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Information Circular No. 26

THE AMERICAN UPPER ORDOVICIAN STANDARD

II. Development of STRATIGRAPHIC CLASSIFICATION OF ORDOVICIAN ROCKS in the Cincinnati Region

By
Malcolm P. Weiss
and
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COLUMBUS
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II. DEVELOPMENT OF STRATIGRAPHIC CLASSIFICATION OF ORDOVICIAN ROCKS IN THE CINCINNATI REGION

Malcolm P. Weiss[1] and Carl E. Norman[2]

ABSTRACT

The development of the classification of the rocks in the region about Cincinnati, Ohio is shown in tabular form. The successive columns of stratigraphic names that make up the chart have been correlated in order that the history of the nomenclature of even the smallest stratigraphic units may be traced. The text accompanying the table supplements it in certain respects and includes an historical analysis of the stratigraphic unit called Madison or Saluda.

INTRODUCTION

A number of authors, particularly of theses and dissertations, have found it helpful to trace the complicated development of the classification and nomenclature of the beds in the Cincinnati region. Casual references to the rock section or faunal succession, as well as references to parts of these, are abundant in the literature. Often such references make comparisons with one or another of the various full classifications that have been proposed, but without indicating how these classifications relate to others. Thus it seems that a table showing the development of Cincinnatian nomenclature and a direct comparison of the classifications employed would be of very considerable assistance to persons working on any aspect of these rocks. It is hoped that the accompanying table (Plate 1, in pocket) and discussion will fulfill this large purpose.

The general title of this article is the title of a proposed series of articles on the American Upper Ordovician standard, of which this is the second. The rocks of generally recognized Middle Ordovician age that occur in the Ohio Valley and are included in the base of the accompanying chart are not to be construed as Upper Ordovician because of the title of the series. For article number one see Sweet and others (1959).

The table was constructed after a thorough analysis of the literature concerning the type Cincinnatian and was compiled chronologically; that is, each successive proposal of a new classification was checked against pre-existing ones. By this means, it is believed, the horizontal sequences of names across the chart correctly represent the

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same rock and/or faunal unit to the extent that this is possible. This last property is one about which it is difficult ever to be certain; in renaming and reshuffling units, many authors failed to state explicitly the correspondence of their units with older ones. To some degree, the lateral differences of facies and thicknesses of named rock or faunal units adds to the difficulty of ever resolving details of correlations of one classification with another. Nevertheless, the present tabular summary expresses valid correlations insofar as it is possible to interpret them from the literature.

Professors K. E. Caster and W. C. Sweet have kindly given suggestions and criticism that have been helpful, but neither is in any way to be considered responsible for errors or ommissions that we may have committed. Mr. E. R. Sharp assisted with early stages of the bibliographic work. The study was supported in part by a grant (No. 5813) from the Development Fund of The Ohio State University.

THE SCOPE AND CONSTITUTION OF THE CHART

The rocks exposed along the Ohio River above Cincinnati are the oldest included in the chart. The columns extend upward to include the balance of the Ordovician rocks in the "Cincinnati region", southwestern Ohio, southeastern Indiana, and adjacent parts of Kentucky. It is the rocks in this region that have received the most intensive study and the most abundant coverage in the literature. Classifications of these rocks as they are developed farther south have been omitted deliberately because the facies changes in that direction introduce so many variables that the value of the chart would have been destroyed. Comparison and correlation of the Ordovician rocks of the Jessamine dome with those of the Cincinnati region are matters beyond the scope of this work.

With few exceptions, entries on the chart are limited to works that classified the entire succession of rocks under consideration. No attempt has been made to include on the chart each work in which new names were proposed, although, in the nature of the case, most such works do occur thereon. Many papers were reviewed that deal with particular aspects or parts of this rock succession or the contained fauna but include no general classification. Such papers are not included on the chart nor in the list of references. Proposals or conclusions of such papers that influenced taxonomy are considered to have had their effect upon later classifications, and thus to be represented on the chart.

The chart has no scale, and the thicknesses of the major divisions are determined mostly by the space required to show their subdivisions. The typical thicknesses or ranges of thickness of the several units are included in each category for which the author provided them. Differences among the thicknesses cited for any particular interval by several authors, or even by the same author in different papers, are sometimes considerable. This is doubtless due, in part, to different localities of study on which the various classifications are based. But such differences may, and probably do, result partly from lack of strict correspondence of named rock units or faunal zones. It is this lack of identity of named concepts that must always remain an unsolvable problem. The description of the thicknesses, nature, faunal content, and boundaries of individual units is frequently, especially in the older literature, not cited in sufficient detail to settle such questions.

Many of the published correlation charts of the sort accompanying this paper apparently were intended to make direct correlations only between the larger units. Certain it is that, in some such charts, the names of some of the smaller units are set on the same horizontal line with names that we are certain the author of the chart had no intention of placing in correlation. Sources of possible errors in the correlations indicated on the present chart have already been called to the attention of the reader. But the correlations on the present chart are the best decipherable from the literature, and are not inadvertent.

Considerable variation occurs in the specifications of the tops and bottoms of the columns on the chart (Plate 1). These have been plotted as authors presented them. In most instances the rocks of the Silurian Brassfield formation lie atop the highest named unit in the Ordovician column, although such was not specifically stated in most papers. Likewise, most columns extend to the top of or include the Cynthiana formation; the detail in which the lower part of the columns is classified varies widely among the several papers cited. Foerste, in several papers, included a number of units that underlie the Cynthiana in Kentucky. These are omitted deliberately for the reasons given above.

All question marks inserted in stratigraphic boundaries on the chart were put there by us to indicate uncertainty of position.

NAMES OF WHICH THE ORIGINAL DESIGNATIONS ARE NOT INCLUDED ON THE CHART

Several Cincinnatian stratigraphic units were proposed in papers that did not attempt to display the complete classification of the section in the Cincinnati region. Consequently these do not appear in Plate 1, but are discussed briefly in this section.

Marble Hill - Owen, 1837 (1838)

Owen (1837 (1838), p. 28 et seq.) referred to a shell marble, 20 feet thick, exposed in a quarry on Marble Hill near Madison, Indiana. He called it the Marble Hill stratum. Borden (1873 (1874)) also studied and described these beds; his and Owen's measured sections are on pages 140-141 of the report. It is clear from these sections that the Marble Hill stratum is well down in the Ordovician part of the section. Borden (1873 (1874), p. 141) referred to the abundance of gastropods in this unit, and identified them as Murchisonia bellicincta and M. bicincta [Lophospira]. Foerste (1896 (1897), p. 219) referred to the same unit as the "gasteropod layer", and described it as 140 feet below what we now call Brassfield. In a table on p. 218 he gives the alternative designation of Marble Hill bed. This stratigraphic name apparently fell into disuse near the turn of the century, and the exact stratigraphic position of the unit is of little concern, but for one thing. Cumings (1922, p. 439) refers briefly to this unit and misleads the reader: Owen's reference is on p. 28. not 128; Foerste's reference is on p. 219, not 129; the Marble Hill may well once have been known as the Murchisonia bed, as Cumings states, but the well-known Murchisonia bed, and the one to which numerous references have been made in the literature, is the Murchisonia hammelli bed at the top of the Ordovician, the one that Foerste later (1903, p. 347) named the Hitz bed.

Madison - Borden, 1873 (1874)

Borden's proposal (1873 (1874), p. 139) of the "Madison rocks" is not very specific, and it is difficult to be certain where in the rock succession his Madison rocks lie. Wilmarth (1938) interpreted them as the top formation of the Cincinnati group. This is the concept of the meaning of the term followed by most authors. Because of confusion with Madison formations in the Cambrian and also in the Mississippian, Foerste substituted the name Saluda in 1902 (Foerste, 1902, p. 369). The history of the interpretation of the stratigraphy of the Madison-Saluda is difficult to unravel, and is treated extensively in a later part of this report.

Belfast - Foerste, 1896

An almost unfossiliferous, sandy and argillaceous limestone, locally grading to clayey shale, and three to six feet thick, was described and named the Belfast bed by Foerste in 1896 (p. 189, 190). It is overlain by "...the Clinton or Montgomery bed..." (Brassfield), and is typically developed only along the eastern flank of the arch, in south-central Ohio. Foerste later (1935, p. 147-148; 187-188) described its thinning to the

north and west from south-central Ohio, with its place beneath the Brassfield being taken by the thin Centerville clay formation, which in turn thins southeastward and pinches out beneath the Belfast. Neither the Belfast nor the Centerville are known from the Indiana side of the Cincinnati arch. Foerste recognized the transitional nature of these rocks and the scanty faunas in them; in his earlier reports he seemed to favor Ordovician affinities, but in his 1935 report he regarded them as the initial Silurian deposits in the areas where they occur.

Saluda - Foerste, 1902

Saluda bed is the name that Foerste applied (1902, p. 369) to the well known Madison bed at the top of the Ordovician section in extreme southeastern Indiana. The change was made in order to avoid confusion with the use of the word Madison for Cambrian and Mississippian formations elsewhere in the country. He chose a locality on Saluda Creek, six miles south of Hanover, Indiana, that displayed virtually all of the unit, as the source of the name. Nevertheless, he stated that the exposures of the unit in the vicinity of Madison, Indiana should continue to be considered the typical exposures. The stratigraphy and correlation of the Saluda is considered more fully below. Not only others, but even Foerste himself (1904b; 1905b) did not always use the new name.

Hitz - Foerste, 1903

Hitz bed is the name that Foerste gave (1903, p. 347) to the zone of Murchisonia (Lophospira) hammelli, sometimes called the "gasteropod layer", that lies at the top of the typical Madison beds in the vicinity of Madison. Cumings (1922, p. 438) considered that the Hitz bed represents part of the tongue of Whitewater that overlies the Madison (Saluda) in the Madison region.

Brassfield - Foerste, 1905

Although the Brassfield is not Ordovician in age, it has long been recognized as the upper limit of the Ordovician rocks classified in the accompanying table. Many of the columns displayed in the table have no specification of what does lie atop the highest Ordovician unit, but there is no doubt that the authors of these columns knew it is the rock of the Brassfield formation, or an equivalent earlier name. The name Brassfield was first published by Foerste (1905a, p. 145) in a table of some Kentucky formations. He referred to it as the "Brassfield division (Clinton)", containing beds called "Brassfield Limestone". In a later paper (1906, p. 10), he tabulated it as the Brassfield member of the Clinton formation. On page 27 of the 1906 report the unit is described, and is there called the Brassfield limestone.

Tate - Foerste, 1906

The name Tate was applied by Foerste (1906, p. 19, 212) to the more argillaceous and siliceous phases of the Fairmount that he found in eastern Ordovician outcrops in Kentucky. Foerste (1912b, p. 23) supplements his column by plotting the stratigraphic position of several units that are characteristic only of the periphery of the Cincinnati

region. One of these units is the Tate, which he plots as an apparent Bellevue equivalent, but states (p. 18) that it lies between the Fairview and McMillan "divisions". The final disposition of the Tate appears in the column for Foerste's report of 1924.

Gratz - Ulrich, 1911

The part of the Cynthiana formation known as the Gratz member was first named the Gratz shale by Ulrich (1911, p. 416-418, 569, and Pl. 27). This unit is generally recognized only in that part of the Cynthiana that is below water in the Ohio Valley, and it is also far enough south into Kentucky to be part of a somewhat different facies or expression of the Cynthiana formation. Consequently, the Gratz does not figure significantly in the accompanying table.

Turkey Track - Wolford, 1930

The "Turkey Track layer" (Wolford, 1930, p. 304) is not a formal stratigraphic unit of any sort and was not proposed as such. Nevertheless, some use has been made of the term and concept, and it appears in the texts and stratigraphic columns of some subsequent articles, although not as a named rock unit. Consequently it does not appear in the present table. The "Turkey Track layer" consists of less than a foot of unfossiliferous limestone that occurs in southwestern Ohio along the crest of the Cincinnati arch. Its top is marked in a characteristic way that suggested the name. Although Wolford considered it to be the basal bed of the Whitewater formation, others (Caster, Dalve, and Pope, 1955, p. 13) include it in the top of the Liberty formation

Centerville - Foerste, 1931

A thin clay shale that occurs in southwestern Ohio immediately beneath the Brassfield formation and pinches out to the southeast under the Belfast bed of Foerste (see above), was named the Centerville by Foerste in 1931 (p. 173; 184-185). Prior to that time he had always regarded this rock as the topmost part of the Elkhorn formation, but discovery of a Silurian fauna in it prompted its designation as a separate unit. Foerste regarded the name Centerville as "provisional". Although he did not specify a type locality or type section, it is clear from context that the name derives from Centerville, Ohio, eight miles south of Dayton. The significance of the Centerville and its lateral and vertical relations to the Belfast bed are set forth more fully in a later paper (Foerste, 1935, p. 147-148; 187-188). This unit should not be mistaken for the Centerville limestone that Foerste named (1901, p. 397, 402, 407) from Centerville, Hickman County, Tennessee. The latter Centerville is a Middle Silurian formation in western Tennessee. This review of the Ohio Centerville, together with the discussions of the Belfast and Brassfield units, is helpful in interpreting the top of the Ordovician, even though many of the authors cited in the table did not specify the unit bounding the top of the Ordovician column.

REVIEW OF THE STRATIGRAPHY OF THE MADISON-SALUDA

A glance at the table comparing the various classifications that have been applied to the rocks in the Cincinnati region will show that the unit called Madison, and later called Saluda, has had a most unusual history. Few stratigraphic units have been moved from

the top of a stratigraphic column to a place within the column, and survived. The name Madison was proposed by Borden (1873 (1874), p. 139) and replaced by the name Saluda by Foerste (1902, p. 369).

By historical accident the Ordovician sections closest to the Ohio River were studied earlier than those farther to the north in both Ohio and Indiana. Thus the Madison was named and used by geologists before the equivalent rocks in east-central Indiana were studied and classified. In addition, many turn-of-the-century stratigraphers knew little of, or did not believe in, facies changes, and were reasonably certain that a stratigraphic unit, once identified, could be traced continuously over an area such as the Cincinnati region. As it happened, later work seems to have demonstrated that the Saluda is merely a tongue or wedge of rock that is apparently equivalent in age to other named units in east-central Indiana, and that the Saluda is only locally the uppermost Ordovician. As a consequence of this the classifications of the rocks in the Cincinnati region evolved (see chart) from those expressing the stratigraphy in the vicinity of Madison, Indiana to a more general type that expresses the full succession of named Cincinnatian rock and faunal units in the entire region. Probably the most significant papers pertaining to this development are Cumings (1907 (1908) and Shideler (1914), although the latter is difficult to interpret. Additional important contributions have been made by Cumings and Galloway (1912 (1913)), Strete (1939), and Conkin (1952).

Papers in which the older view of the Saluda obtains, and in which an abundance of data on occurrence, nature, thickness, and contained fossils appears, are those of Foerste (1896; 1896 (1897); 1899 (1900); 1902; 1903; 1904b; 1905b; and 1909b) and Nickles (1903). Some confusion that made the work of later authors more hazardous is also contained in these many papers; for example, within the first eight pages of one of his reports, Foerste (1899 (1900) states three very different specifications of the lithology of the Saluda within its type area.

Probably the first inkling that the older classification of the Saluda as the top of the Ordovician section might be incorrect came from Foerste (1904b). On page 332, he referred to the fossils at the top of the Saluda as a recurrence of Whitewater species.

The first critical studies of the Ordovician rocks in Indiana, from Richmond southward toward Madison, were made by Cumings (1907 (1908)), although Nickles (1903) had previously named some parts of the Richmond group from that area. Cumings depended upon a number of measured sections for his data and published them in his report. He correlated them from north to south on the basis of both rock characters and faunal content, one of the most important criteria being ledges ("reefs") of numerous Tetradium sp. His conclusions regarding the stratigraphy of southeastern Indiana were demonstrated by a diagrammatic cross-section of the rocks from Richmond to Madison. There are some minor inconsistencies between thicknesses in the cross-section and those in the text and measured sections, but these do not vitiate the work; his conclusions have stood up well since their publication. Cumings (1907 (1908), p. 612-626; 672-679) showed that the Tetradium beds which lie near the base and in the upper middle part of the Saluda in the Madison-Barbersville area converge toward the north. Similarly, the rock characteristic of the Saluda, lying almost wholly between the two "coral reefs", reduces in thickness, so that only a few feet of Saluda remain in the vicinity of Richmond. There, at the northern limit of its occurrence, the Saluda consists almost wholly of its lower Tetradium bed, as diagrammed by Cumings. The shaly lower part of the typical Saluda grades to more limy rock toward the north and appears to pinch out in that direction.

Cumings found that the Saluda lies between the Liberty and Whitewater in this northern area, and that about 50 feet of Ordovician rock remains above the Whitewater. Demonstrably not Saluda, this latter unit was named Elkhorn by Cumings (1907 (1908), p. 678). In the same report, Cumings explained the northward wedging-out of the Saluda and the southward thinning of the Whitewater and Elkhorn against the top of the Saluda by lack of deposition of the Whitewater and Elkhorn in the south; he regarded the Madison

area as dry land during the latest Ordovician. He therefore concluded that the Brassfield formation is unconformable upon the tilted and regionally limited Ordovician beds.

This notion of unconformity is avoided in later reports (Cumings and Galloway, 1912 (1913); Cumings, 1922). However, in both of these papers Cumings persisted in regarding the Saluda as lying wholly between the Liberty and Whitewater. In both reports he remarks upon Ulrich's (no date given) desire to place the Whitewater base some 10-15 feet below the base of the Saluda because of the occurrence there of the earliest Whitewater fauna; certainly he knew of Shideler's (1914) similar conclusion. Nevertheless, Cumings remained adamant on the subject of a Saluda below, rather than within, the Whitewater.

Cumings (1907 (1908), p. 685) was uncertain as to just how far south the Whitewater extends over the Saluda, but he concluded from reports by Foerste that the Lophospira hammelli fauna (Hitz bed of authors) at the top of the Ordovician at Madison, Indiana represents some part of the Whitewater.

In 1914 Shideler published a review and extension of the work of Cumings. The main points of Shideler's field data, distribution of the coral beds, and naming of the stratigraphic units are shown graphically in Figure 1. Descriptions of the several coral beds and their correspondence to those diagrammed by Cumings (1907 (1908)) are given in Table 1, as derived from Shideler (1914).

Study of Figure 1 and Table 1 together will show how Shideler (1914) concluded that the Saluda is a tongue or wedge of rock that thins northward wholly within the Whitewater of authors. Recognition of this facies relationship led him to conclude that the divergence of coral beds 2 and 3 from 5, toward the north, was proof of more rapid accumulation of sediments in the north. Furthermore, he considered the southern Saluda and Hitz faunas to be of near-shore type, thus leading him to the conclusion that the Elkhorn and most of the Whitewater are deeper-water equivalents of the Saluda. Shideler learned that the only Saluda in Ohio is in northern Butler and southern Preble counties, so the tongue must diminish toward the east also.

Concerning the Ordovician-Silurian contact, Shideler states that coral bed 5 is no more than 14 feet below the base of the Silurian (at Waynesville, Ohio) and that a purple shale occurs about five feet above this coral bed everywhere on the east side of the arch. Adding these circumstances to his view of the conditions of late Ordovician sedimentation in the region, Shideler decided that the Ordovician-Silurian contact is generally conformable, with only local unconformities. His observations of the contact convinced him of the regional conformity.

Strete (1939) studied a section of the Saluda near Oxford, Ohio, where it is about five feet thick. A detailed comparison of faunas above and below the Saluda showed (p. 215) that, "Practically all species occurring within 15 feet below the Saluda were also found to occur above it, and but very few species were found to come in new within 15 feet above.". Strete then checked the fossils still lower in the section and found that a number of species are introduced about 30 feet below the Saluda. Most of these species had been reported by Austin (1927) only from the Whitewater. Strete concluded (p. 217) that the Saluda belongs within the Whitewater because it contains a number of fossils typical of the Whitewater and because the most significant "faunal break" (excluding the Saluda coral bed itself) is 30 feet below the Saluda.

Working south of Madison, and east of Louisville, Kentucky, Conkin (1952) confirmed and extended the work of Shideler and Strete. Conkin found there that the Saluda is somewhat thicker than at Madison, that the lower Whitewater is still present although thinner than at Madison, and that the Liberty is thicker than it is in southwestern Ohio. He recognized the Hitz bed in his area as the southern remnant of the upper Whitewater. If the work of Conkin and the others is accurate, the southward thinning of the upper and

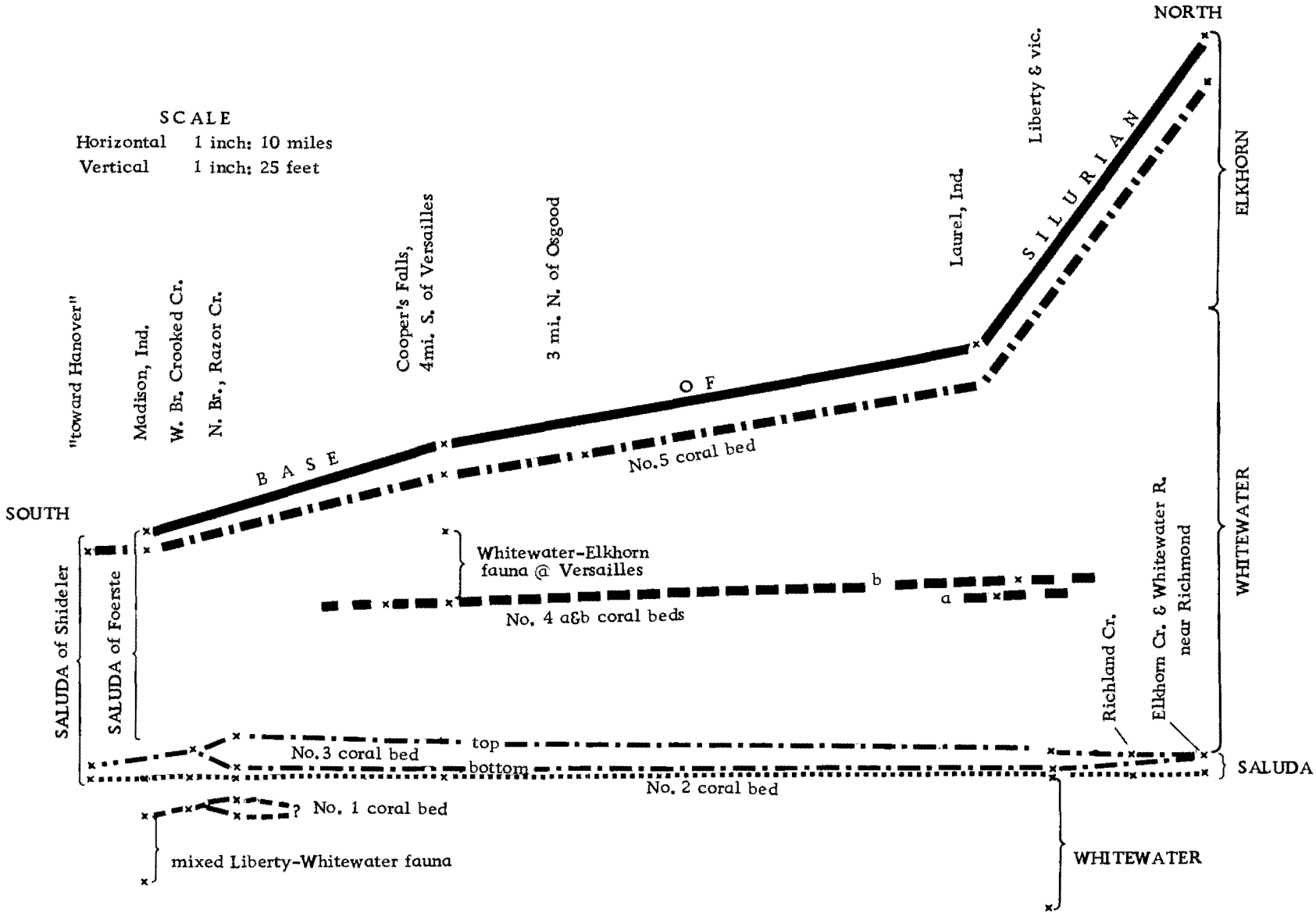

Figure 1 - DIAGRAM OF SALUDA STRATIGRAPHY ACCORDING TO SHIDELER (1914).

TABLE 1. CORAL BEDS OF THE RICHMOND OF INDIANA
(compare Figure 1)

	Shideler (1914)	Cumings (1907 (1908)
BED		
	Tetradium minus and Labechia spp.; containing or just below the Hitz fauna at and south of Versailles; correlated in error with No. 4 by Cumings at his section 1.59H.	
4-b	T. minus with much Labechia montifera and other spp. of L.; equals the upper T. "reef" of Cumings except at his section 1.59H.	This is apparently the third and uppermost of Cumings' "reefs" except at section 1.59H, but Shideler does not explain the fact that he finds his bed 4-b higher above 2 and 3 in the Laurel-Liberty area than did Cumings.
4-a	T. minus 2-3 feet below 4-b; only in the area west of Oxford, Ohio.	
3	T. minus plus molluscs; included with bed 2 by Cumings.	The second and middle one of Cumings' "reefs" which he put in the basal Saluda everywhere but at Madison, was separated into beds 2 and 3 by Shideler.
2	Columnaria alveolata and T. minus; the basal element of the Saluda; with bed 3, it constituted Cumings' basal Saluda "reef" north of Madison.	
1	C. alveolata; pinches out to the north; part of lower Whitewater; equal to lower Columnaria "reef" of Cumings; Conkin (1952) shows that it pinches out to the south also.	The first and lowest of Cumings' "reefs" and the one which marked the Liberty-Saluda contact at Madison (section 1.12D).

lower Whitewater is complemented by a northward thinning of both the Saluda and the Liberty.

In conclusion it should be noted that although the Saluda has been called a tongue, facies, or facies wedge of the Whitewater many times since 1908, it is really part of a faunal zone that is called the Whitewater formation. Nonetheless, the Saluda differs lithologically, as well, especially in the southern half of its distribution in Indiana, where the lower part is very shaly. It may someday be possible to demonstrate north-south interfingering of both lithofacies and biofacies more convincingly than at present.

A CURRENT CLASSIFICATION OF CINCINNATIAN ROCKS

The classification of Caster, Dalvé, and Pope (1955, p. 13) is much used and is representative of modern knowledge of the rocks in the Cincinnati region. Even so, and although it does recognize the Cincinnatian as a time-rock unit, the distinctions between rock units and faunal units are not expressed at the formation-member level. Of course, no classification can be devised to express these distinctions until the relations of these kinds of units to each other have been demonstrated in the field. To do this will require long study of both the rocks and the fossils, study largely of a different sort from so much that has been done on these rocks.

It is, then, too soon for a new classification, but that of Sweet and others (1959) may serve for the time being. It is the only one of the many on our chart that attempts a clear distinction between time-rock and rock units. Names are used that were originally proposed for, or have come to mean, the time-rock or rock units that Sweet and others express by them. Some may question whether some of the formations in their Richmond group are really distinguishable rock units. Judging from the literature, they are to a degree, at least locally. Again, whether these formations will be confirmed or modified can only be settled by field study. Sweet and others (1959) introduced the classification saying, "... if the reference section of the Cincinnatian... be considered to include all those strata between the Pt. Pleasant (Cynthiana) and the Brassfield and their lateral equivalents, it is possible to recognize eight reasonably distinct formational units in the sequence. ".

Although their classification divides the Covington and Richmond groups, and the Maysville and Richmond stages at the Mt. Auburn-Arnheim boundary, the faunal and lithologic "break" within the Arnheim may be of greater significance. Sweet (personal communication) recognizes this possibility also, but he and the writers regard the classification of Sweet and others (1959) as a versatile means of expressing current work on the rocks of the Cincinnati region, against the day when a more representative classification can be proposed.

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Development of Stratigraphic Classification of Ordovician Rocks in the Cincinnati Region

BY

MALCOLM P. WEISS AND CARL E. NORMAN

Plate 1

DIVISION OF GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF OHIO
INFORMATION CIRCULAR NO. 26
1960

SILURIAN

ORDOVICIAN

RIDDELL, 1837 — BLUE LIMESTONE

LOCKE, 1838 — Flinty limestone; Marle 24'; BLUE LIMESTONE 1000'(?)

BRIGGS, 1838 — GREAT LIMESTONE DEPOSITE

MEEK AND WORTHEN, 1865 — NEWBERRY, 1869 (1871) — CINCINNATI GROUP

ORTON, 1873 and 1878 — Clinton ls. — LEBANON BEDS 293'; PROPER 425'; HILL QUARRY BEDS 125'; MIDDLE (EDENI) SHALES 250'; RIVER QUARRY BEDS 50+'; PT. PLEASANT BEDS 50'

NEWBERRY, 1873 — BELL, 1882 — Clinton — Medina 20' — CINCINNATI GROUP 1000'; LEBANON BEDS; EDEN SHALES; MT. PLEASANT

MILLER, 1881 — TRENTON GROUP 7-7-7-7-7; HUDSON RIVER GROUP 800'; UTICA GROUP 7-7-7-7-7

ORTON, 1888, 1889, 1890, and 1895 — Clinton series — Medina shales 25' — LOWER SILURIAN HUDSON RIVER GRUP 300'-750' OR SERIES 300'-1050'; Utica shale(s) N. Ohio 0-300'; TRENTON LIMESTONE 50'

PHINNEY, 1891 — BLATCHLEY AND ASHLEY, 1897 (1898) — Clinton ls. sh. — Medina (?) 60' — HUDSON RIVER FORMATION 260'-860'; UTICA FORMATION 0-300'; GALENA AND TRENTON FORMATIONS 486'-525'; TRENTON PERIOD

WINCHELL AND ULRICH, 1897 — CINCINNATI PERIOD 770'-870'; RICHMOND GROUP 350'; LEBANON BEDS 7-7-7-7; LORRAINE GROUP 200'; UTICA GROUP 250'; TRENTON GROUP (UPPER 50 OF 230'); TRENTON PERIOD

NICKLES, 1902 — CINCINNATIAN SERIES; RICHMOND GROUP 200'-300'; LORRAINE GROUP 310'; UTICA GROUP 260'; CINCINNATI PERIOD 770'-870'; Upper 7-7-7-7-7-7-7-7; Middle; Lower; Warren (Homotrypa bostleri beds) 80'; Mt. Auburn (Platystrophia lynx beds) 20'; Corryville (Chiloporella nicholsoni beds) 7'; Bellevue (Monticulipora molesta beds) 15'; Fairmount (Dekayia aspera beds) 80'; Mt. Hope (Amplexopora septosa beds) 7'; Upper Utica (Dekayella ulrichi beds) 60'; Middle Utica (Batostoma jamesi beds) 120'; Lower Utica (Aspidopore newberryi beds) 80'; Pt. Pleasant beds 130'

FOERSTE, 1903 — CINCINNATIAN SERIES; RICHMOND STAGE 235'; LORRAINE STAGE 300'; UTICA STAGE 260'; Hitz bed; Saluda; Richmond or U. Richmond bed 60'; Middle Richmond 115'; Lower Richmond 60'; Warren bed 70'; Mount Auburn bed 20'; Corryville bed 60'; Bellevue bed 20'; Fairmount bed 80'; Mount Hope bed 50'; Upper Utica bed 60'; Middle Utica 120'; Lower Utica 80'

NICKLES, 1903 — FOERSTE, 1904[a] — HOPKINS AND FOERSTE, 1903 (1904) — Clinton — CINCINNATIAN SERIES; RICHMOND 160'-200'; LORRAINE; UTICA; Madison 30'-40'; E. of Arch 40'-60' W.; Whitewater 45'-50'; Liberty 35'; Waynesville 50'; Warren 70'; Mount Auburn 20'; Corryville 50'; Bellevue 20'; Fairmount; Mount Hope; Upper 60'; Middle 120'; Lower 80'; TRENTON

PROSSER, 1903, 1905 — Clinton ls. 10'-50' — Belfast bed 5'; Saluda bed 20±; RICHMOND FORMATION 300'±; LORRAINE FORMATION 300'; UTICA SHALE (1903) EDEN SHALE (1905) 250'; TRENTON LIMESTONE 130'; MOHAWKIAN (UPPER BEDS)

FOERSTE, 1905[b] — CINCINNATIAN; RICHMOND; MAYSVILLE (LORRAINE) FORMATION; EDEN (UTICA) GROUP 260'; Saluda; Versailles; Waynesville; Arnheim 63'; Mount Auburn; Corryville; Bellevue; Fairmount; Mount Hope; Garrard; Middle Eden; Lower Eden; (Fulton layer); Point Pleasant 100'

NICKLES, 1905 — CINCINNATIAN SERIES; RICHMOND GROUP; MAYSVILLE (LORRAINE) GROUP; WICHESTER GROUP; Saluda (Madison); White-water; Liberty; Waynesville; Arnheim (Warren) 80'; Bellevue 10'-15'; Fair-mount; Mount Hope; Upper; Middle; Lower; Point Pleasant

FOERSTE, 1906 — NIAGARAN SERIES; RICHMOND 140'-210'; MAYSVILLE (LORRAINE) FORMATION; EDEN FORMATION; CINCINNATIAN SERIES; NIAGARAN SERIES; LAURELLEN LIMESTONE FORMATION; Brassfield member; CINCINNATIAN SERIES; RICHMOND FORMATION; MAYSVILLE FORMATION; EDEN FORMATION; CINCINNATIAN SERIES; CYNTHIANA FORMATION 40'-90'; (Lower Winchester); Saluda member 20'-40'; VERSAILLES 70'-100'; White-water member; Liberty member; Waynesville member 50'-70'; Arnheim member 50'; Mount Auburn member 20'; Corry-ville member 60'; Bellevue member 20'; Fair-mount member 80'; Mount Hope member 50'; UPPER GARRARD; LOWER GARRARD; MILLION (Upper Winchester) 120'-200'; Paint Lick member 40'-60'; Middle Eden member; Lower Eden member; UTICA; Fulton member 0-3'; Point Pleasant member; Green-dale member

BASSLER, 1906 (Classification prepared with Ulrich) — CINCINNATIAN SERIES; RICHMOND GROUP 240'; COVINGTON GROUP 415'; EDEN FORMATION 230'; MILLION 95'; TRENTON 45'; Saluda formation 35'; Whitewater formation 40'; Liberty formation 35'; Waynesville formation 50'; Arnheim formation 80'; McMillan formation 85'; Mt. Auburn member 35'; Corryville member 35'; Bellevue member 15'; Fairmount member 50'; Mt. Hope member 45'; McMicken formation 60'; Southgate member 120'; Economy member 50'; Fulton 45'; Point Pleasant formation 15'; Bromley formation 30'

CUMINGS, 1907 (1908) — WILLIS, 1912 — CINCINNATI GROUP; RICHMOND; MAYSVILLE OR LORRAINE; EDEN OR UTICA; Elkhorn (Platystrophia morituras zone); Whitewater (Rhynchotrema dentata zone); Saluda (Tetradium minus zone); Liberty (Strophomena planumbona zone); Waynesville (Dalmanella meeki zone); Arnheim; Upper; Middle; Lower; Hebertella sinuata zone; Calliapora lycoperdon zone; Rafinesquina alternata zone; Plectorthis plicatella zone; McMicken (Upper); Southgate (Middle); Economy (Lower); Drakeus ulrichi zone; Calliapora Wasselli zone; Dalmanella multisecta zone

FOERSTE, 1909[a] — RICHMOND FORMATION; MAYSVILLE FORMATION; EDEN FORMATION; CINCINNATIAN SERIES; CINCINNATIAN SERIES; CYNTHIANA FORMATION; Elkhorn; Whitewater; Liberty; Waynesville; Arnheim; Mount Auburn; Corryville; Bellevue; Fairmount; Mount Hope; McMicken; Southgate; Economy; Fulton beds 5'; Nicholas beds 35'; Point Pleasant beds

FOERSTE, 1909[b], 1910 — BRAUN, 1916 — LATTMAN, 1954 (Part only) — RICHMOND FORMATION; MAYSVILLE FORMATION; EDEN FORMATION; CINCINNATIAN SERIES; CINCINNATIAN SERIES; CYNTHIANA FORMATION; Elkhorn; Whitewater; Saluda; Liberty bed 32'; Waynesville bed; Arnheim bed; Blanchester division; Clarksville division; Fort Ancient division; Oregonia division; Sunset division; Mount Auburn; Corryville; Bellevue; Fairmount; Mount Hope 30'; McMicken or Point Lick bed 66'; Southgate bed; Economy bed; Fulton bed; Nicholas bed 50'±; Greendale bed 50'

FOERSTE, 1912[a] and 1912[b] — RICHMOND FORMATION; MAYSVILLE FORMATION; EDEN FORMATION; CINCINNATIAN SERIES; CINCINNATIAN SERIES; CATHEYS FORMATION; Elkhorn; Whitewater; Saluda; Liberty; Laughery; Waynesville; Blan-chester; Clarks-ville; Fort Ancient; Arnheim; Oregonia; Sunset; Mount Auburn; Corryville; McMillan; Bellevue; Fairmount; Fairview; Mount Hope; McMicken; Southgate; Economy; Fulton; Cathays; Nicholas; Greendale

ULRICH, 1913 — SILURIAN; MEDINAN; CINCINNATIAN; ORDOVICIAN; CINCINNATIAN; MOHAWKIAN; TRENTON; RICHMOND; MAYSVILLE; EDEN; Elkhorn; Whitewater (including Saluda); Liberty-Waynesville; Arnheim; McMillan; Fairview; McMicken; Southgate; Economy; Fulton; Cynthiana

CUMINGS & GALLOWAY, 1912 (1913) — CINCINNATIAN SERIES; RICHMOND GROUP; MAYSVILLE GROUP; EDEN GROUP; Elkhorn; Whitewater 30'± (Homotrypa worthenі zone); Saluda (Tetradium minus zone) 10'; Liberty (Strophomena planumbona zone) 50'; Waynesville (Dalmanella meeki zone) 105'); Corryville-Arnheim or Hermon (Rafinesquina fracta zone) 110'; Bellevue (Rafinesquina ponderosa zone); Mt. Hope-Fairmount (Fairview) (Plectorthis plicatella zone) 75'; McMicken (Heterotrypa ulrichi zone) 75'; Southgate (Hallopora ostelli zone); Economy

A B C D

BASSLER, 1915
FOERSTE, 1924
(Kentucky names in parentheses)

SILURIAN (Bassler) — UPPER ORDOVICIAN (Foerste)
MEDINAN (Bassler) — RICHMOND (Foerste)
RICHMONDIAN (Bassler) — RICHMOND (Foerste)

ORDOVICIAN — CINCINNATIAN
MAYSVILLE — EDEN
EDEN — MOHAWKIAN
TRENTON — CYNTHIANA

Elkhorn (Belfast)
VERSAILLES — Whitewater-Saluda (Madison-Fowler)
Laughery — Liberty
Waynesville — Blan-chester
Clarks-villa — Fort Ancient
ARNHEIM — Oregonia — Sunset
McMILLAN — Mt. Auburn — Corryville (Gilbert) — Bellevue (Tate)
FAIRVIEW — Fairmount — Mt. Hope (Upper Garrard)
Million — Southgate — Economy
Fulton
Rogers Gap — Gratz — Bromley — Greendale

FENNEMAN, 1916 — EDEN GROUP; RICHMOND GROUP; Whitewater formation 50'-100'; Liberty limestone — 85' total —; Waynesville; Arnheim shale 80'; McMillan formation; Fairview formation; Mount Auburn concretionary shale 20'-35'; Corryville shale 35'-50'; Bellevue limestone 0-23'; Fairmount limestone 70'-85'; Mount Hope shale 16'-50'; Latonia shale 180'-230'; Utica shale 0-24'; Cynthiana formation 100'

MILLER, 1919 — Brassfield — CINCINNATIAN SERIES; RICHMOND STAGE; MAYSVILLE STAGE; EDEN STAGE; CINCINNATIAN SERIES; MOHAWKIAN SERIES; Saluda 0-40'; Liberty 50'; Waynesville 40'-50'; Arnheim 50'-100'; Mt. Auburn 20'; Corryville 60'; Bellevue 20'; Fairmount 80'; Mt. Hope 50'; Garrard (Paint Lick) 60'; Million 160'-200'; Fulton 5'; Point Pleasant; Greendale

CUMINGS, 1922 — SILURIAN; MEDINAN; ALEXANDRIAN; Brassfield — ORDOVICIAN; CINCINNATIAN; RICHMOND; MAYSVILLE; EDEN 200'-240'; MOHAWKIAN; TRENTON; Elkhorn 50'; Whitewater 80'; Saluda 0-7'; Liberty 25-50'; Waynesville 50-100'; Arnheim 80'+; Mt. Auburn 0-20'; Corryville 40'-50'; Bellevue 25'; Fairmount 75'; Mt. Hope; McMicken; Southgate; Economy; CYNTHIANA (Point Pleasant)

REEVES, 1925 — Brassfield — SILURIAN; MEDINAN; RICHMOND; CINCINNATIAN; MAYSVILLE; EDEN; MOHAWKIAN; TRENTON; Elkhorn; Whitewater; Saluda; Liberty; Waynesville; Arnheim; Mount Auburn; Corryville; Belleview; Fairmount; Mount Hope; McMicken; Southgate; Economy; Cynthiana

WOLFORD, 1930 — CINCINNATIAN SUBSERIES; RICHMOND SUBSERIES; MAYSVILLE SUBSERIES; EDEN SUBSERIES; MOHAWKIAN; Elkhorn formation; Whitewater formation; Liberty formation; WAYNESVILLE FORMATION; ARNHEIM FORMATION; Blanchester member; Clarksville member; Ft. Ancient member; Oregonia member; Sunset member; Mt. Auburn member; Corryville member; Bellevue member; Fairmount member; Mt. Hope member; McMicken member; Southgate member; Economy member; UTICA FORMATION

CHAPPARS, 1935 — Median — ORDOVICIAN; CINCINNATIAN; RICHMOND (of Median Age according to Ulrich and Bassler); MAYSVILLE; EDEN; LATONIA; UTICA; TRENTON; CYNTHIANA; Brassfield formation 0-30'; Elkhorn formation 50'; Whitewater (and Saluda) formations 90'; Liberty formation 40'; Waynesville formation 95'; Arnheim formation 75'; Mt. Auburn formation 15'; Corryville formation 45'; Bellevue formation 30'; Fairmount formation 60'; Mt. Hope formation 55'; McMicken formation 70'; Southgate formation 120'; Economy formation 45'; Fulton 0-50'; Rogers Gap formation

FLOWER, 1946 — MOHAWKIAN SERIES; CINCINNATIAN SUBSERIES; RICHMOND SUBSERIES; MAYSVILLE GROUP; EDEN GROUP; Elkhorn form.; Whitewater formation; Liberty form.; Waynesville formation; Arnheim formation; Fairview beds; Upper Whitewater; Saluda coral beds; Lower Whitewater; Blanchester member; Clarksville member; Fort Ancient member; Oregonia member; Sunset member; Mount Auburn member; Corryville member; Bellevue member; Fairmount member; Mount Hope beds; McMicken beds; Southgate member; Economy member; Fulton beds; Cynthiana limestone; Point Pleasant limestone; Bromley shale; Greendale limestone

BERNHAGEN AND SCHAEFER, 1947 — CINCINNATIAN SERIES; EDEN GROUP 300'; MAYSVILLE GROUP 200'; EDEN GROUP 200'; MOHAWKIAN SERIES; Elkhorn formation; Whitewater formation; Liberty limestone; Waynesville shale; Arnheim shale; McMillan formation; Fairview formation; Latonia shale; Fulton shale; Cynthiana formation 150'

KOTTLOWSKI AND WATERS, 1950 — Brassfield limestone — CINCINNATIAN; RICHMOND; MAYSVILLE; EDEN; MOHAWKIAN; Trenton limestone; Elkhorn fm. 50' (Platystrophia morituras); Whitewater fm. 75' (Rhynchotrema dentatum); Saluda fm. 50' (Columnaria alveolata); Liberty fm. 50' (Strophomena planumbona); Waynesville fm. 75' (Dalmanella meeki); Arnheim fm. 80' (Diaorthis carleyi); Mt. Auburn fm. 10' (Platystrophia auburnensis); Corryville fm. 45' (Chiloporella flabellata); Bellevue fm. 25' (Platystrophia ponderosa); Fairmount fm. 60' (Strophomena planoconvexa); Mt. Hope fm. 25' (Dekayia aspera); McMicken fm. 60' (Heterotrypa ulrichi); Southgate fm. 120' (Climacograptus typicalis); Economy fm. 80' (Amplexopora persimilis); (Sowerbyella rugosa); (Constellaria emaciata)

KERR, 1951 — (Thicknesses are only for exposures in Cincinnati) — CINCINNATIAN; UPPER ORDOVICIAN-CINCINNATIAN SUBSERIES; RICHMOND; COVINGTON SUBSERIES; EDEN GROUP; ARNHEIM FORMATION; Sunset member; MAYSVILLE GROUP; McMillan formation; Fairmount Fm. (in chart) Fairmount member (in text); Mt. Auburn member 15'; Corryville member 44'; Bellevue member 28'; Fairmount member 60'; Mt. Hope member 53'; McMicken formation 69'; Southgate formation 120'; Economy formation 44'; Cynthiana formation

PATTON, PERRY AND WAYNE, 1953 and GÜTSTADT, 1958 — (Thicknesses as in S.E. Indiana) — ALBION; MEDINA; Brassfield — CINCINNATIAN SERIES; RICHMOND GROUP; MAYSVILLE GROUP; EDEN GROUP; MOHAWKIAN SERIES; TRENTON GROUP; Elkhor.; Whitewater 4'-5'; Saluda 40'-45'; Liberty 50; Waynesville 65'-75'; Arnhim 70'-0'; Mount Auburn 5'-2'; Corryville 20'-5'; Bellevue 25'-30'; Fairmount 30'-40'; MountHope 25'-45'; McMicken 60'-80'; Southgate 70'-110'; Economy 50'-80'; Cynthiana 40'-50'

TWENHOFEL AND OTHERS, 1954 — (Based on Cumings and Cumings and Galloway) — CINCINNATIAN SERIES; RICHMONDIAN STAGE; EDENIAN STAGE; CINCINNATIAN SERIES; RICHMOND GROUP; EDEN GROUP; ?; ?; Elkhorn limestone; Whitewater – Saluda; Liberty shale and limestone; Waynesville shale and limestone; Arnheim shale and limestone; Mt. Auburn shale and limestone; Corryville shale and limestone; Bellevue shale and limestone; Fairmount shale and limestone; Mt. Hope shale and limestone; McMicken shale; Southgate shale; Economy shale; Fulton shale; Cynthiana limestone

CASTER, DALVÉ AND POPE, 1955 and BUCHER, CASTER AND JONES, 1945 — Brassfield — CINCINNATIAN SERIES; CINCINNATIAN SUBSERIES; COVINGTON GROUP; CINCINNATIAN GROUP (Thicknesses of sub-Eden group from 1945 edition.); Elkhorn formation 60'±; Upper Whitewater member 40'±; Saluda member 6'; Lower Whitewater member 30'±; Whitewater formation 97'; Liberty formation 28'; Blanchester member 35'; Clarksville member 26'; Ft. Ancient member 36'; Arnhim formation 62'; Oregonia member 27'; Sunset member 35'; McMillan formation 87'; Mt. Auburn member 15'; Corryville member 44'; Bellevue member 28'; Fairmount member or Mill Quarry beds 90'; Fairview formation 113'; Mt. Hope member 53'; McMicken member 69'; Southgate member 122'; Economy member 52'; Latonia formation 243'; Fulton beds; Pt. Pleasant or "River Quarry beds" 34'; Bromley shale 15' exposed

SWEET, TURCO, WARNER AND WILKIE, 1959 — Time-rock units applicable to North America — Rock units in the Cincinnati region — CINCINNATIAN SERIES; RICHMOND STAGE; MAYSVILLE STAGE; EDEN STAGE; COVINGTON GROUP; Brassfield formation; Elkhorn formation; Whitewater formation; Liberty formation; Waynesville formation; Arnheim formation; McMillan formation; Fairview formation; Eden formation; Pt. Pleasant (Cynthiana)

SILURIAN

ORDOVICIAN