the Great Valley, regards this formation as stratigraphically and faunally the same as the Knox dolomite of Tennessee, and the name "Knox limestone" is therefore adopted . . . The Knox is limited above by homo-

> geneous, fine-grained, dove-colored, pure limestone, extensively quarried throughout the Valley. It contains a few leperditia, gastropods, and brachiopods of Stones River age, and since the rock is lithologically the same as the Stones River of Tennessee, and apparently occupies the same interval, the name "Stones River limestone" is applied here. Overlying the Stones River are darker and more crystalline limestones, somewhat cherty at the base and interbedded in the upper portion with argillaceous limestone. Fossils . . . in . . . the upper portion contains a large . . . fauna, referred by Ulrich to the Chazy and Black River. The formation is . . . named the "Chambersburg limestone . . . The calcareous strata are followed by a series of shales and soft sandstones previously called the "Martinsburg shale." At the base are a few feet of dark calcareous shale and thin beds of carbonaceous limestone, transition beds, containing a fauna regarded as Trenton in age. These are followed by dark to gray platy shale, with . . . Utica forms, including numerous graptolites, and it is therefore named the "Utica shale" . . . Above it are greenish to buff, soft sandstone which is named Eden because it contains a fauna referred by Ulrich to the Eden and is regarded by him as stratigraphically its equivalent.[81]

The Eden fauna mentioned in the quotation was a Lower Cincinnatian fauna of the Cincinnati Arch area and is correlated between the Utica shale and the Lorraine shales of New York.[82] The Stonehenge limestone member of the Beekmantown limestone is distinguished by it silicified banded beds and large "edgewise conglomerate" from the rest of the Beekmantown formation. The Stonehenge member has the characteristic fossil Ophileta complanata.[83] In Pennsylvania the Stones River was recognized as having three lithologic divisions. A lower series of interbedded massive pure beds and magnesian layers, a middle band of massive pure granular limestone containing the large gastropod Maclurea magna and thin beds of black chert that weather into small rectangular blocks, and an upper series of thin-bedded pure limestones. The middle division yielded fossils comparable with the Chazy in New York and the Maclurea magna was characteristic of a bed above the Knox dolomite in Tennessee so that this bed was about the same age as the Stones River beds in Tennessee.[84] The overlying Chambersburg limestone was found to have four faunal groups in the Chambersburg

limestone belt in the Mercersburg quadrangle immediately adjacent to the Chambersburg quadrangle. The lowest Chambersburg bed contained numerous Nidulites, Bryozoa, and a layer of cystoid heads.[85] In the description of the Martinsburg-Chambersburg district Stose notes that the Juniata formation overlying the Martinsburg shale was of the same age as the Maysville (Upper Cincinnatian)Group of the Cincinnati Arch area. In Virginia and Tennessee the Bays sandstone and the Juniata were considered equivalent in some areas. The Juniata was the Upper Ordovician in Virginia according to Stose.[86]

In 1905 P. E. Raymond re-examined the fossils of the type New York Chazy limestone and based on this study concluded the Stones River was later than Chazy and earlier than Trenton in age. Safford' Malurea limestone which he had correlated with the Chazy of New York Raymond found to be Trenton in large part but one section around Leniors, Tennessee gave him Chazy fossils of the Maclurites magna faunal division of the Chazy.[87]

In 1907 Bassler wrote the section on cement and cement materials in the Mineral Resources of Virginia by T. L. Watson. Since Bassler described the same areas and used much of the same material in his 1909 work (see below) which was in more detail this paper will not be discussed in much detail. The only major change in nomenclature in 1909 form the 1907 work was the recognition in 1907 by Bassler of some beds near Pearisburg, Virginia, which occurred between the Moccasin limestone and the Knox dolomite. Bassler proposed to use the name Pearisburg limestone for these beds. This term included a coarse limestone of the Holston type in addition to dove-colored and magnesian limestones at Pearisburg.[88] The term Lenoir was here used by Bassler for the beds between the Knox dolomite and the Athens shale. The Lenoir was considered the bottom part of the Chickamauga limestone in Tennessee and southwest Virginia.[89]

Bassler in 1909 used the nomenclature devised by Stose (1909) and Ulrich in Pennsylvania, described above, to describe the geology of the northern part

of the Great Valley in Virginia. H. D. Campbell's Natural Bridge limestone was equated with the Beekmantown of Stose and the Knox dolomite of Safford.[90] This was followed by Stose's Stones River which was in northern Virginia a heavily bedded alternating dolomitic and calcareous rock. It varied from fine grained to a coarse black limestone with dove-colored rock predominating. The upper layers were characterized by a single tubed species of Tetradium. Bassler noted that cedar trees were partial to the Stones River soils and that areas of the outcropping of this group could be detected by this means in many cases. In southwestern Virginia the dove limestones of the Stones River Group appear in the lower part of the Chickamauga limestone which is referred to as Stones River age.[91] The Chambersburg formation overlies the Stones River and nine beds were recognized by Bassler at Strasburg, Virginia. In a generalized section for northern Virginia four major beds were noted for the Chambersburg limestone. A pure limestone with cherty portions, a nodular and thin bedded gray argillaceous limestone with numerous fossils in the lower third, a thin bedded to massive dove and black limestone holding Nidulites in more or less abundance, and a gray earthy limestone with numerous fossils in the upper part were described by Bassler. The third and fourth beds were the most consistently found with the fourth bed being the most persistent in the Chambersburg formation. Tretaspis and Christiania are especially characteristic fossils of bed four.[92] The fauna of the Chambersburg formation is an unusual one which appeared in New York only in a conglomerate. The finding of the fauna in beds still in place in Virginia and Pennsylvania is noteworthy. The fauna is of early Trenton age.[93] While there is no physical break in the sediments there is a faunal break between the Martinsburg shale above and the Chambersburg limestone below. On the east side of the Great Valley the Martinsburg is an Upper Trenton shale with the characteristic fossil Corynoides. On the west

side of the Great Valley in northern Virginia the Martinsburg formation is a thin bedded limestone with interbedded lower shales instead of a dark calcareous or argillaceous shale as to the east.[94] The Middle and Upper Martinsburg shale are said by Bassler to be the most constant divisions of the geologic succession in western Virginia. The Middle Martinsburg is correlated with the Utica shale of New York and the upper shale with the Eden fauna developed near Cincinnati, Ohio. The Upper Martinsburg has a high silica content.[95] In central western Virginia Bassler used the nomenclature of H. D. Campbell. Between the Murat and Natural Bridge limestones Bassler and Campbell noted a pure dove and laminated mottled limestone which Campbell had not considered of sufficient importance to name and which Bassler correlated as the Stones River representative in central Virginia. The Liberty Hall limestone overlay the Murat in central Virginia.[96] Bassler lists the following section near Lexington, Virginia:[97]

Geologic sections, Lexington, Virginia, and vicinity	feet
III. Lowville and Black River limestones, including Liberty Hall and Murat formations.	
2. Liberty Hall formation:	
(d) More or less thin-bedded argillaceous limestone and calcareous shales.	500±
(c) Fine-grained, dark, massive argillaceous limestone with an obscure conchoidal fracture.	250±
(d) Argillaceous knotty limestone with many fossils, brachiopods and trilobites particularly numerous. Ampyx and Agnostus characteristic fossils.	40
(a) Crystalline and subcrystalline limestone full of bryozoa, sponges, etc. Often absent from sections	10
1. Murat formation:	
Massive gray crystalline limestone weathering into a red, clayey soil comparatively free from chert.	100

II. Stones River limestone.

(b) Massive, somewhat cherty mottled blue limestone, seldom shown and of slight thickness. Fossils numerous. ---

(a) Massive, dove limestone. Seldom present in the section and thickness slight when present ---

I. Natural Bridge limestone.

Gray and light blue magnesian limestone weathering into chert. Conspicuous beds of chert near the top. ---

The section shows that two well marked members are present in the Stones River formation. Both of these divisions are better shown in the eastern portion of the Great Valley in southwestern Virginia. The upper bed resembles the Chazy of New York in fossil content and lithologic character. Bassler remarked that in Tennessee the dove-colored limestone beneath the argillaceous rather thin bedded, mottled blue limestone holding Chazy fossils was not included in the name Lenoir used by Safford and Killebrew (1876) to define this formation beneath the Athens shale in Tennessee. Only part of the Stones River in southwestern Virginia is equivalent to the Chazy in New York according to Bassler.[98] Bassler recognized that the Murat had Chazy fossils and was equivalent to Upper Stones River age. The Murat was considered a marble like lens of limestone restricted to central western Virginia. The Liberty Hall shale corresponded in a general way to the Chambersburg formation in northwestern Virginia. The Liberty Hall shale had fossils of Chazy age and this fauna was similar enough to the fossils at the base of the Athens shale in Tennessee for Bassler to correlate these formations. Lithologically the Athens shale and the Liberty Hall shale were hard to distinguish. Bassler also notes that west of the Great Valley the outcrops of Ordovician limestones seemed to be of Lowville and Trenton age and replace the shaly Liberty Hall limestone with

dove and black limestones. The Martinsburg shale is recognized by Bassler in central Virginia to be equivalent to the Sevier shale farther south.[99]

In southwestern Virginia the formation names used by Bassler were the same as those defined in the geologic folios on southwestern Virginia and northeastern Tennessee.[100] Bassler recognized a thin siliceous blue limestone, equivalent to the Lenoir of Tennessee, and a thin dove limestone of Stones River age as occurring locally between the Knox and the Athens formations in southwestern Virginia.[101] The Lenoir limestone was the name given by Safford and Killebrew to the Maclurea beds in east Tennessee in 1876.[102] The Holston limestone as used by Keith in 1901 was the coarsely crystalline limestone at the base of the Chickamauga limestone.[103] In southwestern Virginia the name Holston was used by Bassler for coarsely crystalline limestones which lay below the Moccasin formation and above the Knox dolomite.[104] Bassler noted three divisions of the Knox dolomite the middle and upper of which were considered of Ordovician age and the upper portion was believed to be equivalent to the Beekmantown (Calciferous) limestone of New York.[105] Reefs were recognized to occur in the upper Knox dolomite appearing as a massive conglomeritic limestone.[106] The term Shenandoah limestone was not preferred by Bassler in southwestern Virginia since it was divisible into smaller mappable units.[107]

The Chickamauga limestone, which succeeds the Knox dolomite, was originally used by C. W. Hayes (1891) to cover a thick series of limestone.[108] Bassler recognized that this series was subdivisable in various places. Thus the Moccasin formation was the thick series of red impure limestones succeeding the purer blue limestones of Virginia and Tennessee. The Holston was the lower part of the Chickamauga limestone which was considered as embracing rocks of Stones River, Black River, and Trenton in age in various places.[109] In the Walker Mountain area Bassler recognized the Holston as occurring above the Athens

shale and he called the pure limestones above the Knox dolomite the Stones River formation. This included the Maclurea beds of the Lenoir limestone of Tennessee. The Stones River was again correlated with the Chazy of New York. Bassler's Walker Mountain section is as follows:[110]

Walker Mountain section, north of Marion, Virginia

Clinch sandstone:

Massive white quartzite and sandstone forming crest and southern slope of mountain.	100±
Bays sandstone: Red to brown sandstone, sandy shale and conglomerate.	300
Sevier shale: Brown to olive and gray shales, calcareous in basal part argillaceous above and arenaceous in upper third.	1,500
Moccasin limestone: Impure and argillaceous limestone.	300
Holston marble and associated strata:	
(e) Unfossiliferous drab shales.	40
(d) Nodular limestone and yellowish to gray shales holding many bryozoa.	30
(c) Massive gray and pink marble with numerous bryozoa.	30
(b) Clayey nodular limestone and shale. Some of the layers crowded with Receptaculites.	50
(a) Massive crystalline limestone.	40
Athens shale: Dark to black shale with black slaty limestone at the base.	500±
Stones River formation:	
(c) Coarsely crystalline gray to blue limestone weathering into layers one to four inches in thickness. Upper beds pinkish and of a marblelike structure.	100
(b) Mottled gray massive magnesian limestone	40
(a) Massive dove limestone speckled with calcite spots. Gastropods, especially a large Maclurea, the most abundant fossil	30
Knox dolomite:	
Massive grayish dolomite with little chert	---

Addendum

The term Holston was extended by Bassler in 1907 to include beds which he called the Pearisburg limestone but since the United States Geologic Survey objected to his usage he used the term "Holston marble and associated strata" in southwestern Virginia.[112] In the Clinch Mountain area near Speery Ferry, Virginia, the Holston was noted as occurring immediately over the Knox dolomite without the Athens and Stones River formations intervening.[113] In southwestern Virginia the Sevier shale was used to the same type of beds of the same age that the Martinsburg formation covered in northwestern Virginia.[114] In a geologic section at Pearisburg, Virginia, the Chickamauga was evidently used to cover the Holston and Stones River beds in Virginia with the Athens shale being absent.[115] At Wytheville, Virginia, the Athens was described as following the Knox dolomite without any intervening Stones River formation.[116] Above the Sevier shale is the Bays sandstone in Tennessee and Virginia which Bassler believed was of Lorraine age.[117]

Cambrian and Ordovician formations of southwest Virginia.

General Time scale	Bristol area	Walker Mt. area	Clinch Mt. area	Copper Creek area	Powell Mt. area
Upper Ordovician		Clinch Bays Sevier	Clinch Bays Sevier	Clinch Bays Sevier	Clinch Bays (Lorraine) Sevier (Eden)
Middle Ordovician	Tellico Athens Stones River (often absent)	Moccasin Holston Athens Stones River	Moccasin Holston and Associated strata	Moccasin Chicamauga	Chicamauga (Trenton) (Tyrone) (Stones River)
Lower Ordovician	Knox	Knox	Knox	Knox	Knox
Sarotogan (Upper Cambrian					

TABLE 14 [11]

In 1902 E. O. Ulrich and Charles Schuchert published a short paper in which they advanced the thesis that the Appalachian geosyncline in which the Ordovician sediments were deposited was divided into various troughs at various times which may or may not have been connected to one another. They felt that this helped to account for the varying thicknesses and lithologic variations between sediments which lay close to each other and were contemporaneous. In this paper Ulrich and Schuchert defined two major channels in the Appalachian geosyncline which they believed had been formed by a barrier rising between the channels during the early Cambrian period and which continued to exist thru the Ordovician to the end of Paleozoic time. The barrier was called the Appalachian Valley

Fold and the eastern channel was again divided into three smaller basins. In the south there was the Lenoir basin which covered southern Virginia and northeastern Tennessee. In the western channel the middle basin was called the Cumberland basin. The Lenoir basin was divided into an eastern Athens Trough and a western Knoxville Trough.[118]

In 1911 Ulrich published his monumental Revision of Paleozoic Systems which held the attention of Appalachian geologists for a generation. Ulrich had done much work in Tennessee, Virginia, and Pennsylvania. He used these areas for examples to make his points and to justify his concepts. Ulrich continued to use the barrier concept that he and Schuchert had proposed in 1902. Ulrich mentions but rarely defines with sections or other adequate material a number of formations in this paper many of which persisted in the literature for some time and others which are now rarely mentioned or which never were mentioned again after Ulrich used them. Ulrich agreed with the American stratigraphic nomenclature that Chamberlain and Salisbury used but he made certain modifications which will be discussed below.[119]

In the early Ordovician in the Lenoir Basin the Beekmantown (Knox) dolomite was being deposited. At the end of this time says Ulrich the Appalachian Valley Barrier again emerged. In the central basin of the eastern channel formed by the Appalachian Valley Barrier, the Beekmantown was deposited in northern Virginia and Pennsylvania after which an erosion interval cut out the succeeding Stones River and Chazy beds which were deposited in other basins. Rocks of Lowville, Black River, Trenton, Utica and Frankfort ages were then deposited in the central basin before the trough was uplifted to cut out the Lorraine shales which were deposited in other basins during this erosion interval.[120]

In the Athens (southern) trough the Athens shale was deposited in Ordovician time and it graded west into the Chickamauga limestone which was composed

the Lenoir limestone at its base and contained lenses of coarsely crystalline Holston limestone above this. The Tellico sandstone above the Athens in the east was recognized as interfingering with the Moccasin formation in the Knoxville Trough to the west and the Sevier shale was said to overlie these formations in both troughs. Elevation and tilting of the troughs was said to have taken place at the end of the deposition of the Sevier shale and the Bays and Clinch sandstones were deposited when the troughs again subsided.[121]

For the Pearisburg Basin in northeast Tennessee and southwestern Virginia Ulrich used the terms Pearisburg limestone and Heiskell shale for apparently equivalent formations below the Lowville and above the Shenandoah limestone (top of Knox Group) and below the Chickamauga limestone although no boundary was indicated between the Chickamauga and Pearisburg limestones by Bassler who first defined the term Pearisburg limestone.[124]

Ulrich's work was intended to help unravel stratigraphic puzzles by the use of detailed paleontologic work and the recognition of troughs, barriers, and emergent and submergent areas which occurred throughout Paleozoic time. His methods proved useful in many areas. Ulrich believed that north-south oscillations in the sea occurred many times during the Ordovician in the Appalachian geosyncline and elsewhere. As a result of his studies on submergence and emergence of the various North American troughs and the correlation of their sediments Ulrich decided that two new periods could be introduced into the geologic time scale to help clear up former difficulties in stratigraphy. He recognized that thousands of feet of sediments might be deposited while erosion was continuing elsewhere. Ulrich separated the Beekmantown limestone (Calciferous) of New York from the overlying Chazy unit and used the term Canadian to represent the period of time which these sediments covered. These sediments were very thin in New York, but they were thick elsewhere as in the southern Appalachians.[122]

The thickness of Canadian limestones in Pennsylvania Ulrich divided into four parts. All were included within the Beekmantown formation as the term was used by Stose in 1908. Stose had recognized a bottom limestone member of the Beekmantown in Pennsylvania which he called the Stonehenge limestone. Ulrich kept this term but he divided the remaining series of as much as 3500 feet of dolomites and limestones into three parts. The dolomite above the Stonehenge was called the Nittany dolomite. Above this was a thin limestone formation called the Axeman limestone by Ulrich and which is absent in Virginia. Above the Axeman limestone came the Bellefonte dolomite and above this the Stones River Group occurred disconformably.[123]

Ulrich further justified his Canadian System on the basis of its overlapping the Ordovician and Cambrian periods as they were generally thought of. This overlapping said Ulrich was the result of shifting seas. Ulrich's Canadian system included all rocks whose age fell within the Beekmantown and Tribes Hill formations of New York. The Knox dolomite of Tennessee was considered Ozarkian by him. The Ozarkian was an Upper Cambrian series of rocks below the Canadian System which Ulrich also elevated to the rank of a system. The Beekmantown of Pennsylvania was considered to be a complete series of Canadian rocks by Ulrich. Ulrich had thus restricted the Ordovician to those beds lying above the Canadian System and below the Medina sandstone or its equivalent of the Silurian.

In Canadian and Ordovician times Ulrich recognized eight invasions of the Appalachian trough by waters from the Atlantic region. One Pacific invasion occurred during the Canadian period. Three Gulf invasions and an Arctic invasion occurred also during Ordovician time in the Appalachian region of Virginia. These invasions were determined on the basis of fauna.[125] Schuchert's paleographic maps are essentially the same as Ulrich's conclusions and they represent a

Ulrich, E. O. Plate 27, Vol. 22, Bulletin of the Geological Society of America

				Central Pa.	Md. Basin	Cent. Va.	Athens Trough		Knoxville
Silurian		first formation		Tuscarora	Tuscarora	Clinch/Clinton			Clinch
Ordovician	Mohawkian		Juniata	Juniata ss.	Massanutten				
		Mays-	McMillan (O)	Oswego					(West East
		ville	Fairview (O)	(Bald Eagle)	Red ss. ss.	Red ss.	?		"Bays"
		Eden	Frankfort (N.Y.)		(Eden ss.	Frankfort	?		"Sevier"
			Utica (N.Y.)	Shale	member)				
			Catheys (T)		Martinsburg	Trenton ls.			North of
			Perryville (Ky)	Trenton	shale				Clinch
			Flanagan (Ky)	ls.			Bays ss.		Mt. Mocca-
		Trenton	Bigby (T)				(Bays ss.		sin
			Wilmore (Ky)	Lower			typical		
			Hermitage (T)	Trenton					
			Prosser (Min)	ls.					
			Kimmswick (Mo)		Up. Chambersburg	Liberty Hall			
		Black	Decorah (Ia)	Amsterdam					
		River	Watertown (N.Y.)						
			Lowville (N.Y.)	Lowville	Lowville	Lowville			Lowville
	Chazyan		Ottosee (T)				Ottosee		Ottosee sh
			Tellico (T)				Tellico		Tellico
		Blount	Athens (T)			Athens	Athens		
			Holston (T)		Lower Chambersburg	Murat			Holston
			Carters (T)	Pamelia					
			Lebanon (T)		Stones River Group				
		Stones	Ridley (T)				Lenoir		Lenoir
		River	Pierce (T)						
			Murfreesboro (T)						
			Mosheim (T)				Mosheim		Mosheim
	Unnamed Epoch		Joachim (Mo)						
			St. Peter (Min)						
			Everton (Ark)						
Canadian	Bellefonte (Pa)			Bellefonte	Beekmantown	Natural			
	Axeman (Pa)			Axeman	with	Bridge ls.			
	Nittany (Pa)			Nittany	Stonehenge	in part.	Jonesboro		
	Stonehenge (Pa)			Stonehenge	at base		ls.		

Sevier shale

Chickamauga Limestone.

TABLE 15

graphic picture of how Ulrich envisioned the Appalachian Ordovician in terms of land and water at various times during the period.[126]

The Stones River Group was believed to be deposited in about equal volumes at equal times from Alabama to central Virginia although in the very eastern-most part of the Lenoir Basin minor troughs caused local variations or absence of the Stones River Group.[127] This group immediately succeeded the Canadian System of Ulrich. Ulrich without carefully defining by means of type sections used the term Blount Group for between 1500 and 3500 feet of sediments in Blount County, Tennessee[128] which included the Holston limestone, Athens shale, Tellico sandstone, and Sevier shale formations.[129] Ulrich also referred to the top of the Blount Group as the Ottosee limestone which was from 150 to 1200 feet in thickness and included in one place a bed of massive pink marble 80 feet thick.[130] Again no type section or rigorous description was given for the Ottosee formation. The Ottosee replaced the basal calcareous member of the Sevier shale and so by definition excluded all the overlying Sevier shales from the Blount Group which was pre-Black River age.[131] The Sevier shale was of Black River and later age.

Ulrich's prime example of deposition of different facies in adjoining troughs which contained the same faunal layers was worked out with the Chambersburg limestone in Pennsylvania. The Chambersburg limestone in southern Pennsylvania and northern Virginia is used as an example of oscillation of the seas and separation by barriers of formational units. There were two troughs in this area and the thickness of the same formations vary greatly from trough to trough. In one basin four separate fossil zones were defined. The lower zone contained the coral Tetradium cellulosum and varied in thickness in the west trough from nothing to 800 feet. It was apparently absent in much of northern Virginia but was present in its upper 100 feet or more at Middletown

Appalachian Province			
Middle Third	Lenoir Basin		Generalized Time Scale for Eastern North America
	Knoxville trough	Athens trough	
Land			Lorraine
Frankfort	Land	Land	Frankfort
Utica			Utica
	Sevier	Sevier	Upper Trenton
Trenton			Normanskill
	Moccasin	Tellico	Lower Trenton
Black River			Black River
Lowville			Lowville
Land	Lenoir	Athens	Stones River
Beekmantown	Beekmantown	Beekmantown	Beekmantown

TABLE 16 [132]

and Strasburg, Virginia. The second zone was called the lower Echinosphaerites bed, 40 to 50 feet thick, which was also present at Strasburg, Virginia, and at Martinsburg, West Virginia. The third zone was called the Nidulites bed which also showed great local variations. The Christiania bed overlay the Nidulites bed and is found in Virginia. The west trough had all but the last faunal zone but these zones occupied very thin layers which took a good deal of work to distinguish. The Martinsburg shale covered both troughs equally. The east trough in addition to the above four beds contained a fifth bed of granular limestone containing later fossils than are found in earlier beds but younger ones than are found in the overlying Martinsburg shale. The east trough seems to have been more stable and received fewer sediments than the oscillating seas deposited in the west trough. The lower Martinsburg faunal zone (Corynoides bed) of argillaceous limestone and calcareous shale increased in thickness from Pennsylvania to Virginia and west to east from Martinsburg to Strasburg, Virginia.[133]

In order to account for faunal and lithologic differences from north to

south in the Appalachian Ordovician rocks Ulrich proposed two minor barriers in Virginia. One lay in the area of Staunton, Virginia and the other was in the Wytheville, Virginia area. The Staunton barrier prevented, according to the Ulrich, The southward extension of the Chambersburg and Stones River formations of Pennsylvania and northern Virginia and the northward extension of the Murat, Athens shale, and Liberty Hall formations of central Virginia. The Wytheville barrier prevented the Liberty Hall limestone and Stones River formations of central Virginia from overlapping southward and the Knox, Holston, Tellico formations from overlapping northward. In the western part of the trough in central Virginia the Murat limestone which Ulrich recognized to be at least partially equivalent to the Holston was thought to have overlapped northwards from the Knoxville Basin into the central Virginia area but was stopped at the Staunton Barrier.[134]

According to Ulrich the Martinsburg and Beekmantown formations were tracable to New York from Pennsylvania and Virginia.[135] In the Athens trough south of Lexington, Virginia, the sparingly cherty Knox dolomite immediately below the Mosheim limestone was considered to represent the Beekmantown of New York. Ulrich divided the Chazy of New York into two groups, the Blount and the Stones River. Only the Valcour limestone in New York corresponded to any part of the Blount Group which was deposited in its type locality in Tennessee. The Black River and Trenton beds of New York were put under the term Mohawkian and were represented by the Sevier and Martinsburg shales in Virginia and Tennessee. Ulrich recognized a mixup of terms in Tennessee. The terms "Bays" and "Sevier" were used for different age formations in two different places. The Sevier shale of the Knoxville and Athens Troughs was of Black River and Trenton age. Ulrich also noted that the Moccasin formation is used loosely for beds of both Black River and Trenton ages.

The Lowville which followed the Blount group extended over a wide area and is very uniform.[136] The Black River deposits which succeeded the Lowville were very irregular at their base evidently due to warping of the basins in the geosyncline. Such warping of the basins in the geosyncline strictly limited the faunas as barriers would do and helped in dating the relative ages of formations.[137] The Lowville overlays disconformably the Stones River Group in many places and Ulrich showed that in this interval the Blount Group was deposited elsewhere. This is contrary to the previously held belief that the Lowville in Virginia and Tennessee was of upper Stones River age. This relationship is made by Ulrich not on the basis of fossils faunas alone but by the fact that a tongue of coarse limestone presumably Holston lay between Stones River and Lowville rocks near Sneedville, Tennessee. The Holston evidently overlapped from the eastern basin. Ulrich on the basis of fossils identified the lower part of the Chambersburg formation in Pennsylvania as equivalent to the Holston of Tennessee. The fossil fauna of the Murat was considered the same as the Holston and since the Ottosee which was the top of the Blount lay in one area between the Holston and the Lowville Ulrich felt sure of placing the Blount Group between the Stones River and Black River Groups.[138]

Although work continued on the Ordovician stratigraphy in Virginia very little was published from the time of Ulrich's work in 1911 until about 1930. In 1914 S. L. Powell wrote a very short article comparing the Ordovician section near Salem, Virginia, with that of the type sections of New York. Powell stated that the New York divisions of the Beekmantown, Chazy, and Black River were recognizable in Virginia and these agreed in many cases in both lithology and fossil content with the New York divisions. The Athens corresponded to the Middle Trenton of New York and the Hudson River beds were said to be virtually the same as in the north. The major difference in the sections

according to Powell was that the Bays sandstones beneath the Medina in Virginia was very fossiliferous in contrast to the New York and Pennsylvania areas of the Juniata formation corresponding to the Bays sandstone of Virginia. In 1915 Powell wrote a short paper on the discovery of the Normanskill graptolite fauna in the Athens shale in southwestern Virginia. At that time this fauna was recognized as of Black River age by Ruedamann and upper Chazy in the Athens of Tennessee by Ulrich.[140]

In 1923 Stose in Wise County used the following nomenclature in Virginia:[141]

Sequatchie formation	200+	Red calcareous sandstone; of Richmond age.
Reedsville shale	460+	Soft shale and nodular impure limestone; of Maysville and Eden age.
Catheys limestone	225+	Highly fossiliferous gray crystalline limestone of upper Trenton age.
Cannon limestone	375+	Chiefly impure limestone with occasional beds of fossiliferous purer limestone; of middle Trenton age.
Lowville limestone with Moccasin limestone member at the top	540+	Reddish argillaceous limestone (Moccasin member). Fine grained drab limestone

The Lowville was the youngest formation found in Wise County and was regarded as equivalent to the Lowville of New York. The upper part, which was a reddish limestone, was called the Moccasin member but was markedly different from the type Moccasin in Tennessee said Stose.[142] The Cannon limestone was first used by Ulrich in 1911 and included formations from the Bigby thru the Catheys in the Nashville dome area (see Table 15).[143] In 1922 Bassler and Ulrich emended the term to include limestones between the Catheys and Bigby on the east flank of the Nashville dome.[144] Stose used the term

Cannon and the overlying Catheys evidently on the paleontologic evidence which Ulrich gave. Both formations are considered of Trenton age by Ulrich. The Reedsville shale is of Maysville, Eden and Trenton ages and was considered the southwestern Virginia equivalent of the Martinsburg shale.[145] However, the Reedsville was defined by Ulrich originally in central Pennsylvania.[146] The Sequatchie formation is the Bays sandstone of the Estillville Folio but as used in this folio was not equivalent to the type Bays in Tennseess, but Ulrich had correlated it with the Sequatchie sandstone in east Tennessee, hence the use of the name by Stose. It was also equivalent to the Juniata formation of Pennsylvania which was considered to be Richmondian in age and belonged to the base of the Silurian according to Ulrich. However, Stose includes it in the top of the Ordovician in Wise County.[147]

In 1926 Ulrich summed up previously world-wide work on the Ordovician-Silurian boundary. On the basis of diastrophic and faunal evidence Ulrich was convinced that the Ordovician-Silurian boundary was between the Cincinnatian and Richmondian, i.e. between the Juniata and Oswego (as used by Butts, 1933) formations in Virginia.[148]

In 1927 A. M. Giles used the following section to describe the Ordovician stratigraphy of the Rose Hill Oil Field in Lee County, Virginia, which is structurally a fenster.

Ordovician	feet
Sequatchie formation (Upper Cincinnatian) Red sandstone, sandy shale, red and buff limestone	200+
Reedsville shale (Lower Cincinnatian) Shale and limestone	600+
Chickamauga limestone Includes Catheys and Cannon limestone (Trenton, Lowville and Upper Black River limestone, and Stones River limestone (Chazy)	1,750

Ordovician and Cambrian

Knox dolomite (Beekmantown and Upper Cambrian)	2,800±
Thick beds of dolomite with blue magnesium limestone and chert layers[149]	

Giles used the Chickamauga limestone to include all the Lower Ordovician limestones and did not distinguish the upper Knox dolomite (Beekmantown) from lower dolomite beds which were all grouped as Cambrian and Ordovician.

In 1927 Butts writing on the same type of structure which also occurs to the southwest of the Rose Hill fenester used the following stratigraphic sequence and nomenclature.

Ordovician	feet
Sequatchie formation; Shale and limestone, in part red.	400
Reedsville shale, or Lorraine (Maysville and (Eden) age; Shale, calcareous sandstone, and limestone in thin layers.	350
Trenton limestone, approximately equivalent to Hermitage and Cannon limestones; Limestone, generally thin bedded coarsely crystalline.	250
Lowville limestone, of Black River age; Medium, thick-bedded limestone, largely of compact texture; includes at top 100 feet or so of shaly beds, probably of post-Lowville Black River age.	1,000
Stones River limestone; Thick-bedded, compact and coarse-grained crinoidal limestone	
Beekmantown dolomite; Dolomite, thick-bedded, gray, generally coarsely crystalline, some compact.[150]	1,200

The Beekmantown is the Canadian System of Ulrich. Butts stratigraphic column is more detailed than Giles.

In 1927 Giles also described the geology of Little North Mountain in West Virginia and Virginia. In this paper he included the Beekmantown and the Juniata formations in the Ordovician. Giles recognized five zones within the

Beekmantown. The bottom was the Stonehenge limestone member, a massive blue to dove limestone which is granular in texture. The upper division of the Stonehenge consisted of sandy laminated strata and an edgewise conglomerate. A Cryptozoon stelli zone succeeded the Stonehenge upward. Above this occurred a Ceratopea zone whose weathered surfaces frequently projected this fossil. A Turritoma zone was above this and the rocks consisted of a pure dove gray magnesian limestone. The upper zone of the Beekmantown was a fine-grained gray finely laminated limestone bed alternating with gray magnesian layers. These zones ranged from 200 to 600 feet thick.[151]

The Stones River beds succeeded the Beekmantown and were divided by Giles into three zones. The lower one was an alternation of massive magnesian and pure limestone beds. This corresponded to the Murfreesboro limestone of southwestern Virginia. The middle zone consisted of an alternation of dark subangular limestone with fine-grained, dove colored purer limestone. Chert occurred in bands in the purer limestone. The upper division was a very pure limestone and was very fossiliferous.[152]

The Chambersburg is the same here as described in Pennsylvania by Stose and Ulrich. Giles notes that Bassler had said that the Tetradium cellulosum zone (Lowville) of the Chambersburg in Pennsylvania is not present from Martinsburg to the Maryland-Pennsylvania lime but occurs farther north and to the south of Martinsburg, West Virginia. The Chambersburg is equivalent to the Black River and Lowville formations of New York.[153] The Martinsburg formations overlying the Chambersburg consisted of the same features described in Pennsylvania and included four faunal zones. The base was Trenton beds, the next were Eden beds, then upper and lower Maysville beds occurred. No characteristic fossils are listed by Giles.[154] Giles notes that the Junista affords few exposed sections in the Little North Mountain area and it is only about 100

feet thick where it is exposed.[155]

In 1928 Butts published a paper which summed up previous work on the Appalachian stratigraphy and which added his own comments on present work and conclusions which he felt could be drawn. Butts recognized Ulrich's concepts of narrow troughs and shifting continental seas the result of tilting of basins. He noted that a lack of adequate fossil interpretation had prevented the fullest accuracy in the correlation of formations in the U.S.G.S. folios of the eighteen nineties. Butts using these concepts of Ulrich made the following conclusions. The Nittany dolomite extended throughout the Appalachian Valley and could be recognized by the fossil fauna characterized by the genus Lecanospira (Ulrich). Above the Nittany was a bed of dolomite which contained the characteristic fossil gastropod genus Cerotopea. Both of these beds were equivalent to Ulrich's Beekmantown Group of his Canadian System. The Lenoir and Holston followed the dolomite beds. The Murat limestone was the Holston equivalent in Rockbridge County in central Virginia. Above the Holston limestone came the Athens shale which carried the Normanskill graptolite fauna. In Tennessee the Tellico sandstone succeeds the Athens in places and the Holston limestone elsewhere. The Tellico is overlain by the Sevier shale the lower part of which is the Ottosee limestone in northeastern Tennessee and southwestern Virginia. The early geologic folios on southwestern Virginia erroneously called the Sevier shale equivalent to the Martinsburg shale of northwest Virginia while the typical Sevier shale and its basal limestone the Ottosee was mapped as part of the Chickamauga formation. However, in southwestern Virginia according to Butts the Ottosee is succeeded by the Moccasin limestone which is equivalent in northern Virginia to the Martinsburg shale. The Martinsburg shale included the Trenton limestone of Pennsylvania and New York in its basal part. In Pennsylvania the two Martinsburg parts are called the Reedsville shale and

the Trenton limestone, the limestone being the older of the two formations. The Juniata formation of Pennsylvania or its fossiliferous equivalent the Sequatchie of southwestern Virginia and northeastern Tennessee overlays the Reedsville or the Martinsburg formation.[156]

Butts recognized as Ulrich pointed out that between central Virginia and Alabama a great series of sediments were deposited between the Stones River (Chazy) ahd Lowville (Black River) time. Ulrich had called this the Blount Group and Butts discusses it in some detail. The beds above and below this group were clearly recognizable from fossil fauna. The Lowville bed above contained Crytophragmus and Tetradium cellulosum while the Lenoir beds below contained Maclurea magna as the index fossil. To account for the intercalation of the Blount Group a basin was recognized as occurring from Staunton, Virginia, almost to Alabama while the deposition was taking place. The Holston limestone went as far north as Staunton. The Tellico sandstone was restricted to Tennessee but the Ottosee limestone extended north as far as Tazewell and Wytheville, Virginia. The sequence shown in plate does not occur in any locality and is a time relationship based on fossil studies. Butts recognized a great hiatus between the Mosheim and Nittany in which 2000 feet of the Nittany were gone in Virginia and Tennessee.[157] To the northwest of Clinch Mountain the Mosheim and Lenoir were absent which was believed to have been caused by a barrier preventing deposition to the west. Farther south this barrier did not prevent, says Butts, contemporaneous deposition of part of the Mosheim and Lenoir but both contained quite different fossil faunas because of the barrier. In Tazewell County, Virginia, Butts noted that the Athens shale overlay the Holston and it in turn was overlain by the Ottosee and Moccasin formations.[158] The Athens shale was used by Butts as an example of facies variation. At Lexington, Virginia, it was almost wholly a dark black limestone and shale

called the Liberty Hall limestone. At Mation and Wytheville, Virginia, it is an alternating succession of shale and limestone beds. In the Wytheville-Bristol area in Virginia a sandstone facies occurs at the top of the Athens. Butts notes that this bed had previously been mapped as the Tellico sandstone but its Athens age is proven by Normanskill fossils found in shale partings high up in the sandstone.[159]

The Lowville limestone which is typically a blue or dove limestone occurs in southwestern Virginia with layers of greenish argillaceous crumbling limestone or calcareous mudrock. The mudrock resembles the overlying Moccasin formation but is not red. The Trenton limestone which is easily detected elsewhere is represented by fossils in the base of the Martinsburg in Virginia.[160] The Blount Group was considered upper Chazy by both Butts and Ulrich.

In 1929 Ulrich in an extremely readable technical paper on a genus of trilobites defined the Whitesburg formation of Tennessee and Virginia. He notes that the trilobite genus Telephus first occurs in the Whitesburg limestone and that succeeding species occur only in the Blount Group of the Upper Chazy. A few species of Telephus are found only below the Normanskill graptolite fauna of the succeeding Athens shale and Ulrich regarded these as adequate indicators that a formation is Whitesburg in age.[161] The term Whitesburg Ulrich propo-ed for a dark crystalline limestone that in many places south of Stuanton, Virginia, underlies the dark calcareous Athens shale. The Holston limestone underlies the Whitesburg where present and the Whitesburg lies on the Lenoir at some places in southwestern Virginia.[162] Ulrich notes that the Blount Group pinches out to the west in Virginia and Tennessee not far from its thickest deposits. The Stones River and Lowville contact represents the absence of the Blount Group.[163]

In northern Virginia Ulrich recognizes the Chambersburg formation as over-

lying the Lowville.[164] Ulrich had previously believed that the Murfreesboro limestone had overlain the Mosheim limestone (see Table 15). In 1928 Butts and Ulrich found a section in Lee County, Virginia, showing the Mosheim to overlie the Murfreesboro. To the southeast of this point the Murfreesboro was absent and the Mosheim directly overlay the Canadian System (Beekmantown) of Ulrich. In most of Virginia except Lee County the Murfreesboro seemed to be absent and the Mosheim lay directly over the Beekmantown.[165] The Mosheim was said to pinch out to the west just the opposite of the Murfreesboro. The Lenoir succeeding the Mosheim spread all over southwestern Virginia and did not pinch out until it reached central Kentucky. The Chambersburg which succeeded the Lowville was not recognized south of Staunton, Virginia.[166]

In 1932 the Virginia Geological Survey published a bulletin on the geology of the Roanoke, Virginia, area by H. P. Woodward. Woodward used the term Canadian System as defined by Ulrich and the term Nittany dolomite for the cherty dolomites of this formation. The Nittany was a light gray to blue dolomite whose texture varied from finely crystalline to compact. It was Beekmantown in age. The most abundant and diagnostic fossil was Lecanospira. The Nittany was equivalent to the upper part of the Natural Bridge limestone of H. D. Campbell. The Ordovician rocks above the Nittany were listed as follows by Woodward:

	feet
Upper Ordovician	
Martinsburg shale	50-125?
Mayville division	150-125
Eden division	100-200
Middle Ordovician	
Martinsburg shale	
Trenton division	750±
Moccasin formation	150-300

Lower Ordovician (restricted)

Chazyan series	
Blount Group	
Athens shale	970±
Whitesburg limestone	0- 15
Holston limestone	0- 50
Stones River Group	
Lenoir limestone	50±
Mosheim limestone[167]	0- 30

In the Roanoke area the Mosheim, Lenoir, and Holston limestone crop out in an area seldom more than 200 yards wide below the Athens shale. The Mosheim was a pure, fine grained limestone of uniform blue or dove color. The lower seven feet was conglomeritic and contained blocks of Nittany dolomite some of which contained fossils. The Lenoir conformably overlay the Mosheim in the Roanoke area the contact being very sharp, but Woodward states in another passage that the Lenoir was deposited upon the apparently unevenly eroded surface of the Mosheim. The Lenoir was very fossiliferous and the fossils of both it and the Mosheim were of Chazy age. The Mosheim was, however, basal Chazy and the Lenoir middle or upper Chazy. The Holston was a gray, massive, coarsely crystalline limestone that resembled marble. The lower part contained chert nodules. In the Roanoke area the Holston appeared to be conformable with the Athens shale.[168] The Whitesburg formation was only formally defined by Ulrich in 1929[169] although he and Butts had used the term in previous reports since 1924. Both Ulrich and Billings published and described fossils from the Whitesburg.[170]

The Athens shale which was first named by Hayes in 1894[171] was called in central Virginia the Lexington limestone by J. L. Campbell in 1879[172] and the Liberty Hall limestone by H. D. Campbell in 1905.[173] The Athens is a thick mass of black shale and thinly bedded blue-black limestone in the Roanoke area. The formation weathered to a grayish-yellow. The Athens appears to thin to the

northeast and southwest in the Roanoke area. The fossils of the Athens are middle Chazyan in age containing the Normanskill graptolite fauna of New York.[174] The Moccasin formation follows the Athens and is a bluish gray and red-brown calcareous sandstone in layers four to eight inches thick interbedded with thin layers of sandy and red shale and was considered of Black River age.[175]

The Martinsburg shale overlay the Moccasin formation and Woodward calls attention to the fact that it is no longer considered equivalent to the typical Sevier shale of Tennessee which is now known to be older than the Martinsburg. On the geologic map of the Roanoke area Woodward shows the Martinsburg immediately overlying the Stones River Group on the northwest side of Sinking Creek Mountain west of Roanoke. In other areas the Moccasin and Athens formations intervene between the Martinsburg and the Stones River Group. On the basis of fossils three divisions of the Martinsburg were recognized which were the Trenton, Eden, and Maysville divisions. The Trenton was the thickest division in the Roanoke area. The Maysville was distinguished by an abundance of Orthorhynchula.[176]

In the Ordovician and Canadian column which Woodward described he recognized two unconformities occurring between the beginning and the end of these periods. One was at the top of the Canadian System or the Nittany dolomite and the other was between the Mosheim-Lenoir and Athens or Holston contact depending on which formation was present in the area of the contact. The break at the end of the Nittany was one of the reasons for Ulrich believing that the rocks below it should constitute a separate system.

In 1933 Butts wrote a short description of formations to accompany his geologic map of the Appalachian Valley in Virginia. Butts used the nomenclature of formations and division into systems as proposed by Ulrich in 1911 and after. The Canadian System of Ulrich was included by the United States Geologic Survey

in the Ordovician, but Butts and Ulrich among others considered it a separate period of time. The Canadian in Virginia consisted of the Stonehenge limestone at the bottom followed by the Nittany and Bellefonte dolomites both of which were very thick in Virginia and were very hard to distinguish so that Butts mapped both of them together as the Beekmantown dolomite. In Pennsylvania these formations were distinguishable by a limestone bed which intervened between them called the Axemann limestone. The Stonehenge was correlated with the Tribes Hill limestone of New York which is part of the Beekmantown Group there. The Nittany was cherty in southern Virginia and much less so in the northern parts of the state. It was distinguished by the gastropod genera Lecanospira and Roubidouxia. The Bellefonte was characterized by the fossil Ceratopea and it became a very calcareous formation in northern Virginia.[177]

The Ordovician system as used by Butts began with the Stones River Group and included the Murfreesboro, Mosheim, and Lenoir limestones. The Murfreesboro occurred only in the southwestern portion of the state generally on the western side of the valley. Elsewhere only the Lenoir and the Mosheim were found. The Lenoir had the characteristic fossil Maclurea magna.[178] The Mosheim was a pure, compact, or glassy textured limestone (a typical vaughanite). Above the Lenoir occurred the Holston limestone which was a thick-bedded coarsely crystalline limestone. This represented the bottom formation of the Blount Group. The Whitesburg limestone was a coarse grained bluish, rusty weathering, fossiliferous limestone and was persistent in belts southeast of Clinch Mountain in southwestern Virginia. It was five to twenty feet thick generally but could be as thick as 75 feet.[179] The Athens shale overlay the Whitesburg.

The Athens was a variable formation of black graptolitic shales. In northern and central Virginia it was a black limestone. In southwestern Virginia

a sandstone occurred at the top of the Athens. The Nemagraptus graptolite fauna was represented in the Athens by Nemagraptus gracilis and corresponded to the fauna of the Normanskill shale of New York.[180] The top of the Blount Group was represented by the Ottosee limestone which represented part of the Sevier shale of Tennessee and was the same as the Chickamauga limestone as mapped on the Morristown, Tennessee folio.[181] The Blount Group may be compared to a great elliptical lens thinning out entirely in all directions from the Bristol, Virginia, and Knoxville, Tennessee, areas. It was not present in Pennsylvania where the Lowville limestone of Black River age overlay the top of the Stones River. The Lowville had been correlated with the New York formations by the characteristic fossils Tetradium cellulosum and Beatricea gracilis which were also present throughout the Lowville in Virginia.[182]

The Moccasin limestone which Butts mapped separately in places on his map of the Great Valley in Virginia was considered a facies of the Lowville limestone. It was a limestone, sandstone, and in places a fine conglomerate. The characteristic of the formation was its red color. The Lowville age was established by stratigraphic correlations and the occurrence of diagnostic Lowville fossils like Tetradium cellulosum. The Chambersburg formation which should follow the Lowville did not occur with it in Virginia and it was overlain by the Athens shale or Lenoir limestone in southwestern Virginia. The Chambersburg occurred only in northern Virginia and was a blue thin-bedded limestone which contained a few bentonite (volcanic ash) beds near Strasburg, Virginia.[183] The Chambersburg was characterized by the peculiar sponge Nidulites and the brachiopod Christiania in the uppermost beds of the formation which formed a characteristic faunal zone. The Trenton limestone occurred in southwestern Virginia where it overlaid the Lowville limestone. It was part of the Martinsburg shale farther north.[184] In southwestern Virginia the Trenton was succeeded by the Reedville shale which was erroneously called the Sevier

shale in the United States Geological Survey folios of Virginia and

shale in the United States Geological Survey folios of Virginia and Tennessee. It was composed of yellow weathering shale with thin layers of argillaceous limestone and fine-grained sandy rock. The Reedsville was Upper Ordovician and probably corresponded to the Eden Group and the lower half of the Maysville Group of the Cincinnati, Ohio, area. In northern and central Virginia the Reedsville shale and Trenton limestone were both included in the Martinsburg shale which included one or more beds of bentonite in its bottom part. In the Massanutten syncline this formation was at least 3000 feet thick.[185]

The Martinsburg contained three faunal zones. The Trenton or bottom zone was characterized by the trilobite Cryptolithus tessellatus, the bryozoan Praspora simulatrix, and the graptolite Diplograptus simplexicaulis. The Eden age of the overlying shales was shown by the trilobite Crytolithus bellulus and the brachiopod Dalmanella multisecta. The Maysville age was shown by the occurrence at the very top of the formation of the brachiopods Orthorhyncula linneyi and Byssonichia radiata. This top bed was present from Pennsylvania to Tennessee in the Great Valley.

The Oswego sandstone was considered the top of the Ordovician by Butts and was thought to be possibly correlated with the McMillan formation near Cincinnati which was at the top of the Maysville Group of Upper Ordovician time. The Juniata and Sequatchie formations underlying the Clinch sandstone were considered part of the Silurian system by Butts.[186] The Juniata and Sequatchie were equivalent formations. The Juniata was used in northern Virginia where it was a red shale, mudrock or sandstone and the term Sequatchie was used in the same relationship in southwestern Virginia where the formation was predominantly limestone with shale as a minor constituent. The Sequatchie was a thin bedded limestone partly argillaceous and partly stained red.[187] The shale was green or, where it formed shale partings in the limestone, red. Butts

Ordovician and Canadian groupings of formations is as follows:

Silurian System
Juniata formation(in north)and Sequatchie formation (in south)

Ordovician System
Oswego sandstone
Martinsburg shale
Reedsville shale
Trenton limestone
Black River Group
Chambersburg limestone
Moccasin limestone
Lowville limestone
Blount Group
Ottossee limestone
Athens shale and limestone
Whitesburg limestone
Holston limestone
Stones River Group
Lenoir limestone
Mosheim limestone
Murfreesboro limestone

Canadian System
Bellefonte dolomite
Nittany dolomite
Stonehenge limestone

In 1932 Butts, G. W. Stose, and Anna I. Jonas had written a description of the Appalachian Valley rocks which was essentially the same material as Butts gave in his text of the Great Valley map in Virginia.[188] The major distinction was not in the formation names or descriptions but in the overall grouping of the formations. The United States Geologic Survey nomenclature was used in which the Beekmantown Group of dolomites and limestones was placed in the Ordovician rather than in a separate system.[189] Also the Juniata-Sequatchie formation was considered a part of the Ordovician rather than the Lower Silurian. The Juniata was still regarded by Butts, Ulrich and Stose as Silurian and Butts and Ulrich considered the Beekmantown Group as a separate system, the Canadian.[190] In addition, the Chambersburg beds which had previously included the

Lowville limestone as defined by Stose and Ulrich (1909) was emended to exclude the Lowville and its Moccasin facies which was considered by Butts and Stose as distinct enough to mappable over a large area.[191]

In 1934 A. A. L. Mathews named the post-Lowville Black River beds of Giles County, Virginia, the Eggleston formation which was considered the Chambersburg equivalent in southwestern Virginia. The formation was of upper Black River age and was a thin to thick-bedded, fine grained, argillaceous, dark buff to light-brown limestone which fractured to form cuneifrom blocks with jointing perpendicular to the bedding.[192] Bentonite was present in some beds. Mathews also used the term Fairview limestone but he did not define it in Virginia.

In Ohio, Indiana, and Kentucky it overlies the Eden Group and was the lowest formation of the Maysville Group. Presumably this was how Mathews used it from its position in his stratigraphic table.[193] Mathews stratigraphic columns of Ordovician formations is below (see also Table 15).

Silurian
- Juniata formation

Ordovician System (restricted)
- Fairview limestone
- Eden (undivided)
- Trenton limestone (undivided)
- Eggleston limestone
- Moccasin limestone
  - Red Moccasin limestone member
  - Lower Moccasin marble member
- Lenoir limestone
- Mosheim limestone
- Murfreesboro limestone

Canadian System
- Bellefonte dolomite
- Nittany dolomite
- Stonehenge limestone[194]

It can be noted from the above that the Juniata was excluded from the Ordovician and the Bellefonte, Nittany, and Stonehenge formations of the Beekmantown Group were considered a separate system.

From 1922 to 1936 a number of papers were written on the Ordovician bentonite beds and their correlation. W. A. Nelson recognized the occurrence of bentonite beds in Tennessee, Kentucky, and Alabama and noted that they occurred during the deposition of the Lowville limestone in this area during Black River time. One large ash fall over a large area makes an excellent base for stratigraphic correlation.[196] In 1926 Nelson noted bentonite in the Ordovician in Rockbridge County, Virginia, and stated that this was the result of the same ash fall he had recorded in 1922. The deposit in Rockbridge County was reputed to be 10 feet thick. In 1927 A. W. Giles wrote a paper on the Rockbridge bentonite which Nelson had described. After a careful check of the literature on the composition of bentonite and after running chemical analyses had been made of the Rockbridge bentonite Giles concluded that it was not bentonite at all but a fine clay shale caused by dynamic metamorphism. He noted also that chemical data on bentonite had been analyzed and published in only two or so previous papers in spite of the occurrence of the name in the literature and that the material called bentonite in various reports was described in a half a dozen different ways. For this reason and for its evidently relatively wide stratigraphic range Giles looked askance on the term bentonite and on its use as a stratigraphic marker. He noted, however, that Esper Larsen, among the mineralogists who were consulted concerning the chemical analyses, considered the Rockbridge County material bentonite.[197]

In 1932 Woodward and Nelson found a bentonite bed on the north slope of Catawba Mountain and farther north apparently at the same horizon in the Roanoke, Virginia, area. The bed of bentonite was eighty feet above the top of the Athens shale and within the Moccasin formation. The bentonite was in thin beds the total thickness of which was about two feet.[198]

In 1933 L. R. Rosenkrans wrote a short paper on bentonite in northern

Virginia. He noted that L. Whitcomb the year before had correlated six bentonite beds in the basal portion of the Salona formation (late Black River or early Trenton age) in central Pennsylvania. Rosenkrans was attempting to correlate the Pennsylvania beds with those in adjacent areas. Rosenkrans noted at least six beds of bentonite in the Martinsburg formation at Strasburg, Virginia, and he followed these beds along their strike for forty miles. Rosenkrans noted that his bentonite beds No. 1 and 2 seemed to be persistent over a wide area in Pennsylvania and Virginia although the other correlations were less certain. Fossil evidence seemed to establish the stratigraphic equivalence of the lower Martinsburg and the Salona formations. Bentonite and bentonitic shale was noted also in the top of the Chambersburg limestone under the Martinsburg shale. Both Rosenkrans and Whitcomb looked at the Virginia section containing the bentonite layers and both were impressed by its resemblence to the equivalent Pennsylvania stratigraphic column.[199]

In 1935 Rosenkrans and Whitcomb correlated the bentonite beds of the lower Chambersburg formation between Chambersburg, Pennsylvania, and Martinsburg, West Virginia, in which four bentonite beds recognized and correlated although not all occurred in any single section. Bed three was distinct enough in seven stratigraphic sections to be correlated over the entire area. Fossils were also used to help date the beds. It was noted that bentonite beds at the base of the Chambersburg at Tumbling Run, Virginia, might possibly be correlated with these beds.[200]

In 1936 Rosenkrans discussed the bentonite deposits of southwestern Virginia. He recognized that Virginia was a particularly favorable area for bentonite correlation of Middle Ordovician stratigraphy. He noted that some barrier concepts must be revised because overthrusting had placed some formations adjacent to each other which have originally been quite far apart. He

He felt that this was true of the Lowville-Moccasin-Bays sequence in south western Virginia.[201]

In 1935 G. M. Kay wrote on the distribution of Ordovician altered volcanic materials and related clays. He noted that many clays which resembled bentonite were of stratigraphic significance and he used the term metabentonites for such materials.[202] Kay discussed the Lenoir-Chambersburg-Martinsburg sequence in southwestern Virginia. On the basis of faunal evidence the Chambersburg limestone with metabentonite in its lower and upper parts was thought to extend in age from the Black River Lowville to the Trenton Hull time. The base of the Martinsburg was considered to be of Sherman Fall age.[203] The New York type sections had recently been redefined on the basis of new knowledge and Kay used this newer nomenclature for the formations of the Trenton and Black River Groups in New York (see Table 17). Detailed work had led to a finer and finer division of beds and the tracing of these thinner formations over a wide area in New York. The Rideau was a shale facies of the Pamelia evidently deposited near the shore of the advancing Pamelia sea and so is of variable age for this reason. A disconformity was recognized between the Chaumont and Rockland and the Lower Collingwood and the Upper Utica formations. Kay used faunas, more than detailed descriptions of the occurrence of the metabentonites, to correlate these beds stratigraphically from region to region. The Moccasin-Martinsburg sequence in southwestern Virginia was believed to be of Hull-Sherman Fall age, the lower Martinsburg metabentonite beds being equivalent to the Sherman Fall formation in New York.[204] On the basis of his discussion Kay noted that in Black River-Lowville time the sea spread over a great portion of middle United States from central Virginia west and that the same was true of Trenton early Sherman Fall time. The seas were decidedly restricted during lower Trenton-Rockland time and this seems to account for fossil differences

Cincinnatian				feet
	Trenton Group	Gloucester		75
		Collingwood	Upper Utica	75
			Lower Collingwood	10
		Upper Cobourg		65
		Lower Cobourg		100
		Sherman Fall		200
Mohawkian		Hull		100
		Rockland		60
	Black River Group	Chaumont	Watertown	25
			Leray	40
		Lowville		40+
		Pamelia		
		Rideau		

TABLE 17 [205]

in the Mississippi area from those of the Appalachian trough. Only western Virginia was receiving sediments from Appalachia of which the bentonite beds latter changed to metabentonite were a part. The extent of the seas was postulated from the bentonite deposits all over Eastern United States. The thickest bentonite of Sherman Fall time thinned from North Carolina north to New York indicating the presence of the volcanoes blowing out the ash in the North Carolina-Virginia area.[206]

Rosenkrans (1936a) recognized that the precise boundary between the Moccasin and Trenton (lower Martinsburg shale elsewhere in Virginia) limestone was difficult to draw in southwestern Virginia. Hubbard and Croneis had located the boundary at the base of an 18 inch bed of massive non-fossiliferous, blocky bluish-gray limestone which was found forty feet below the first of the gray, coarsely crystalline limestone of undoubted Trenton age. In this case the boundary was 100 feet above the red calcareous mudrock facies (Moccasin). Kay, as we have seen, placed the boundary immediately above the Moccasin facies

and considered the transitional beds to be Martinsburg (i.e. lower Martinsburg or Trenton). These transition beds were called the Eggleston formation by Matthews and correlated with the Chambersburg formation of northern Virginia as we have noted above. The Chambersburg was considered of Black River age. Using the bentonite beds as part of his correlation and the cunieform[207] limestone bed, which was persistent over a wide area as described by Mathews in addition to Rosenkrans, it was concluded by Rosenkrans that four facies of Black River strata were distinct in southwestern Virginia. He recognized as grading from west to east the Lowville limestone facies, the red Moccasin mudrock facies, and the Bays sandstone facies. The Eggleston greenish mudrock facies was a transitional zone between the red Moccasin facies and the overlying Trenton limestone facies of the Martinsburg formation. Note that all these formations were considered of Black River age.[208] To the west the Eggleston seemed to replace the Moccasin. The facies changes seem to be the result of the distance from the shore line rather than troughs of sedimentation. This correlation of facies was due to the persistence of the cunieform limestone beds just above a hiatus above which was the Eggleston formation and to a group of fourteen distinct bentonite beds tracable over wise areas. This hiatus at the bottom of the transition beds mentioned above appeared to be the best place to draw the Black River-Trenton boundary in southwestern Virginia.[209] Also in 1936 Rosenkrans suggested that the ratio of the mineral contents of bentonites might help to better establish the specific bentonite beds from area to area.[210]

In 1936 Cooper in discussing the geology of the Marion area in Virginia noted that the Ceratopea zone of the Canadian System representing the Bellefonte limestone of the Beekmantown Group was missing in the Marion area as the result of a large hiatus. In addition, the Murfreesboro at the bottom of the overlying Stones River Group was absent. The Holston was missing between the

Stones River and Blount Group and the Ottosee formation overlay the Athens in this area.[211] The lithology of the Ottosee varies greatly in the Marion area.[212] The Moccasin was recognized as a shallow water facies of the Lowville limestone and was a facies not a formation of the Black River Group. An unconformity appeared between the Martinsburg formation containing the Trenton, Eden, and Maysville Groups and the underlying Moccasin.[213] A hiatus at the end of the Martinsburg deposition cut out the Oswego sandstone at the top of the Ordovician and the entire Silurian System including its basal Juniata formation. This great hiatus seems restricted to the Marion area and is not of wide occurrence in southwestern Virginia.[214]

In his discussion of the stratigraphy of the Big A Mountain area in southwestern Virginia R. A. Bates does not divide the beds of Beekmantown age of the Canadian system in this area. The Stones River Group of the Ordovician contained the Murfreesboro, Mosheim, and Lenoir limestones in this area. A large hiatus was indicated at the end of Stones River time by the absence of all the formations of the Blount Group but the topmost Ottosee formation. The Moccasin formation occupied Black River time in the Big A Mountain area. A hiatus at the end of the Martinsburg formation cut out the Oswego formation. The Juniata occurred in place at the bottom of the Silurian. The Juniata was considered Richmondian in age.[215]

In an abstract B. N. Cooper noted that the unconformity between the Canadian and Ordovician Systems (as defined by Ulrich) in Pulaski County, Virginia, was of short duration but had a relief of as much as 400 feet while the Athens which was overlain by the Chambersburg formation in the same general region showed no unconformity but had both the Ottosee and Lowville formations missing. Relief concluded Cooper is no clue to the time interval involved.[216]

By 1939 the Virginia Geologic Survey abandoned Ulrich's nomenclature and

adopted that system used by the United States Geologic Survey. This meant that Ulrich's Canadian System of Beekmantown age became the base of the Ordovician and that the Juniata-Sequatchie formation considered at the base of the Silurian by Ulrich and Butts became the top of the Ordovician. This change in grouping is evidenced in R. A. Bates report on the geology of the Powell Valley in Lee County, Virginia. In this report (1939) the beds of Beekmantown age were not divided but fossils recovered indicated that beds of both Bellefonte and Nittany time were present in the area.[217] No evidence for an erosional unconformity was present at the base of the Mosheim in this area and Bates suggests that Ulrich may be wrong in assigning the St. Peter sandstone as occurring before the Chazy (Mosheim-Lenoir) in the Mississippi Valley. The Mosheim and Lenoir were conformable.[218] In the Powell Valley area the whole Blount Group of upper Chazy age was lacking and the Lenoir was overlain by the Lowville limestone. Bentonite occurs in the Lowville formation and two sections of it were described in detail by Bates.[219] The Chambersburg which overlay the Lowville was absent here and the Trenton overlay the Lowville limestone.[220]

Bates doubted the value of Stose's (1923) division of the Trenton into two formations in this area since the formation was lithologically uniform from top to bottom. The Martinsburg in southwestern Virginia was divided into the Trenton limestone at its base and the Reedsville shale of Eden and Lower Maysville age. A hiatus in which the Oswego sandstone was lacking was noted between the Reedsville shale and Sequatchie (Juniata in the north) formation in the Powell Valley. The Sequatchie was recognized as the marine facies of the Juniata formation.[221]

R. S. Edmundson described a thin ridge making sandstone in Frederick, County, Virginia, which formed low ridges. Such a bed proved on detailed work to be a good stratigraphic marker and a help in interpretation of structural

geology where faults were covered by soil. Bentonite beds were noted by Edmundson in the Chambersburg which overlies the Athens shale in this area without any intervening Lowville limestone.[222]

Butts and Edmundson in describing the geology of Little North Mountain Virginia included the Chepultepec limestone, a thick-bedded blue finely crystalline persistent limestone, at the base of the Ordovician. This formation was previously considered a part of the Cambrian. The Beekmantown Group with its Nittany and Bellefonte horizons was present. The entire Blount Group and the Lower Black River Lowville was absent between the Lenoir and the Chambersburg. There was no known break between the Lenoir and the Mosheim. The Oswego sandstone occurred here between the Martinsburg shale and the Juniata formation.[223]

In the Draper Mountain area B. N. Cooper recognized the Stonehenge member of the Beekmantown Group as being absent but he divided the Nittany formation into two members. The lower member he called the Oglesby marble member which he describes as a very fine grained vaughanitic limestone of various colors. It is 120 to 155 feet thick in its type section near Oglesby School, Virginia.[224] The upper member Cooper calls the Draper dolomite member and it is a medium bedded light-gray dolomitic limestone and dolomite. Most of the beds are siliceous and slightly argillaceous. The fossil fauna of the Nittany indicates middle Beekmantown age in this area.[225] The Bellefonte succeeds the Nittany and an unconformity overlies it as indicated by the absence of the Murfreesboro formation in this area. Cooper (1939) had noted the unconformity between the Lenoir and the Holston or Whitesburg formations as showing a large relief. In nearby areas the Holston was completely cut out of the stratigraphic column.[226] Both the Ottosee and Moccasin formations were cut out of the Draper stratigraphic sequence by an unconformity and the Chambersburg overlay

the Athens limestone in this area. As usual of southwestern Virginia the Juniata overlies an unconformity caused by the absence of the Oswego sandstone.

Cooper had previously published an abstract on unconformities in the Draper area but in 1939 he wrote a more detailed account. The unconformity between the Bellefonte and Mosheim formations cut out the Murfreesboro and the Buffalo River beds which do not occur in the Appalachian region (see unnamed epoch, Ulrich; Table 15). The erosion here is thought to have caused the silification of the remaining Bellefonte dolomite after erosion had occurred. The unconformity between the Lenoir and Mosheim was somewhat complicated. Erosion carved deeply into the Lenoir, Mosheim, and the Draper member of the Nittany. The Holston was deposited in its thickest sequence in such a deeply eroded basin. It rose stratigraphically until it had a feather edge in some places between the Lenoir and the Whitesburg showing that a hiatus took place between the Lenoir and Whitesburg in places. A local unconformity occurs at the base of the Athens due to the occurrence of a trench carved during the Lenoir-Whitesburg erosion interval which the Holston and Whitesburg failed to fill. Consequently the Athens was washed by marine currents off some areas in order to fill this trench.[227] In Russell County, Virginia, the Murfreesboro was present but the Athens-Whitesburg and the Chambersburg limestone were not present.[228]

In 1940 Butts published his description of the Appalachian stratigraphy in Virginia. He had abandoned the system of nomenclature used by Ulrich and which he had used in his short description of formations for the geologic map of the Appalachian Valley in Virginia published in 1933. The system used by the United States Geologic Survey was adopted by Butts. However, the base of the Ordovician was considered a part of the late Cambrian or the late Ozarkian of Ulrich who had defined this formation in Alabama in 1911.[229] It was placed provisionally in the Ordovician on the basis of paleontological studies by

Josiah Bridge and G. A. Cooper.[230] Butts description of the formations includes fossil lists, character, correlations and thickness from area to area. The Chepultepec is a rather pure limestone with intercalated beds of more or less magnesian limestone in Virginia. Its thickness varies from 30 to 600 feet. Fossils indicated the relation of the Chepultepec to the Stonehenge formation in Pennsylvania and the Tribes Hill limestone at the base of the Ordovician in New York while the same evidence could be used in support of a pre-Stonehenge age for the Chepultepec. In northern Virginia the Chepultepec if present is very thin and merges with the Stonehenge.[231] The Beekmantown Group was considered as a whole by Butts and was not subdivided into Bellefonte and Nittany although he recognized fossil zones in the Beekmantown. This is opposed to what has been noted above from B. N. Cooper who not only mapped the Nittany and Bellefonte formations but recognized two members of the Nittany formation, the Oglesby limestone and the Draper dolomite. The Ceratopea (lower) and Lecanospira (upper) zones are recognized in the Beekmantown and Butts notes that in some places the upper Beekmantown contains a very compact limestone which very much resembles the Mosheim which overlies the Beekmantown in places. The Axemann formation which occurs between the Nittany and Bellefonte in Pennsylvania is not recognized litholo[illegible]ically in Virginia but the characteristic fossil of this formation Maclurites affinis occurs in the Virginia Beekmantown Group. The Murfreesboro limestone overlies the Beekmantown in natural sequence.[232] Butts defines two facies of the Murfreesboro. Generally to the northeast of Clinch Mountain the Murfreesboro is an almost wholly dove colored vaughanitic limestone and is called the St. Clair facies. Southeast of the belt where the St. Clair facies is found the Blackford facies is found which is a heterogeneous sequence of red shale, red mottled argillaceous dolomite, gray shale, gray clay, and gray magnesian limestone. Fossils in the Murfreesboro correlated with basal

member of the Chazy of the Lake Champlain area.[233] Butts added very little new information about the Mosheim and Lenoir relations as we have discussed them above. He does note, however, that Ulrich questioned the identity of the Lenoir in Virginia with that in Tennessee although no reasons are given.[234] The Lenoir is recognized as being almost everywhere in the Ordovician sequence in the Great Valley in Virginia but the Mosheim is less regular evidently due to local hiatus and poor depositional conditions.[235] Since the Lebanon and Valcour limestones were not recognized in Virginia (the Valcour was upper Chazy, i.e. upper Stones River) a hiatus was postulated between the Lenoir and overlying formations. The succeeding group being called the Blount Group as previously noted.[236] The basal member of the Blount Group, the Holston, varied in thickness and it was absent in some places. In normal sequence the Whitesburg and Athens would overlie it but in places the Ottosee overlay it showing a hiatus indicated by the lack of Whitesburg and Athens formations. The Holston did not correlate well with any part of the Chazy in New York and so the Blount was placed according to Ulrich's study between the Chazy and Black River Groups of the New York type section. The Athens shale was described as having a black fine grained limestone facies that breaks with a conchoidal fracture and a shale facies. No names are given to these facies. In addition a sandstone facies as is noted elsewhere in this paper. An unusual feature was the occurrence of a conglomerate, evidently an alluvial cone, within the Athens formation near Pincastle, Virginia. It was probably formed by a river with a torrential current depositing off shore onto the Athens shale.[237] Butts believed the Athens to be more than 5000 feet thick in places but it thinned to the northwest.[238] The Tellico sandstone which occured between the Athens and Ottosee in Tennessee was not recognized in Virginia and a hiatus was postulated here.[239] The Ottosee followed the Athens in Virginia.

The Lowville follows the Ottossee but apparently this sequence occurs in only two places without a hiatus in Virginia and this is in the Rich Valley and Rye Cove areas between Walden and Clinch Mountains.[240] The Moccasin was recognized as the red argillaceous facies of the Lowville by Butts. The New York Lowville guide fossils Cryptophragmus antiquatus and Tetradium cellulosum were found in the Lowville in Virginia. Butts recognized the Eggleston as a separate formation overlying the Lowville-Moccasin in Virginia and as far as it goes this corresponds with Rosenkrans (1936a) conclusions.[241] The Chambersburg as defined by Stose and Ulrich (1909) included the Lowville limestone. Butts emended this to exclude the Lowville since the Lowville was identified by its characteristic fossils. The important fossil guide to the Chambersburg was the sponge Nidulites pyriformis. Butts does not give a detailed discussion of the Virginia occurrence of the faunal zones of the Chambersburg which Ulrich described for the type section in Pennsylvania. The Christiania and Nidulites beds were recognized and the Tetradium beds were assigned to the Lowville. The Chambersburg was recognized as far south as the Draper Mountain area. The Chambersburg was correlated with late Black River time but Butts noted that newer work was casting doubt on the stratigraphic position and correlation of the Chambersburg in Virginia.[242] The overlying Martinsburg shale was one formation in northern Virginia but its lower part becomes a limestone and is called the Trenton limestone in southwestern Virginia while the overlying shale is called the Reedsville shale. The Oswego and Sequatchie-Juniata relations are used by Butts as described elsewhere in this paper. Fossils established the Richmond age of the Juniata-Sequatchie formation.[243]

In 1941 Holden described a "Black Rock"-Mosheim unconformity which occurs over large areas in Virginia. The Mosheim is a lenticular formation and the overlying "Black Rock" is a crystalline and cherty black limestone. The contact

between the two is every where knife edged but locally the contact is irregular and abrupt offsets of as much as six inches occur.[244] (The"Black Rock" is possibly the Lenoir.)

Edmundson makes the following statement about the Ordovician formations in northern Virginia in an abstract.[245]

> A comparison of Ordovician formations that drop out on the east and west flanks of the Massanutten syncline in northern Virginia suggests the following facts or inferences: (a) The Nittany horizon of the Beekmantown is thinner and the Bellefonte equivalent is thicker to the east; (b) the Stones River limestones (Mosheim and Lenoir) show greater variations in thickness to the east; (c) limestone of Athens lithology is absent to the west but the horizon, as suggested by a few fossils, may be represented in the basal part of the Chambersburg limestones; (d) the Chambersburg limestone is thinner to the east; (e) the Oswego and Juniata formations are present to the west but absent to the east; and (f) the Chepultepec limestone is less fossiliferous to the east.

B. N. Cooper (1941) noted that some geologists considered the Athens formation absent northwest of Clinch Mountain in southwestern Virginia, but Cooper found 120 feet of limestone which was stratigraphically equivalent to the Athens and which contained an Athens fauna except for graptolites in Tazewell County northwest of Clinch Mountain. The beds above and below the Athens northwest of Clinch Mountain appeared to be the same as those to the southeast of it.[246]

In an abstract Cooper and Prouty (1940) noted that the Middle Ordovician in Tazewell County, Virginia, consisted of 28 lithologic faunal zones comprising six formations (discussed below; see Table 18). Prouty (1941) noted that the tracing of these formations in Tennessee and Virginia showed that previous correlations had been inadequate.

> Type Lenoir of Tennessee, nodular limestone containing Maclurites and Girvanella, passes well below the Helicotomaria-phospira zone (Murfreesboro) in Virginia and changes to dark cherty and coarse gray limestones; this coarse limestone has been called Holston in the median

> belts of Virginia but is older than similar beds called Holston in most of the Tennessee belts. Above the Virginia "Holston" a Nidulites zone, directly beneath the Helicotoma-Lophospira zone, extends throughout the median belts of Virginia. Southwest of Newcastle, Virginia, this zone carries Echinosphaerites and Receptaculites and has been mapped as Stones River; it is called Athens in the same belt from south of Goodwins Ferry to northeast of Abingdon. Above the Helicotoma-Lophospira zone, a nodular limestone carrying Maclurites and Girvanella extends from Narrows, Virginia, to at least Thorn Hill, Tennessee; it has been classed as Lenoir in many sections, whereas the northwest belts show large breaks in the lithologic and faunal record.[247]

B. N. Cooper (1942) regarded the Moccasin not as a facies of the Lowville but as a distinct formation which overlies the Lowville in the type area. Underlying the Moccasin was 54 feet of fine-grained limestone containing Camarocladia, 28 feet of a coarse grained limestone containing Cryptophragmus antiquatus, 40 feet of calcilutite containing Tetradium cellulosum and 42 feet of red straticulate mudrock. The Camarocladia bed would indicate the presence of the Chickamauga limestone which was originally excluded from the definition of the Moccasin formation. He thought the Lowville-Moccasin term should be abandoned.

Cooper and Prouty (1943) published a paper on the work which was summarized in an abstract (1940). A detailed description of 29 faunal and lithologic zones is given and stratigraphic sections described on the basis of which incoccsistencies are found in the use of the terms Stones River, Murfreesboro, Mosheim, Lenoir, Blount, Holston, Ottosee, Lowville, and Lowville-Moccasin in southwestern Virginia. The zones are given numbers and are described in Table 18. It was recognized that some zones were similar lithologically and beds 5-9 showed a considerable degree of facies variation and thickness.[249] We have noted Rosenkrans (1936) use of the cunieform beds but Cooper and Prouty note that while in places these beds occur above a red siltstone in other places

Zones	Members	Formations
Zone 29 Cuneiform beds		Eggleston
Zone 28 Red Siltstone Zone 27 Red mudrock Zone 26 Red marble		Moccasin formation
Zone 25 Camarocladia beds Zone 24 Cryptophragmus beds Zone 23 Fourth calcilutyte Zone 22 Upper laminated limestone		Witten limestone
Zone 21 Red mudrock tongue Zone 20 Brown sandstone tongue		Bowen formation
Zone 19 Buff shale Zone 18 Third coarse-grained limestone Zone 17 Receptaculites biconstrictus beds Zone 16 Stromatocerium rugosum beds		Wardell formation
Zone 15 Third calcilutyte Zone 14 Lower laminated limestone		Gratton limestone
Zone 13 Cross-bedded limestone Zone 12 Chasmatopora beds	Burkes Garden limestone	Benbolt limestone
Zone 11 Opikina beds Zone 10 Coarse-grained limestone	Shannondale limestone	
Zone 9 Second calcilutyte Zone 8 Lophospira beds	Peery limestone	
Zone 7 Nidulites beds Zone 6 First coarse-grained limestone	Ward Cove limestone	Cliffield formation
Zone 5 Sowerbyites beds	Lincolnshire limestone	
Zone 4 First calsilutyte	Five Oaks limestone	
Zone 3 Blocky chert Zone 2 Ash-gray shale Zone 1 Basal clastics	Blackford member	

TABLE 18 [248]

a drab-gray argillaceous limestone occurs above the highest red siltstone and below the cuneiform beds.[250] Cooper and Prouty noted that their detailed investigation showed that some formational terms were used for different beds which were lithologically the same but not of the same age. Keeping in mind Butts usages they drew the following series of conclusions:

(1) Beds which do not contain the fauna of the Murfreesboro limestone of Central Tennessee have been referred to that formation.

(2) Some of the coarse-grained limestones which have been called Holston underlie beds carrying the fauna of the Murfreesboro limestone.

(3) Other so-called Holston beds overlie limestones containing fossils which are supposed to be valid guides to the Ottosee and Lowville.

(4) Certain fossils, such as Nidulites pyriformis, which have been considered indicative of the Ottosee formation have been found below beds containing the Murfreesboro fauna.

(5) Nodular limestones, described by Butts as typical Ottosee beds, overlie calcilutytes containing Tetradium cellulosum and Tetradium racemosum, both of which he considers valid index fossils of the Lowville.

(6) In various parts of Tazewell County, two different zones of calcilutyte have been identified as the Mosheim. One is 200 to 850 feet stratigraphically above the other.

(7) The Lenoir limestone of Butts has been identified largely on the basis of its superposition with respect to beds supposed to be Mosheim, resulting in the identification of two different zones as Lenoir.

(8) Beds which are both faunally and lithologically similar to part of the Athens, as recognized by Butts in Bland County, have been found in Tazewell County in lower part of Butts' Ottosee.

(9) Mistakes in identification of formations have resulted from the use of lithologic criteria and index fossils which are invalid.[251]

Hence, Cooper and Prouty proposed to rename the 29 zones which they had

distinguished. The Cliffield formation was proposed for beds one through nine and five members of this formation were distinguished. The Blackford member of zones 1-3 was a term that had been previously used by Butts to describe what he considered a facies of his Moccasin formation. Zone four was called the Five Oaks limestone. Zones six and seven were called the Ward Cove limestone. Zone eight and nine were called the Peery limestone member. The Benbolt formation consisted of zones 10-13, the Gratton of zones 14 and 15, the Wardell of zones 16-20, the Bowen of zones 20-21, and the Witten of zones 22-25. The Moccasin term was retained for beds 26-28 which were red siltstone, mudrock, and marble considered typical of the Moccasin as first defined by M. R. Campbell in 1894. The formation contains few fossils. The Eggleston was retained as a name for that portion of the cuneiform zone which underlies beds of the lowest coquina limestone containing Sowerbyites curdvillensis and Dalmanella rogata. No correlation is attempted between these newly defined formations and the type sections in New York.

Butts and Edmundson (1943) in discussion the stratigraphy of the southwestern end of Walker Mountain used Butts Ordovician nomenclature of his 1940 paper. The Chepultepec was considered part of the Ordovician. Butts recognized that northwest of Clinch Mountain the blue Lowville limestone was separated from the nodular Ottosee by a few feet of red beds of the Moccasin facies. Butts and Edmundson proposed the name Walker Mountain sandstone member for the upper two sandstones in the Moccasin formation. They believed this member to be the same as the sandstone which Keith (1905) called Clinch in the Bays Mountain area. Both are overlain by the Martinsburg formation.[253]

Secrist and Evitt (1943) in discussing the upper Martinsburg formation of the Massanutten Mountain, Virginia, recognized four lithologic divisions in the underlying Chambersburg limestone. The first was a massive impure limestone with several thin beds of bentonite near the base. The second was a nodular

thin bedded argillaceous limestone. The third zone was a blue limestone in beds 12 to 18 inches thick separated by thin beds of shale and the fourth was a compact, medium bedded, impure limestone with numerous clay partings when unweathered. Overlying the Martinsburg was the Massanutten sandstone which had first been used by Geiger and Keith (1891)[254] and subsequently by Darton (1894) in the Staunton Folio. The major purpose of Secrist and Evitt paper was to discuss the paleontology of the upper Martinsburg for which they used the term Maysville as Bassler (1909) had previously done. They made the statement that the Maysville fauna in the Massanutten area is recognized not so much by individual species as by general faunal assemblage. The western sections seem to have two zones of Maysville fossils but the eastern sections have only one zone which Secrist and Evitt call the Passage Creek zone. The Orthrhynchula linneyi is supposed to be a guide fossil to the top of the lower Maysville but only one specimen of it was found at the top of the Passage Creek zone. Such a lack of characteristic forms suggested striking differences in conditions of both environment and deposition between the eastern and western sections of the upper Martinsburg. A Cub Run and a Passage Creek section forty miles from one another were discussed and the lack of characteristic fossils at both localities suggested that they were formed under deltaic conditions with the Cub Run section being closer to the source of the sediments. In the Massanutten area measurements of the thickness of the Martinsburg is difficult because of lithologic and structural readjustments by folding, faulting and deformation of beds.[255]

B. N. Cooper (1943) said the following in an abstract about the newly named formations in southwestern Virginia:[256]

> Faunal and lithologic studies of the lower Middle Ordovician succession between Burkes Garden, Tazewell County, Virginia, and Luttrell, Union County, Tennessee, show that (1) The Moccasin, Witten, and Bowen formations

> persist without much change throughout the Clinch Mountain belt (165 miles). (2) Beyond the southwestern limits of the Gratton limestone, in Tazewell County, Virginia, the Wardell formation directly succeeds the Benbolt limestone; the two are readily distinguished as far southwest as Eidon, Tennessee, but at Thorn Hill and Luttrell their boundary is less distinct. (3) The Wardell, unlike the Benbolt abounds in bicherms and biostromes, composed of stromatopoids, corals, sponges, and calcareous algae. (4) The Benbolt becomes increasingly shaly toward Speers Ferry, Scott County, Virginia; between Nensonville, Virginia, and Eidon, Tennessee, it is richly fossiliferous. (5) Southwest of Tazewell County, Virginia, dark bluish-gray cherty limestones in the Cliffield interfinger with coarse pinkish calcarenytes (Holston-type limestone). Where the calcarenytes are thickly developed, members of the Cliffield recognized in Tazewell County, Virginia, are not readily distinguishable, except for the Dinorthis atavoides-Sowerbyites triseptatus zone which persists at least as far southwest as Eidon, Tennessee. (6) In Russell County, Virginia, the zone of basal clastics of the Blackford member has intercalations of pinkish Holston-type limestone which contain rhychonellid brachiopods like those in the Lenoir of Tennessee.

B. N. Cooper (1944) defined a number of new formations in his discussion of the geology of the Burkes Garden quadrangle. The Chepultepec limestone appeared to be absent in the area and only the Ogle by (lower) member of the Nittany formation of the Beekmantown Group seemed to be persistent in the area. Many non-persistent limestone facies occurred in the Beekmantown. The Lecanospira fauna was present indicating the Nittany formation but the Ceratopea fauna of the Bellefonte formation of the Beekmantown was apparently eroded in this area at the end of Beekmantown time. The Beekmantown was used to include all the Ordovician formations below Chazy age as they occur in New York State.[257] Cooper used the nomenclature he and Prouty had defined in the Tazewell area for the post-Chazy formations but he recognized two different succession of beds. One was to the northwest and the other to the southeast of Clinch Mountain. The differences of succession occurred within the Cliffield Group. Northwest of Clinch Mountain the succession is the same as defined in

the Tazewell area by Cooper and Prouty. Southeast of Clinch Mountain Cooper elevated the Blackford, Five Oaks, Lincolnshire, and Peery limestone members of the Cliffield formation to formation status and called these formations plus the Effna, Whitesburg, and Athens formations lying between the Lincolnshire and Peery limestones, the Cliffield Group. The Blackford member and formation refers to the Blackford facies of the Murfreesboro as used by Butts (1940) in Virginia. The calcilutytes of the Five Oaks member and formation were evidently used for the Mosheim of Butts but Butts had used the term for younger calcilutyte beds also. The Lincolnshire limestone contains the characteristic fossils Sowerbyites triseptatus and Dinorthis stavoides southeast of Clinch Mountain. This bed was what Butts had called the Lenoir limestone but it was not the same as Butts Lenoir northwest of Clinch Mountain which is the bottom of the Peery limestone of Cooper and Prouty (1943). Southwest of Clinch Mountain the Lincolnshire is succeeded by the Effna limestone which was called the Holston by Butts but without adequate basis according to Cooper. It may be equivalent to H. D. Campbell's Murat limestone but no correlation could be made at the time.

The calcarenite of the Blackford formation may be the same as the Effna southeast of Clinch Mountain. The Whitesburg and Athens are used as Butts used them and they succeed the Effna southeast of Clinch Mountain. The Peery overlies the Athens here.[258] The Benbolt, Gratton, Wardell, Bowen, Witten, Moccasin, and Eggleston formations are used in the same way as they were in the Tazewell area by Cooper and Prouty (1943). In the Burkes Garden area the Martinsburg formation has the three faunal zones recognized elsewhere but fossil evidence here indicates only the lower Trenton Hull to Lower Cobourg age (New York sections described below). The upper Trenton fauna appears to be absent in this area of Virginia. However, no break is indicated between the Trenton and

Eden zones in the Burkes Garden area. Almost all the Eden appears to be present but only the lower Maysville fauna is apparently present and again no hiatus is apparent between the Maysville and Juniata formations here.[259] Elsewhere the Oswego sandstone is between the Maysville and Juniata. The upper Juniata is conformable with the Silurian Clinch sandstone.[260]

Cooper (1944) in discussing the industrial limestone and dolomites in Giles County, Virginia, refers to the Five Oaks as equivalent to Butts Mosheim in the same area and the rest of the Cliffield formation and the Benbolt formation as equivalent to Butts Lenoir in this area. The Witten and Gratton were equivalent to the Lowville facies of Butts Lowville-Moccasin formation.[261]

Edmundson (1945) continued to use Butts nomenclature for the northern part of the Great Valley in Virginia.[262] Cooper (in discussing the industrial limestones and dolomites in Tazewell County, Virginia,) discussed the formations immediately under the Blackford as the "Knox" dolomite since the boundaries of the Copper Ridge, Chepultepec, and Beekmantown were not determined in the field this older term covered these formations.[263] The Cliffield Group was evidently dropped by Cooper as a name in this report and its members were elevated to formation status. The Shannondale and Burkes Garden members of the Benbolt formation were dropped in favor of the term Benbolt as a single unit. The Blackford formation was restricted to the lower part of the Blackford consisting of ash gray shales and basal clastics. The blocky chert bed (zone 3, Cooper and Prouty (1943)) was elevated to formational status under the name Elway formation.[264] The "Knox" was divided into six members which are from bottom to top an oolitic member, a sandy member, a lower cherty member, a limy member, an upper cherty member, and a pink dolomite member.[265] The Bowen and Wardell formations appeared to be absent in eastern Tazewell County but present in western Tazewell County. In Russell County the Five Oaks limestone evidently

disappears to the southwest. The Rockdell limestone is used for the Peery and Ward cove limestones which are indistinguishable here.[266] The Gratton evidently does not occur in Russell or Scott Counties since Cooper makes no mention of it. In Scott County the Blackford limestone changes to a coarse grained light-gray to pinkish limestone which Cooper calls the Tumbez limestone.[267] It is found only in the Clinch Mountain belt described in Cooper's report. Table 19 shows the relations of the various Cooper and Prouty nomenclature to older names and to various other areas.

Cooper (1944b) made the following statement about the position of the newer nomenclature and the older nomenclature of the Ordovician:

> Regional studies of the Middle Ordovician in the Appalachian Valley in Virginia show that some of the familiar units generally regarded of different ages are laterally continuous and equivalent. These profound facies variations necessitate a reclassification of the Middle Ordovician in Virginia. Two examples of major variation in facies are especially noteworthy. In the limestone belt along the northwest face of Clinch Mountain 300 feet of "Holston" marble at Luttrell, Tennessee, grades northeastward into a succession including the Blackford, Five Oaks, Lincolnshire, Ward Cove, and Peery formations which are typically developed in Tazewell County, Virginia. The stratigraphic range of "Holston" marble beds, from Blackford to Warbell ("Ottosee"), clearly indicates the megafacies character of the "Holston."
>
> In northern Virginia, the thick body of black "Athens" limestone near Harrisonburg grades northeastward into a thinner succession mainly of cobbly, buff-weathering limestone. The Chambersburg of the type section in Pennsylvania and along Tumbling Run, near Strasburg, Virginia, is a mixture of these two facies. Equivalency of the "Athens" and "Chambersburg" in northern Virginia is well supported by fossils. In contrast, a few key zones, such as the Reuschella edsoni zone directly below the Martinsburg in the Shenandoah Valley and the Witten limestone beneath the Moccasin in southwestern Virginia, are persistent over large areas.[269]

	Eastern Tazewell County, Virginia				Vicinity of Gate City, Scott County		Copper Creek Scott County
	Butts 1940		Cooper and Prouty 1943	Cooper 1945	Butts 1940	Cooper 1943	Cooper 1945
	Eggleston		Eggleston	Eggleston	Eggleston	Eggleston	
Lowville-Moccasin	Moccasin mudrock facies Lowville limestone facies		Moccasin	Moccasin	Moccasin mudrock facies Lowville limestone facies Moccasin facies	Moccasin	Moccasin
			Witten	Witten		Witten	Witten
			Gratton	Gratton			
Blount		Benbolt	Burkes Garden Shannon-dale	Benbolt	Blount	Bowen Wardell Benbolt Rockdell	Bowen Wardell Benbolt Rockdell
	Holston	Cliffield	Peery Ward Cove Lincoln-shire Five Oaks Blackford	Peery Ward Cove Lincoln-shire Five Oaks Elway Blackford	Ottosee Holston		
Stones River	Mosheim Murfrees-boro				Lenoir Murfrees-boro	Lincolnshire Elway Tumbez	Lincolnshire Five Oaks Elway Blackford

TABLE 19 [268]

Huffman (1945) has described the stratigraphy in Lee County, Virginia. His field work was done before Cooper and Prouty (1943) published their new nomenclature of the Tazewell area so that Huffman uses Butts names but in quotations to recognize that the name is being challenged. His Eggleston and Moccasin are evidently equivalent to those formations as used by Cooper and Prouty. Above the Moccasin Huffman described two zones which he calls the Curdsville formation. The upper zone was a Sowerbyella-bearing blue-gray coarsely crystalline limestone which contained Sowerbyella curdsvillensis, Dinorthis pectinella, and Dalmanella fertilis. The Curdsville fauna is widespread in southwestern Virginia but is not defined under this name. The Hermitage formation overlies the Curdsville and consists of three beds. These are in ascending order a Sinuites bed containing Sinuites cancellatus, a gray limestone contain-

ing Dalmanella fertilis and a yellow calcareous shale. The Hermitage is separated from the Curdsville by a hard blue metabentonite bed. The "Cathys-Cannon" as described by Stose (1923) overlies the Hermitage formation and is a blue-gray granular even-bedded, fossiliferous limestone. Huffman did not make a detailed study of the "Cathys-Cannon."[270]

Huffman describes five formations below the Moccasin. The "Lower Moccasin" contained a Cryptophragmus and Camarocladia bearing limestone, Hesperorthis beds, and a Stromatocerium zone.[271] This made it probably equivalent to the Gratton, Wardell, Bowen and Witten formations of Cooper and Prouty. The"Ottosee" beneath the "Lower Moccassin" contained six zones as defined by Huffman all but one of which were limestones. The "Ottosee" here was believed to be equivalent to the Lowville as used by Butts (1940) in Lee County.[272] The "Murfreesboro","Mosheim," and "Lenoir" were used as Butts had used them. It was recognized that Butts guide fossils to the Lowville, Cryptophragmus antiquatus and Tetradium cellulosum, were not as accurate as Butts thought since both have a wider range than once was believed.[273] Huffman tentatively correlated the Benbolt, Peery, and Ward Cove formations with his "Ottosee." His "Lenoir,""Mosheim," and "Murfreesboro" were correlated with the Lincolnshire, Five Oaks, and Blackford formations respectively.

While work had been going on in Virginia the New York type sections were being subdivided and correlated from area to area. In 1937 Kay published a paper on the Trenton Group which included rocks of Trenton and Black River ages. Kay's work ~~was mainly~~ included a correlation of more than sixty names used in various areas for the formations of this group. Kay showed that many formations were facies of a single bed which varied from place to place over the Adirondack Arch in New York State. His nomenclature is shown in Table 20. The Chazyan series below the Trenton in New York was deposited in the narrow Champlain Trough and its section included the Valcour and Crown Point formations. The

Cincinnatian			
Mohawkian	Trenton	Gloucester	
		Collingwood	
		Cobourg	Hillier
			Hallowell
		Sherman Fall	Denmark
			Shoreham
		Rull	
		Rockland	Napanee
			Selby
	Black River	Chaumont	
		Lowville	
		Pamelia	

TABLE 20 [274]

Chazyan sections in Virginia is believed by many to be much more complete than that in New York but correlation is somewhat difficult. Table 21 shows the correlation of Pennsylvania and New York formations of the Middle Ordovician.

Huffman (1945) compares the New York, Central Pennsylvania, and Tazewell and Lee County sections, and a Central Kentucky section. The"Ottosee" and "Lenoir" are equivalent to the Hatter and Loysburg formations of central Pennsylvania. The "Lower Moccasin" is Black River age and corresponds to the Brenner of Pennsylvania (see Table 21). Kay (1942) states that the Nealmont and Lower Salona are equivalent to the Chambersburg in Central Virginia.[275]

B. N. Cooper (1945) discussed all the previous usages of the term Stones River Group. He noted that Ulrich in 1939 abandoned his previous interpretation of the Stones River Group. Ulrich thought it was still Chazy in age but he evidently dropped the name of the Blount Group overlying the Stones River and considered all formations from Murfreesboro to Ottosee in Virginia of

	New York		Pennsylvania		Lee Co., Virginia
Cincinnatian			Reedsville		
Mohawkian	Trenton	Gloucester	Antes		
		Collingwood			
		Cobourg	Coburn		
		Denmark	Salona		
		Shoreham			Hermitage
		Kirkfield	Nealmont	Rodman	
		Rodkland		Centre Hall	Curdsville
				Oak Hall	Eggleston
					Moccasin
	Black River	Lowville	Curtin	Valentine	
				Valley View	
		Pamelia	Bremmer	Stover	
				Synder	"Lower Moccasin"
Chazyan			Hatter	Hostler	"Ottosee"
				Grazier	
				Eyer	"Lenoir"
			Loysburg	Clover	"Mosheim"
				"Tiger-striped"	"Murfreesboro"

TABLE 21 [276]

Chazy age. In addition he added two formations but without defining or describing them. The Speers Ferry was said to overlie the Ottosee and the Strasburg lay between the Lenoir and the Holston in the Pearisburg Trough in southwestern Virginia.[277] Cooper pointed out that Raymond (1905) and Schuchert (1943)[278] both believed the Stones River to be post-Chazy in age. Cooper sums up by saying that previous formations had not been accurately correlated from area to area and introduced again the nomenclature adopted by Prouty and him (1943) in Tazewell area, Virginia. Cooper believed the new nomenclature to be post-Chazy and pre-Black River beds.[279] On this point Cooper said in an abstract in 1945 the following:

> In the southern Appalachian region, beds known certainly to be linked with the New York Chazy are limited to the Lenoir limestone and its clastic equivalent, the Blackford formation. All the other pre-Curdsville Middle Ordovician formations have strong faunal affinities whether with the Black River or the low Trenton. Possibly beds as young as the Lincolnshire limestone may be correlative to the Valcour, but the dominant elements of the Lincolnshire fauna are unknown in the Chazy. The base of the Black River has been drawn too high in previous correlations. Bonafide Black River fossils occur hundreds of feet below limestones identified by Ulrich and Butts as Lowville and by Kay as the Pamelia equivalent. These supposed Lowville or Pamelia beds are no older than late Black River and possibly are as young as early Trenton. Taken together, the Chazy and Black River Groups do not represent so full a record of pre-Curdsville Middle Ordovician time as the succession in the southern Appalachian region into the Middle Ordovician groups of New York. It is suggested that the proposed Appalachian section now be considered the standard for pre-Curdsville Middle Ordovician correlations in the Eastern United States.[280]

Prouty (1946) traced the Cooper and Prouty (1943) nomenclature from southwestern Virginia to northeastern Tennessee and found that the terms they had defined suitable for mapping over large areas. Prouty proposed to limit the Ward Cove to zone 7 of the 1943 classification and called zone 6, which was a calcarenite bed, the Thompson Valley limestone which he found tracable over large areas of Virginia and Tennessee. Prouty redefined the Lenoir limestone and Sevier shale to preserve their identity. The Lenoir was defined in Tennessee as a nodular limestone lying above the calcilutite of the Five Oaks, "Mosheim", formation and below the Farrague, "Holston," formation. The Farragut was a new term for the calcarenite overlying the Lenoir and is partially equivalent to the Thompson Valley formation in Virginia. The Lincolnshire appeared to be a more calcareous facies of the Lenoir. The Benbolt, Gratton and Wardell formations were thought to grade into the Sevier shale in Tennessee. The term "Holton" was abandoned because several calcarenite layers of various ages were included in this term.[281]

In 1946 Cooper and Cooper published a paper on the lower Middle Ordovician in the northern Virginia. They listed the sequence of beds at three places in northern Virginia. At Harrisonburg they identified seven beds immediately overlying the Beekmantown dolomite and underlying the Martinsburg shale. They were in ascending order Tetradium syringoporoides beds, Dinorthis atavoides beds, trilobite beds, black limestone and shale, Nidulites beds, post-Nidulites beds, and Reuschella "edsoni" beds. Near Lantz Mills six beds were recognized. They were a Tetradium syringoporoides bed, Dinorthis atavoides beds, lower Echinosphaerites zone, Nidulites-Lambeophyllum beds, post-Nidulites beds, and Reuschella "edsoni" beds. Near Staunton, Virginia, the beds were Rostricellula beds, Tetradium syringoporoides beds, Hesperorthis beds, granular beds, Dinorthis atavoides beds, trilobite beds, black shale and limestone, Nidulites beds, and Zygospira beds.[282] On the basis of these beds, of which the Tetradium syringoporoides and Dinorthis atavoides seem to be persistent over northern Virginia, and with the information that Cryptophragmus antiquatus thought to be an unmistakable guide to the Lowville had a much wider range than previously thought, and with the knowledge that Nidulites pyriformis was probably a facies fossil and not characteristic of the Chambersburg as previously thought, Cooper and Cooper felt a redefining of formations was necessary in northern Virginia. A careful collecting of fossils and defining of sections indicated that the Chambersburg was not a different formation which overlay the Athens shale but a different facies of the same formation which interfingered with the Athens and Whitesburg formations to the north of Lexington and Staunton, Virginia. To the south around Walker Mountain, Virginia, the same procedure revealed that the Ottosee and overlying Lowville as used by Butts interfingered in the same manner with the Whitesburg and Athens formations.[283] Cooper and Cooper redefined the formations of northern Virginia.

Immediately overlying the Beekmantown came the New Market formation which was essentially equivalent to Butts Mosheim and the Blackford formation as Cooper and Prouty (1943) had defined it in southwestern Virginia. Both the Blackford and the New Market seem to be linked to the type Lenoir of Tennessee and are Chazy in age. The Whistle Creek limestone is introduced for the cherty beds containing the Hesperorthis fauna which succeeds the New Market and underlies the Dinorthis atavoides (Holston) zone of the Lexington area. The age of this formation is not accurately determined but is probably pre-Black River post Chazy. The Lincolnshire formation was introduced for the Dinorthis atavoides zone above the New Market or Whistle Creek limestone and below the trilobite beds (Whitesburg of Butts) or the Echinosphaerites zone where the trilobite beds are not separately recognized. The Lincolnshire included some coarse-grained calcarenites for which Cooper and Cooper proposed to revive the name Murat as used by H. D. Campbell (1905) for a facies name. Dominant Lincolnshire fossils are unknown in New York in the Chazy type sections and a post-Chazy age is suggested for it. The Lincolnshire may be essentially the same as the Effna limestone in southwestern Virginia although the Effna appeared to be a reef in the "Whitesburg" near Saltville, Smyth County, Virginia. The Lincolnshire may be partly or wholly equivalent to the dove limestone containing Tetradium cellulosim in Pennsylvania.

The Athens-Whitesburg-Chambersburg beds were considered one formation and given the name Edinburg formation of which two facies were recognized. The Lantz Mills facies corresponded to the cobbly limestones formerly referred to as the Chambersburg and the black graptoliferous shales were called the Liberty Hall facies reviving a name used by H. D. Campbell (1905) for these shales in the Lexington, Virginia, area. The lower trilobite zone formerly called the Botetourt member of the Edinburg formation. The name St. Luke member was pro-

posed for a rather pure dove-gray limestone occurring above the Nidulites-Lambeophyllum zone and below the Reuschella "edsoni" zone. The name Oranda formation was proposed for the 30-foot zone characterized by Reuschella "edsoni" which overlies the Edinburg formation and underlies the Sinuites beds of the Martinsburg formation. Through the occurrence of the afore-mentioned fossil the Oranda was correlated with the basal (Shoreham) member of the Sherman Fall limestone of the Trenton of New York. The Oranda also corresponds to the "Christiana" bed of the Chambersburg of southern Pennsylvania.

The Collierstown formation was proposed for beds overlying the Edinburg and underlying the Martinsburg formation. This formation occurs only in the westernmost belts of the Middle Ordovician in northern Virginia. The Collierstown occupies the position of the Oranda formation to the southwest and they may be metabentonites. Its fossils and stratigraphic position make it probably equivalent to the Eggleston formation of southwestern Virginia. The Collierstown evidently fills the Rockland-Shoreham interval of the type Trenton in New York State. A marked unconformity occurs at the top of the Beekmantown where almost all of Chazy time is lacking except for Rostricellula pristina beds which occur in a few localities at the base of the New Market formation. The Witten limestone of southwestern Virginia seems linked to the upper Edinburg by the occurrence of Camarocladia and Cryptophragmus antiquatus in both formations.[284] In the Cooper and Cooper paper facies was emphasized more than barriers and shifting seas so that many unconformities of Middle Ordovician time were eliminated. However, Prouty (1947) noted that a barrier did exist between the Alleghany synclinorium of West Virginia and Pennsylvania and the Appalachian region during Middle Ordovician time which proved a good facies barrier. Prouty believes this line has bearing on the fact that northwest of it dolomite predominates in the Beekmantown formation while southeast of it limestone predominates in this formation.[285]

Kay (1947) briefly names and defines a new series name in an abstract.

> The Bolarian Series (new, Bolar Valley, Virginia) comprises rocks younger than Lincolnshire, about late Chazyan, and older than Nealmont, early Trentonian, in the Virginias and Pennsylvania, and time equivalents. The Black River Group of New York and Ontaris is Bolarian. Along the Appalachian Structural Front, the lower Bolarina (Hatterian) in the Virginias comprises Ward Cove, Peery, and Benbolt limestones, and in Pennsylvania, Eyer, Grazier, and Hostler limestones. The group thins principally by convergence and overlap in the Ward Cove from about 500 feet at the James River to about 150 feet along the upper Potomac, and by continued overlap of Eyer (upper Wardcovian) by Grazier to less than 100 feet at the Susquehanna. Diminishing Lincolnshire is subjacent in the Virginias, but is overlapped in Pennsylvania, thinning by truncation to about 60 feet, predominantly Synder, near Maryland, and to about 30 feet of Synder at the James. The thickening Gratton, Bowen, Wardell, and basal Witten take the place of the Synder west of New River, and the Witten type section in Tazewell County seems to contain the Stover-Nealmont disconformity within the "Camarocladia Zone."[286]

In 1948 Kay redefined and divided the Lower Middle Ordovician series into the following classification:[287]

Upper Trentonian	
Middle Trentonian	
Lower Trentonian	
Upper Bolarian	Hunterian
Lower Bolarian	Hatterian
Upper Chazyan	Lincolnshirian
Lower Chazyan	"Blackford-Five Oaks"

Table 22 shows the relative positions of the formations of five areas in relation to the new nomenclature.

C. E. Prouty (1948) for Tennessee and evidently for southwestern Virginia where the rocks had not been eroded after the Beekmantown was deposited proposed the term Mascot dolomite for the uppermost Ceratopea and Orospira beds of the Beekmantown and Kingsport dolomite for the underlying Hormotoma beds. For the

		South West Virginia		South East West Virginia		Central Pennsylvania		Shenandoah Valley, Va.		North West New York
Trentonian	Upper Trenton					Antes Coburn		Martinsburg		Gloucester Collingwood Cobourg
	Middle Trenton	Curdsville		Oranda Eggleston		Salona	Nealmont	Oranda- Collierstown		Denmark Shoreham
	Lower Trenton	Moccasin		Moccasin		Nealmont				Kirkfield Rockland
Bolarian	Hunterian	Witten Bowen Wardell Gratton		Stover Synder		Curtin Stover Synder	Bemer	St. Luke		Chaumont Lowville
	Hatterian	Benbolt Peery Ward Cove Thompson Valley	Cliffield	Benbolt Peery Ward Cove		Hostier Grazier Eyer	Hatter	Edinburg Botetourt		Pamelia
Chazyan	Lincolnshire			Lincolnshire		Lincolnshire		Lincolnshire		Valcour
	Five Oaks-Blackford	Five Oaks Blackford		Five Oaks Blackford		Clover Loysburg		Whistle Creek New Market		

TABLE 22 [288]

Lecanospira beds between the Chepultepec and the Kingsport formations the term Longview dolomite was proposed tentatively. Since the boundaries between formations were so indefinite, new terms were needed according to Prouty. The Mascot and Kingsport were Missouri terms which had previously been correlated into eastern Tennessee.[289] The upper Cliffield (Ward Cove and Peery formations" thin from Virginia into Tennessee disappearing entirely in southwestern Virginia and northeastern Tennessee.[290] Prouty places the Blackford, Five Oaks, and Lincolnshire in the Chazy and the Thompson Valley, Ward Cove, and Peery limestones in the pre-Black River and post-Chazy.

R. L. Miller (1948) in discussing the Rose Hill Oil Field uses the terms Longview, Mascot, and Kingsport for the upper part of the Knox (Beekmantown)

Group as Prouty had done but he continued to use Butts sequence for "Stones River" and Trenton beds.[291]

In 1950 R. L. Miller and W. P. Brosgé proposed a new nomenclature for beds between the top of the Knox and the Trenton limestone in the Rose Hill fenster. These formations are only briefly named, defined, and their type locality given by Miller and Brosgé. Above the Mascot dolomite lies unconformably the Dot limestone and it is overlain unconformably by the Poteet and Rob Camp limestone. The Eggleston limestone is recognized as having a lower and upper mudstone member and a middle limestone member. No correlation is given for the terms used with those in other areas, but the base of the Woodway limestone is said to have a Stromatocerium rugosum zone at its base which would indicate that part of it is equivalent to the Wardell formation of Cooper and Prouty (1943).[292] Miller and Brosgé's stratigraphic column for the Rose Hill fenster is as follows:[293]

	thickness in feet
Trenton limestone	560-600
Eggleston limestone	145-165
Upper mudstone member	
Middle limestone member	
Lower mudstone member	
Hardy Creek limestone	93-151
Ben Hur limestone	127-153
Woodway limestone	256-288
Hurricane Bridge limestone	288-368
Martin Creek limestone	40-182
unconformity	
Rob Camp limestone	0-153
Poteet limestone	45- 97
unconformity	
Dot limestone	120-193
unconformity	
Knox Group	
Mascot dolomite	

N. H. Darton described fossil crinoid remains in the slate belt of the Piedmont, Virginia, which were thought to be Trenton-Lowville or Upper Ordovician age.[294] Watson and Powell (1911) re-examined the slate belt of Darton's paper. The Arvonia slate of Darton's paper and fossils in the Quantico slates

in a more northern slate belt in Virginia were examined to see if any correlation between the two areas could be made. The fossils were very distorted and all that could be determined was that both formations were of late Ordovician age probably Cincinnatian for the Quantico slates and Trenton age for the Arvonia slates. The Martinsburg shale in the Great Valley was thought to be the equivalent of these slates in the west.[295] Butts noted that the Ordovician seas must have been widespread over the Piedmont in Ordovician times and that they furnished sediments for the Great Valley seas after the Ordovician.[296] Lammers (1940) states specifically that stratigraphic, petrologic and structural evidence seemed to lead to the conclusion that the Blue Ridge was elevated at the end of the Cambrian to form two basins in Virginia. The Piedmont sediments were folded at the end of the Ordovician during the Taconic Revolution and gave sediments to the western basin after the Ordovician.[297]

Tabor (1913) noted a conglomerate bed at the base of the Arvonia slate and a bed of a tuffaceous material which was inter-bedded with the slates. A thin bed of quartzite lay between the conglomerate and the slates.[298]

Stose and Stose (1948) reviewed the literature on the Arvonia and Quantico slates noting that paleontologists seemed inclined to an Upper Ordovician age for these sediments probably on the basis of resemblence to Great Valley shales as much as on fossil evidence which was meager in regard to species. The fossils on review were thought to be even as late as Maysville age.[299] Stose and Stose noted that the Arvonia slate in one highly folded syncline had become a knotted slate which had previously been thought to overlie the Arvonia slate because the relationship was found in an overturned isoclinal fold. Detailed work showed the formations to be equivalent. The Bremo quartzite was known to overlie the Arvonia slate in one syncline.[300] It was felt that the Arvonia and Quantico slates were laid down after the Taconic Revolution and this was based

on evidence in Pennsylvania and elsewhere. With such structural evidence and lack of positive fossil evidence to the contrary they felt that the time needed before the slates were deposited in order to make them later than Taconic Revolution was great enough to make these slates of Silurian rather than Ordovician in age.[301]

R. B. Neuman (1951) examined the lower Middle Ordovician stratigraphy in northern Virginia, Maryland, and southern Pennsylvania and on the basis of fossils and stratigraphic sections thought that the Whistle Creek limestone lay not above but below the New Market limestone in central Virginia and in Maryland. Maclurites magnus and especially Rostricellula pristinia were thought to be guide fossils to the Whistle Creek in Virginia and Maryland by Neuman. Cooper and Cooper (1946) had considered Maclurites magnus to be a poor index fossil for formational correlation since it had a rather wide stratigraphic range. No Whistle Creek limestone was supposed to occur north of Staunton, Virginia, until Maryland was reached and for this reason Neuman called the beds underlying the New Market in Maryland the Row Park limestone but considered this equivalent to the Whistle Creek in central Virginia. Cooper and Cooper (1946) had recognized a Rostricellula pristina bed underlying the New Market limestone in the Staunton area which Neuman considered Whistle Creek not New Market limestone. Recognizing that a name was needed for the lower Middle Ordovician formations Neuman proposed for the Maryland area the name St. Paul Group which included the Row Park and New Market limestones in Maryland and the New Market and Whistle Creek limestone in Virginia. Neuman also correlated the St. Paul Group with the Five Oaks limestone in Virginia and the Pamelia limestone of New York and Ontario. The Lincolnshire limestone overlying the New Market in northern Virginia was thought to extend not farther north than the West-Virginia boundary in northern Virginia.[302]

Decker (1952) sums up a lot of work and adds some new information on the Athens shale by studying its characteristic graptolite fauna the world over. He recognizes three zones in the Athens Shale. All three types are represented in various Virginia localities. The lowest zone extends as far north as Abingdon, Virginia. The Middle zone as far north as Staunton, Virginia, and the highest zone as far north as Harrisonburg, Virginia. The Athens is considered to be of Trenton age by Decker and the Normanskill fauna which includes the three zones [redacted] is lower or middle Trenton. Decker concurs with Ruedamann adding additional stratigraphic evidence for the belief that the Normanskill shale is post-Chazy and pre-Black River in age.[303]

The first large problem of Ordovician nomenclature in Virginia was the recognition and division of various beds. This primary naming took until 1900 to be completed. After 1900 the problem was to divide the larger units into smaller ones as the field work became more detailed and smaller units could be traced and mapped over large areas. E. O. Ulrich developed and applied the barrier concept to Virginia stratigraphy in order to explain the formational variations within small areas. Detailed work has shown that while the barrier concept may explain formational variations elsewhere it is not applicable to any great degree within the Virginia Ordovician. Instead it was realized that over-thrusting has caused variations in a formation to appear closer together than was actually the case when deposition took place. In addition, the facies concept was put to its fullest use. This concept explains formational variations by stating that the distance from the shoreline helps to determine the type of rock which will be deposited. Shales and sands can be found close to shores and limestones should be deposited farther out from the shoreline.

Such a concept has explained such a knotty problem as the Athens-Chambersburg-Ottosee relationship in central Virginia. B. N. Cooper made the

following pleas for the development of the facies concept for work in the Ordovician in Virginia:

> Faunal and lithologic studies of the Middle Ordovician succession in the Appalachian Valley of Virginia show that there are a number of characteristic types of facies of limestone. From locality to locality and from belt to belt, the lithologic variations from one limestone facies to another are almost wholly the result of variations in environment of deposition. Most of the confusion existing about the relative ages of various parts of the Middle Ordovician succession in the Appalachian Valley has resulted from the erroneous assumption that these various types of limestone are time units which can be correlated over wide areas.
>
> Recent work shows beyond any question that no type of limestone found in the Middle Ordovician succession is necessarily or actually confined to any particular part of the column. Facies also enter into the problem of evaluating elements of a fauna. Quite obviously there are "facies fossils" which have no precise time value and are little more than earmarks of a sedimentary environment. There are, however, some elements of each fauna which seem not only to pervade all environments and to occur in all facies but also to be confined to a narrow stratigraphic interval hence they are good time markers.
>
> Experience shows that very few formations maintain uniform lithology over wide areas. Correlations based on lithology are almost worthless since no lithology in the Middle Ordovician is peculiar to one portion and only one portion, of the sequence. The most elementary study of sedimentary processes in the sea cannot fail to disclose that the character of accumulating calcareous sediment is determined largely by the environment, and that specific environments of one time are reproduced at other times, though not in the same places.[304]

On the special Virginia series Cooper says the following:

> The Champlainian series of western Virginia embraces more than a dozen major facies and about 35 distinctive hybrid lithologies which result from imperceptible gradations between various major facies . . . The major facies include arkosic sandstone and conglomerate, drab-brown siltstone, maroon-drab sandy shale, dark-bluish gray cherty limestone, calcareous black limestone, buff

> shale, and buff cobbly limestone. Serious mistakes in Appalachian stratigraphy have arisen through the consideration of these facies as vertically restricted time-stratigraphic units.[305]

It is well to remember that such a concept is not a new one but only an old one well applied. Raymond (1920) urged such a concept for Tennessee and Virginia stratigraphy. A reading of the literature shows that Bassler on the basis of fossils could show in 1909 the Chambersburg-Athens equivalence but Butts and Ulrich seemed to have ignored the fact that special faunas can be found under special depositional conditions. Raymond could show in 1905 that the fossil content of the Stones River Group was more of Trenton type than the Chazy but this piece of evidence seems to have been overlooked in defining the age of the Stones River which was always called Chazy in age.

Butts after many years work on Virginia stratigraphy in the Great Valley published a long paper on it in 1940. It might have been expected that Butts would have used some later material in his paper since it was done at a much later date than his map of the Appalachian Valley in Virginia. However, Butts makes no mention of later pieces of literature such as the papers on bentonite correlation which helped to define the Ordovician stratigraphy in southwestern Virginia. The bentonite correlation was thought to be a poor one by some because the stratigraphic range seemed a fairly large one. In the light of new relations proposed by Cooper and Cooper (1946) and Cooper and Prouty (1943) it might be well to re-examine such beds in the hope that the range is not as great as the formational usages of Butts would suppose. In addition, much of Butts work seems taken right out of field notebooks without digesting it in the light of newer work or later correlations. In the light of what followed Butts 1940 work was virtually inadequate by the time it was published. This is not to say that the newer nomenclature will better stand the test of time or that

Butts work was not a major contribution to Ordovician stratigraphy.

B. N. Cooper was early appalled at the usage of the term Martinsburg for such a large geologic time range. Indeed, it is the only one of the Ordovician formations early named that has withstood any essential lithologic subdividion. Three faunal zones are recognized but the shales seem to be uniform over large enough areas to make lithologic correlation and division very difficult. The only special paper on the Martinsburg seems to be the Secrist and Evitt (1943) paper and this paper showed the area studied was one of special depositional features. The Martinsburg remains a major problem in Virginia Ordovician stratigraphy.

H. P. Woodward (1951) who writes on the Ordovician of West Virginia sums up in a beautiful manner the problems of the stratigrapher everywhere. He offers few new names for formations of the Ordovician in West Virginia, but he does make candid statements about the areal relations of many beds and their identification in the field.

Some of the new work in geology has been toward defining what the geosyncline looks like and what the various types are.[306] This may lead to a better understanding of the relations of formations to their deposition and to the rise of barriers where they occur within the geosyncline.

Stratigraphic Nomenclature Which Has Been Used in Virginia

Athens shale (Butts 1933) shale of Blount Group underlies Ottosee limestone and overlies Whitesburg. Where Ottosee absent overlies the Chambersburg limestone.

Bays sandstone (N. R. Campbell 1894a) southwestern Virginia; equivalent to Juniata of Butts and Ulrich.

Beekmantown Group (Ulrich 1911) includes Stonehenge, Nittany, and Bellefonte formations in Virginia; Lower Ordovician.

Bellefonte dolomite (Ulrich 1911) upper member of Beekmantown Group.

Ben Hur limestone (Miller and Brosgé 1950) southwestern Virginia; Rose Hill fenster; below Hardy Creek and above Woodway limestone.

Benbolt formation (Cooper and Prouty 1943) southwestern Virginia; Zones 10-13 as defined in paper; below Gratton formation and above Peery limestone of Cliffield Group.

Blackford facies (Butts 1940) shale facies of Murfreesboro southeast of Clinch Mountain; now (Cooper and Prouty 1943) a full formation which lies above the Beekmantown Group and below the Five Oaks limestone; Zones 1-3 originally but restricted by Cooper (1945) to zones 1 and 2.

Blount Group (Ulrich 1911) Formations which lie between the Stones River Group and the Lowville or Chambersburg limestones; post-Chazy pre-Black River.

Bolarian series (Kay 1948) for rocks that are late Chazyan (post-Lincolnshire) and pre-Trenton in age.

Botetourt member (Cooper and Cooper 1946) central Virginia; base of Edinburg; equivalent to Butts' Whitesburg in central Virginia.

Bowen formation (Cooper and Prouty 1943) southwestern Virginia; Zones 20-21; above Wardell formation and below Witten limestone.

Burkes Garden limestone (Cooper and Prouty 1943) southwestern Virginia; Zones 12-13; above Shannondale limestone below Benbolt formation.

Cambro-Silurian--Ordovician before 1900 in this country.

Cannon limestone (Stose 1923a) southwestern Virginia; lower part of limestone of Trenton age.

Cathys limestone (Stose 1923a) southwestern Virginia; upper part of a limestone of Trenton age.

Chambersburg limestone (Stose 1908) overlies Stones River Group in northern Virginia and the Blount Group in central Virginia.

Chepultepec limestone (Butts 1940) southwestern Virginia; equivalent to Stonehenge limestone; now considered base of Ordovician.

Chickamauga limestone (M. R. Campbell 1894a) southwestern Virginia; underlies Moccasin and overlies Knox dolomite; no longer used in Virginia.

Cliffield formation (Cooper and Prouty 1943) used to cover Blackford through Peery limestones; Cooper (1945) elevated members to formation status and called the Cliffield a group consisting of its members which were raised to formations.

Collierstown formation (Cooper and Cooper 1946) central Virginia; overlies Edinburg and underlies Martinsburg shales; Reuschella "edsoni" zone.

Curdsville limestone (Huffman 1945) southwestern Virginia, Lee County; overlies Eggleston and underlies Hermitage limestone.

Dot limestone (Miller and Brosgé 1950) southwestern Virginia, Rose Hill fenster; underlies Poteet limestone and overlies Beekmantown Group.

Draper member (Cooper 1939a) southwestern Virginia; upper member of the Nittany dolomite in the Draper Mountain area.

Edinburg formation (Cooper and Cooper 1946) central Virginia; shale overlies Whistle Creek (or New Market) limestone and underlies the Oranda formation.

Effna limestone (Cooper 1944) southwestern Virginia; overlies Lincolnshire underlies Whitesburg southeast of Clinch Mountain.

Eggleston formation (A. A. L. Mathews 1934) southwestern Virginia; transition shales between Lowville-Moccassin limestone and Martinsburg shale.

Elway formation (Cooper 1945) Zone 3 (Cooper and Prouty 1943) raised to formation status.

Fairview limestone (A. A. L. Mathews 1934) southwestern Virginia, Giles County; above Eden shale and below Juniata formation.

Five Oaks limestone (Cooper and Prouty 1943) Zone 4; southwestern Virginia; below Lincolnshire formation.

Gratton formation (Cooper and Prouty 1943) southwestern Virginia; Zones 14-15; above Benbolt and below Wardell formations.

Hardy Creek limestone (Miller and Brosgé 1950) southwestern Virginia; below Eggleston formation and above the Ben Hur limestone.

Hatterian (Kay 1948) lower Bolarian includes Thompson Valley, Ward Cove, Peery, and Benbolt formations in southwestern Virginia and Edinburg formation excluding the St. Luke member but including the Botetourt member in central Virginia.

Hermitage limestone (Huffman 1945) southwestern Virginia; overlies Curdville formation and underlies Cathys Cannon formation (Stose 1923a).

Holston limestone--base of the Blount Group; overlies the Stones River Group; a coarse grained limestone.

House Mountain shales (J. L. Campbell 1879) central Virginia; equivalent to Martinsburg shales.

Huntarian (Kay 1948) upper Bolarian includes Gratton, Wardell, Bowen and Witten formation in southwestern Virginia and St. Luke member of Edinburg in central Virginia.

Juniata -- non-marine sandstone overlying Martinsburg formation or Oswego sandstone in northern Virginia

Knox dolomite (Safford 1869) southwestern Virginia; includes at its top the Beekmantown of present usage.

Lenoir limestone (Ulrich 1911) overlies Moshiem limestone; top of Stones River Group.

Lexington limestone (J. L. Campbell 1879) central Virginia; probably equivalent to Edinburg formation.

Liberty Hall limestone (H. D. Campbell 1905) central Virginia; (Cooper and Cooper 1946) equivalent to Edinburg formation and is used as a facies name.

Lincolnshire limestone (Cooper and Prouty 1943) southwestern and now central Virginia; Zone 5 above the Five Oaks limestone and below the Ward Cove limestone.

Lower Silurian - Ordovician before 1900 in the United States.

Lowville limestone (Butts 1933) overlies Blount Group and is equivalent with Moccasin limestone.

Martin Creek limestone (Miller and Brosgé 1950) southwestern Virginia; above Rob Camp and below the Woodway limestone.

Martinsburg shale (Arthur Keith 1894) northern Virginia; overlay Shenandoah limestone, now above Oranda formation.

Moccasin limestone (M. R. Campbell 1894a) underlay Sevier shale overlay Chickamauga limestone; now underlies Eggleston and overlies Witten formations in Southwestern Virginia.

Mosheim limestone (Ulrich 1911) middle member of Stones River Group; a fine grained limestone lying above Murfreesboro limestone and below Lenoir limestone.

Murat limestone (H. D. Campbell 1905) central Virginia; equivalent to Lincolnshire formation used as a facies name within it (Cooper and Cooper 1946).

Murfreesboro limestone (Butts 1933) southwestern Virginia; underlies Mosheim limestone; bottom of Stones River Group.

Natural Bridge limestone (M. D. Campbell 1905) central Virginia; equivalent at the top to the Beekmantown Group as used now.

New Market limestone (Cooper and Cooper 1946) overlies Beekmantown Group in central Virginia.

Nittany dolomite (Ulrich 1911) part of Beekmantown Group above Stonehenge limestone and below Beelefonte dolomite in Virginia.

Oglesby member (Cooper 1939a) southwestern Virginia; lower member of Nittany dolomite in Draper Mountain area.

Oranda formation (Cooper and Cooper 1946) central Virginia; overlies Edinburg and underlies Martinsburg shales; Reuschella "edsoni" zone.

Oswego sandstone (Butts 1933) northern Virginia; upper Ordovician below Juniata formation; absent in southwestern Virginia.

Ottosee limestone (Ulrich 1911) top of Blount Group and base of Sevier shale.

Pearisburg limestone (Bassler 1907) coarse limestone between Moccasin limestone and Knox dolomite.

Peery limestone (Cooper and Prouty 1943) Zones 8-9; above the Ward Cove limestone and below the Shannondale limestone.

Poteet limestone (Miller and Brosgé 1950) southwestern Virginia; above Dot limestone and below the Rob Camp limestone.

Reedsville shale (Stose 1923a) southwestern Virginia; Maysville and Eden fauna of Martinsburg shale; Trenton fauna in a limestone called Cathys-Cannon limestone or Trenton limestone.

Rob Camp limestone (Miller and Brosgé 1950) southwestern Virginia; below the Martin Creek and above the Poteet limestones.

Rockdell limestone (Cooper 1945) southwestern Virginia; used for the Peery and Ward Cove limestone in Russell County, Virginia.

St. Clair facies (Butts 1940) vaughanite facies of Murfreesboro formation northeast of Clinch Mountain.

St. Luke member (Cooper and Cooper 1946) central and northern Virginia; above Nidulites-Lambeophyllum zone of Edinburg and below the Oranda formation; a facies of the Edinburg.

Sequatchie formation (Stose 1923a) southwestern Virginia; marine equivalent of Juniata formation.

Sevier shale (M. R. Campbell 1894a) in southwestern Virginia underlies Bays sandstone overlies Moccasin limestone.

Shannondale limestone (Cooper and Prouty 1943) southwestern Virginia; Zones 10-11; above Peery limestone and below Burkes Garden limestone.

Shenandoah limestone (N. H. Darton 1894) northern Virginia; overlies Shenandoah limestone.

Speers Ferry limestone (Ulrich 1939 in Cooper 1945a) southwestern Virginia; overlies Ottosee; top of Blount Group.

Stones River Group (Stose 1908; Butts 1933) overlies Beekmantown Group in Virginia; Chazy age.

Stonehenge limestone (Stose 1908) northern Virginia; base of Beekmantown Group.

Strasburg (Ulrich 1939 in Cooper 1945a) southwestern Virginia; overlies Lenoir and underlies Holston; bottom of Blount Group.

Thompson Valley (Prouty 1946P southwestern Virginia; Zone 6 of Cooper and Prouty (1943); raised to formation by Prouty.

Trenton limestone (Butts 1928) underlies Reedsville shale and is limestone equivalent to Trenton shale zone of Martinsburg formation in northern Virginia.

Tumbez limestone (Cooper 1945) used for Blackford limestone in Russell County, Virginia, because of facies change.

Ward Cove limestone (Cooper and Prouty 1943) Zones 6-7; Prouty (1946) restricted it to zone 7.

Wardell formation (Cooper and Prouty 1943) southwestern Virginia; Zones 16-19; above the Gratton and below the Bowen formation.

Whistle Creek formation (Cooper and Cooper 1946) central Virginia; overlies New Market; Neuman (1951) says position should be reversed with Whistle on bottom and New Market on top.

Whitesburg limestone (Butts 1933) Blount Group underlies Athens shale and overlies Holston limestone.

Witten limestone (Cooper and Prouty 1943) Zones 22-25; below the Moccasin formation.

Woodyway limestone (Miller and Brosgé 1950) southwestern Virginia; above the Hurricane Bridge and below the Ben Hur limestone.

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Maynardville - Knoxville Quadrangles
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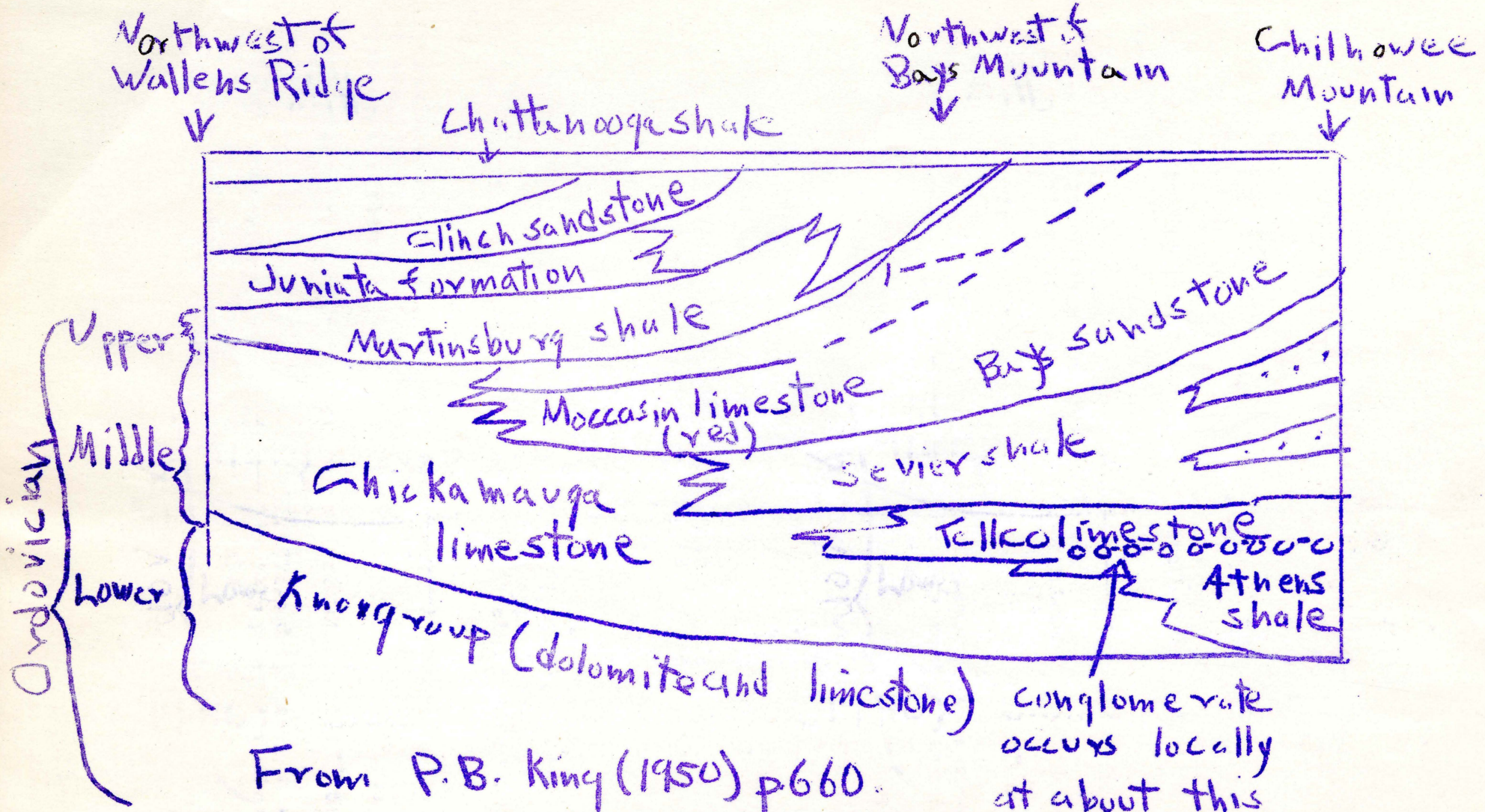
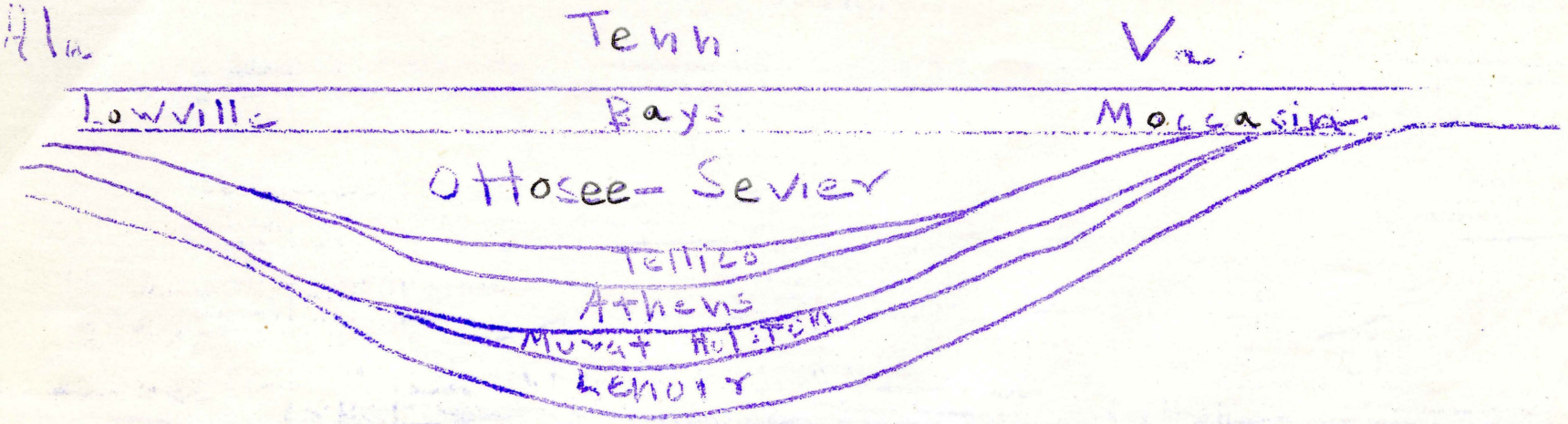


From P.B. King (1950) p660.

Plate 1



Butts (1928, p363) concept of Blount Group in Southern Appalachians

Plate 2

Southwestern Virginia

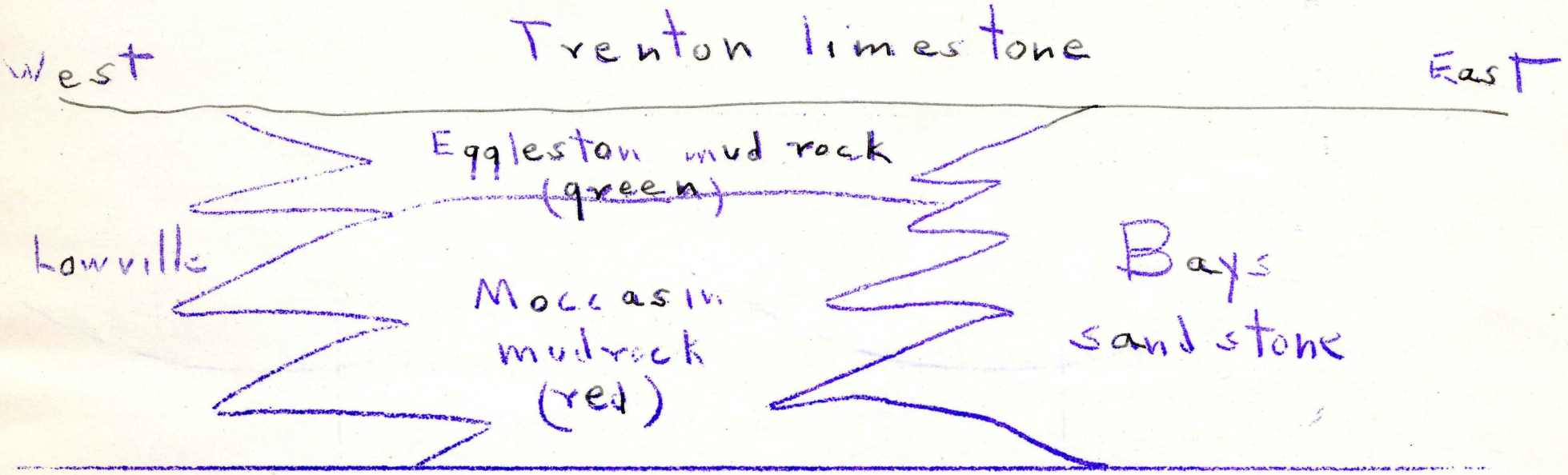
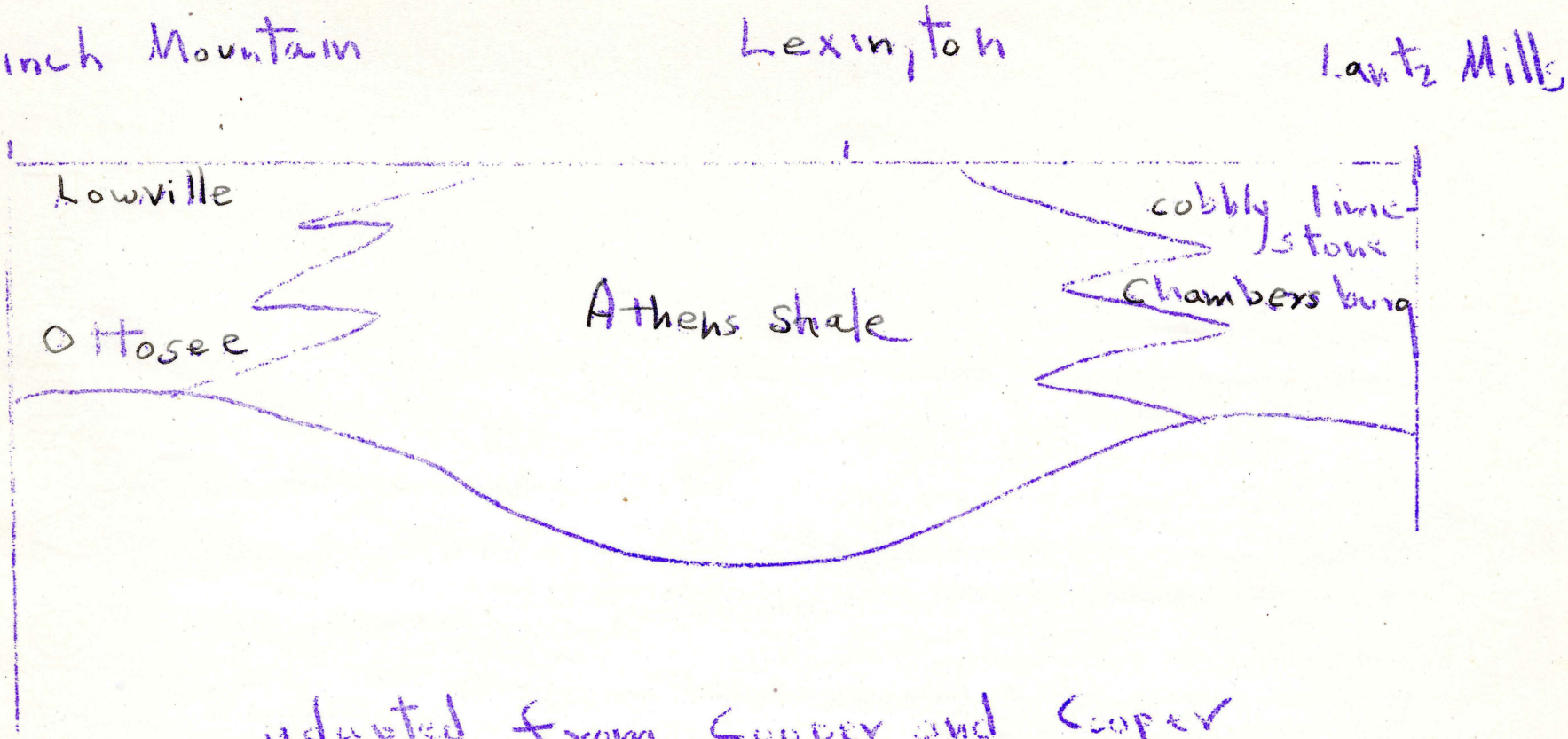


Illustration from description
of R.R. Rosenkrans (1936a) p. 100

Plate 3



adapted from Cooper and Cooper (1946) p. 68.

Plate 4