STATE OF OHIO
George V. Voinovich, Governor
DEPARTMENT OF NATURAL RESOURCES
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Open-File Report 95-1

The Richmond Group of the Cincinnati Province

An unpublished manuscript

By Dr. William Henry Shideler

Edited by Joe H. Marak
Department of Geology, Miami University
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About the man and his manuscript.

The man.

Dr. William H. Shideler

William Henry Shideler was born in 1886 to parents residing in West Middletown, Butler County, Ohio. He attended Middletown High School, then completed his baccalaureate at Miami University in 1907, and earned a doctorate at Cornell University in 1910. He immediately joined Miami University where he taught entomology and related natural science courses.

Shideler founded the Department of Geology at Miami University in 1920 and retired 37 years later. During his tenure, he published some 25 short papers, abstracts, and maps. He was the associate of prominent geologists such as Ulrich, Bassler, Foerste, Williams, Miller, Ruedemann, Case, Flower, and Caster. At one time, more than 100 of his former students were teachers in colleges and Universities. Shideler also served as President of The Association of Geology Teachers (1954-55), President of the Ohio Academy of Science (1951-52), and Vice-President of Sigma Gamma Epsilon (national geology honorary society) in 1954-55.

Upon retirement from Miami University, Shideler served at Hiram College and founded a geology department there. He died in 1958. Geologists have honored Shideler by naming 13 species, 3 genera, 1 family, and one mountain in Antarctica after him.

The manuscript.

The manuscript is composed of type-written copy with hand-written corrections inked in. Occasional notes in the columns are attributed to various readers. The copy is not dated, but Shideler states that this work was done after five years of work for The Ohio Geological Survey. A Report-of-Progress to that survey has been found that is dated 1927.

Although much of the information in this manuscript is out-dated, and some has been discredited, I think much useful information remains. I have attempted to reproduce the manuscript as it was written with only a few changes in spelling and format.

The Ohio Division of Geological Survey has copies of the 1910 to 1930, 15-minute topographic maps noted in this manuscript. These maps are very useful in locating some of the places (eg. school houses) mentioned in the text.

-Joe H. Marak

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Preface

THE RICHMOND FORMATIONS OF SOUTHWESTERN OHIO

Unpublished manuscript of Dr. William H. Shideler.

The Richmond of the Cincinnati Province forms an irregular oval outcrop around the older formations as exposed by the erosion of the central portion of the Cincinnati Anticline, and in south-western Ohio forms the outcropping bed rock over about 2000 square miles, distributed in an irregular crescent. It has been investigated more or less sporadically for almost a century, beginning with John Locke in 1838, but a large part of the information gleaned during this time has never been recorded, since up to a few decades ago the activities of the workers have been directed chiefly to the acquisition of "specimens", without regard for their origin. With the development of new concepts of stratigraphy and paleogeography by such American pioneers as Dr. E.O. Ulrich, Professor Charles Schuchert, and others, it is now necessary that close specific distinctions be made, and that precise stratigraphic positions and geographic ranges be recorded.

Of late years there has been a marked revival of interest in the Richmond of North America, and recent attempts have been made to correlate the Richmond of Ontario and Quebec, and of Michigan, Wisconsin, Illinois, Minnesota, Iowa, Missouri and Tennessee with the typical Cincinnati region. Debates over the position of the Ordovician-Silurian boundary have added to the interest, so that at the present time there seems to be considerable interest in detailed information respecting the Richmond. Lack of detailed facts is responsible for a fair percentage of the controversies. Pioneers in the more critical modern methods as applied to the Richmond of the Cincinnati Province are Dr. E.O. Ulrich, Dr. August F. Foerste, John M. Nickles, and Dr. George M. Austin, but of these only some detailed work done by Nickles and Foerste has been published, and this is more or less scattered. Professor E.R. Cumings has made a good beginning in Indiana, but in the province as a whole much work still remains to be done.

This volume is intended as a record of the observations recorded by the writer over a period of 17 years, of which time five summers were in the service of the Geological Survey of Ohio, devoted specifically to this work. A selected set of sections has been visited annually over 10 years, in some cases several times in a single season, since the shifting vagaries of erosion often temporarily expose important contacts which are ordinarily hidden, or bring to light unexpected lenses and zones of faunules. Extensive collections of fossils have been made, and over 1500 specimens of bryozoa have been sectioned.

The writer wishes to acknowledge his indebtedness to Dr. A.F. Foerste, Dr. Geo. M. Austin, and Professor S.R. Williams for advice and assistance in the field, To Chas. F. Faber for introduction to some of the secret fossil localities of the old collectors, and to Dr. E.O. Ulrich and Dr. R.S. Bassler for general advice and for offering the facilities of the National Museum collections in the identification of many of the species.

The Richmond

The Maysville of the Cincinnati province is followed by a series of beds, predominantly of shales and thin limestones, and of quite variable thickness, but giving a total of about 350' in a generalized section of the northern part of the province as exposed.

These beds, originally described in the Orton survey[1] as the Lebanon Beds, were named Richmond by Winchell and Ulrich in 1879,[2] the term Lebanon being preoccupied by a Trenton formation in Tennessee.

The term Richmond has been in general use ever since.

The exact dividing line between the Maysville and the Richmond has never been agreed upon, nor is there entire agreement as to the limits of the various subdivisions of the Richmond. Considering both faunal and pure stratigraphic factors, the described subdivisions of the Richmond fall rather naturally into three groups, the relationships of which are shown on the chart below.

Subdivisions of The Richmond Group

Richmond	Upper	Elkhorn		53'
		Whitewater-Saluda		85'
	Middle (Laughery)	Liberty		41'
		Waynesville	Blanchester	36'
			Clarksville	22'
			Ft. Ancient	36'
	Lower	Arnheim	Oregonia	30'
			Sunset	42'
				345'
Maysville		Mt. Auburn		

This placing of the base of the Richmond is not generally agreed with by other workers in the Cincinnati Province. Nickles[3] referred the Arnheim (Warren as then named) entirely to the Maysville. Foerste sometimes has had a tendency to raise the boundary to the base of the Oregonia, and in mapping the Maysville-Richmond boundary for the 1920 Geologic Map of Ohio it was so placed. Cumings has repeatedly contended for the inclusion of the Lower Arnheim or Sunset with the Maysville, and the evidence is summarized and his arguments repeated in a recent publication.[4]

On the other hand, Orton included these beds now known as the Arnheim in his "Lebanon", and Ulrich has consistently held for the lower boundary, as also have Bassler, Schuchert, and others.

The discussion as to the base of the Richmond and the relations of the Arnheim is given added importance by the contentions of Ulrich that the Ordovician-Silurian boundary should be dropped to the top of the Maysville, including the whole of the Richmond with the Silurian.

While the question of the Ordovician-Silurian boundary is one which should be considered when dealing with the Maysville-Richmond boundary, no argument will be made here either for the commonly accepted division line at the top of the Richmond, or for the new position between the Mt. Auburn and the Arnheim proposed by Ulrich. It is realized that the problem is too broad a one to be settled by an investigation conducted in a single geologic province. However, a special effort has been made during this investigation to get at the local evidence pertaining to the question, and many significant facts have been developed. Some of these support one contention, some the other. They will be presented for what they are worth, leaving the final settlement of the question to those who have the more

intimate acquaintanceship with the other geologic provinces necessary for argumentation. The commonly accepted Ordovician-Silurian boundary is here retained, however, because of the preponderance of evidence in the Cincinnati Province is regarded strongly in its favor.

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Notes:

[1]Report on the Third Geol. District, Geol. Surv. Ohio Vol. 1 1873 p. 371.
[2]Minn. Geol. & Nat. Hist. Surv., Paleon., Vol. 3 Pt. 2, 1879, p. C111.
[3]Jour. Cin. Soc. Nat. Hist., Vol. 20, 1906, pp. 86-8.
[4]Handbook of Ind. Geol., Part IV pp. 428-9. Pub. 21 Dept. Conservation State of Ind., 1922.

The Arnheim

Naming the Arnheim

Originally the beds now known as Arnheim were called "Warren or *Homotrypa bassleri* beds" by Nickles,[1] who listed 85 species of fossils as occurring in them. Nickles described the beds as follows; "The Mt. Auburn beds pass with little distinction into the next series of beds. For these the name Warren beds is proposed - - - Toward the top of this division the layers, both limestone and shale, especially the latter, become rough and nodular, indicating a marked change in the sedimentation. For this reason these layers are considered to mark the close of the Lorraine. Immediately after them come the even-bedded limestones and marly shales of the lower Richmond." The thickness was given as about 80'.

But Foerste pointed out that the term Warren was preoccupied, and proposed the name Arnheim as a substitute,[2] taking as his type section exposures on Straight Creek, south of the village of Arnheim, Brown County, Ohio, with a thickness of approximately 63'.

At this point it may be mentioned that *Homotrypa bassleri*, while generally present in the Arnheim of Ohio and Indiana, is a quite uncommon species.

The Arnheim is perhaps the most widely distributed formation in the Cincinnati Province, shows no marked thinning toward the flanks of the Cincinnati Arch as do the preceding Corryville and Mt. Auburn, and is well developed around the southern part of the province as exposed in Kentucky, where the Corryville is absent and the Mt. Auburn is reduced or greatly modified (east side of the arch) or missing (west side).

Relation to The Maysville Group

That the thinning down of these Maysville formations is not due to post-Maysville and pre-Arnheim erosion is proven by the presence above the Corryville of a more or less typical Mt. Auburn closing the Maysville at all points in Ohio and Indiana, and a more or less modified Mt. Auburn at all points observed on the east flank of the Cincinnati Arch as far south as Stanford, Kentucky. At Madison, Indiana, a lithologically typical but faunally modified Mt. Auburn 9' thick underlies the Arnheim, but thins rapidly and disappears as one goes southward into Kentucky, so that at Jefferson County, Kentucky and southward to Lebanon the Arnheim rests upon the Bellevue, the Corryville also having pinched out beneath the Mt. Auburn. The Mt. Auburn varies somewhat in thickness, but that its local thinning cannot be attributed to post-Maysville erosion is shown by the fact that three subdivisions of the Mt. Auburn are almost everywhere present, and the thinning of the Mt. Auburn as a whole may be due to the thinning of the lower part, or of the middle part carrying the *Platystrophia ponderosa* var. *auburnensis*, as well as of the upper part.

So far then, as the Cincinnati Province is concerned, there was no noticeable uplift and erosion in any region now exposed, though there must have been erosion going on closely adjacent to the present exposed area, judged by the coarser sediments in the Arnheim of Kentucky.

However, that a general shoaling of the sea did occur at the close of the Maysville is shown by the presence at the base of the Arnheim on the north side of the arch of more or less barren strata composed in part of finely ground fossil fragments. These limestones are distinctly cross-bedded in Brown and Adams Counties, Ohio, and thence southward along the east flank of the arch, and at Madison, Indiana, and thence southward along the west flank.. On both flanks, but more especially on the east, this cross-bedded layer thickens, becomes argillaceous and even sandy in places, and is beautifully sun-cracked between Richmond and Stanford, Kentucky.[3]

It is clear, then, that at the close of the Maysville there was a general shoaling and at least partial if not complete withdrawal of the Maysville sea, but without distinct erosion in the Cincinnati Province. Later, sandy muds and fine sands were drifted into the margins of this area from regions closely adjacent, and this influx continued somewhere or other in the now exposed part of the Cincinnati Province during the whole of the Richmond.

Following the deposition of the basal cross-bedded layer, the sea deepened temporarily over the whole of the area now exposed. Coming in with these deeper waters were faunules of two distinct types, as will be seen later. Wave after wave of invading

The Arnheim

faunules begin to enter the region during the Arnheim and continue through the whole of the Richmond.

The record of these earlier shifting faunules was best preserved in the deeper Arnheim waters about the north end of the Cincinnati Arch. Perhaps the most typical region is that between Arnheim, Brown County, and West Union, Adams County. A composite section of this is given below.

The Russellville to Decatur Composite Section

The data were obtained from the excellent exposures along the North Fork of Eagle Creek east and north of Russellville, and along the creeks crossing the West Union Pike within the first four miles east of Decatur. In succession, going east from Decatur, these creeks are Washburn Run, Ada Run, and East Fork of Eagle Creek.

In constructing the composite section of this region, datum planes used were the basal cross-bedded layer, the well known fauna of *D. carleyi*, *Leptaena richmondensis* var. *praecursor*, etc. which mark the base of the upper Arnheim, two layers of *Strophomena concordensis*, and the base of the Waynesville.

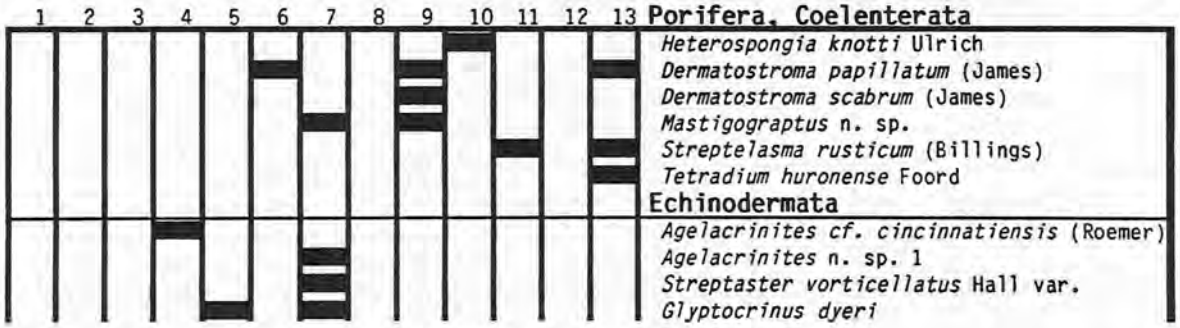
The exposures on the Northwest Fork of Eagle Creek show divisions 1 and 2 a mile and a half east of Russellville. Division 2 rises with the creek and the top forms the floor of the creek beneath the bridge over the creek a mile and a half north of Russellville. Above this, divisions 3-7 are shown completely, and divisions 8-10 in part. The Washburn Run section shows divisions 1 and 2 completely, 3-8 in part, and 9-13 completely. Ada Run shows divisions 1-2 and 9 completely, the others being covered wholly or in part. East Fork shows only divisions 12-13 to advantage.

The section follows:

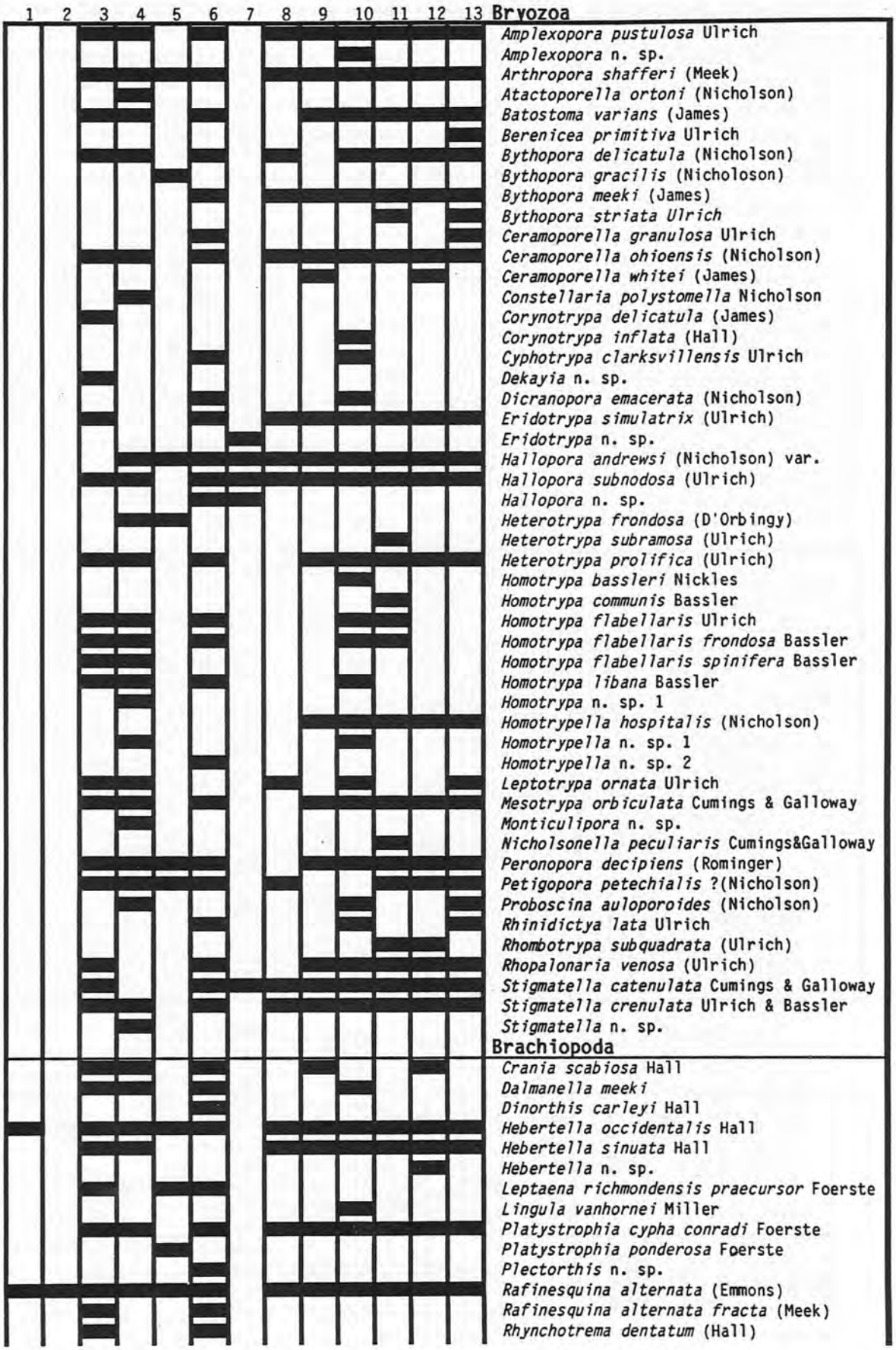
- - - Russellville to Decatur Composite Section - - -

	Thickness
13 - Somewhat lumpy shales, to top of Arnheim.	6'06"
12 - Second *Strophomena concordensis* bed.	2'08"-6'
11 - Even-bedded shales and thin limestones.	10'
10 - Lumpy shales and limestones, more or less typical Oregonia.	10'
9 - First *Strophomena concordensis* bed.	1'-1'8"
8 - Shales and limestones.	13'
7 - Shales. Second *Glyptocrinus dyeri* zone.	2'06"
6 - Shales and thin limestones. *Leptaena* at base. *Dinorthis carleyi* fauna, basal Oregonia.	7'
5 - Shales and harder limestones. First *Glyptocrinus dyeri* zone.	4'
4 - Shales and shelly limestones.	4'
3 - Shales and thin limestones with the first Richmond species.	8'
2 - More or less argillaceous, barren limestones.	2'
1 - Cross-bedded limestones, more or less crystalline, and shelly in spots.	1' 6"-4'

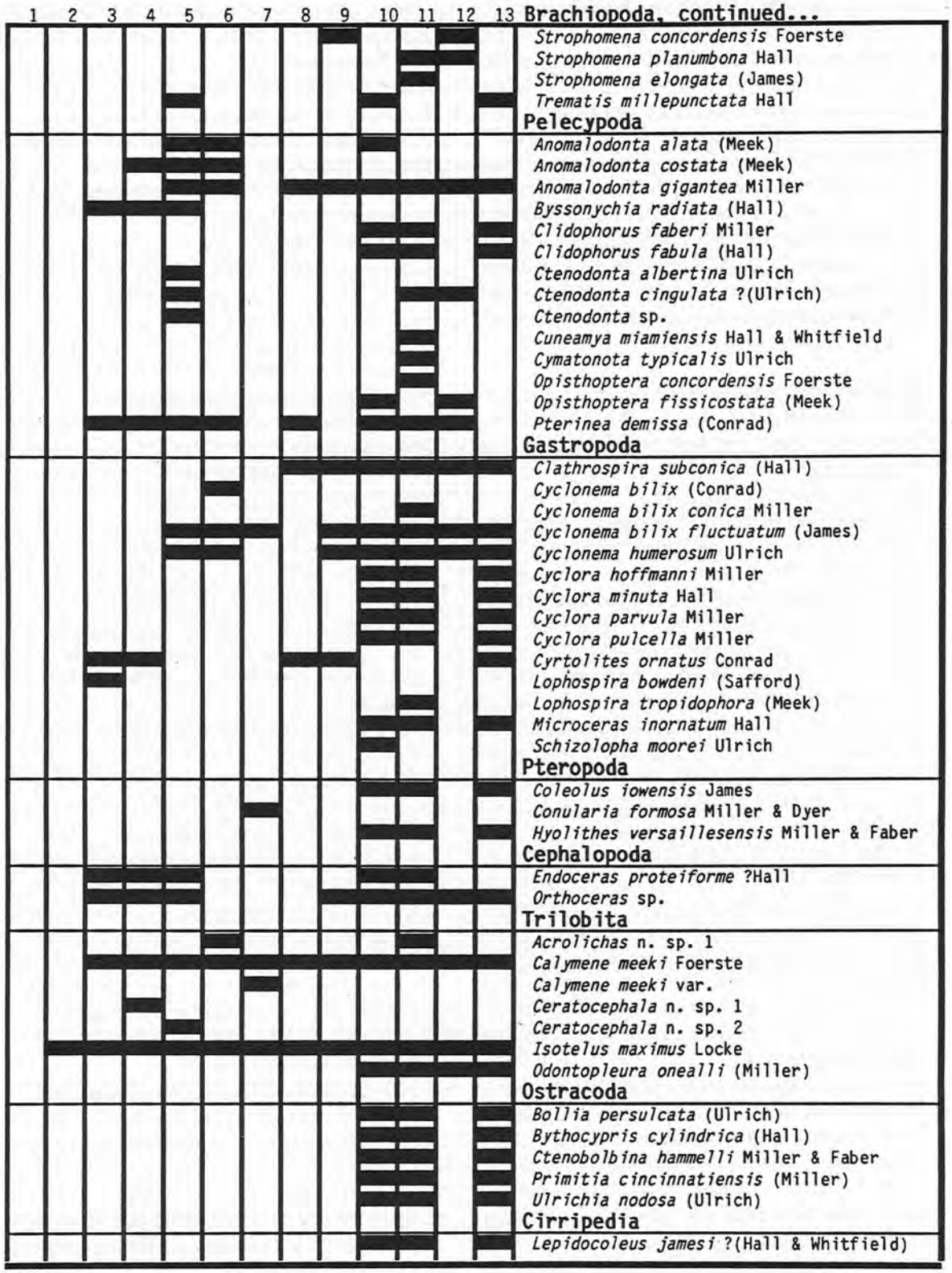
--- Faunal List for the Russellville-Decatur Composite Section ---



The Arnheim


1 2 3 4 5 6 7 8 9 10 11 12 13
Bryozoa
Amplexopora pustulosa Ulrich
Amplexopora n. sp.
Arthropora shafferi (Meek)
Atactoporella ortoni (Nicholson)
Batostoma varians (James)
Berenicea primitiva Ulrich
Bythopora delicatula (Nicholson)
Bythopora gracilis (Nicholoson)
Bythopora meeki (James)
Bythopora striata Ulrich
Ceramoporella granulosa Ulrich
Ceramoporella ohioensis (Nicholson)
Ceramoporella whitei (James)
Constellaria polystomella Nicholson
Corynotrypa delicatula (James)
Corynotrypa inflata (Hall)
Cyphotrypa clarksvillensis Ulrich
Dekayia n. sp.
Dicranopora emacerata (Nicholson)
Eridotrypa simulatrix (Ulrich)
Eridotrypa n. sp.
Hallopora andrewsi (Nicholson) var.
Hallopora subnodosa (Ulrich)
Hallopora n. sp.
Heterotrypa frondosa (D'Orbingy)
Heterotrypa subramosa (Ulrich)
Heterotrypa prolifica (Ulrich)
Homotrypa bassleri Nickles
Homotrypa communis Bassler
Homotrypa flabellaris Ulrich
Homotrypa flabellaris frondosa Bassler
Homotrypa flabellaris spinifera Bassler
Homotrypa libana Bassler
Homotrypa n. sp. 1
Homotrypella hospitalis (Nicholson)
Homotrypella n. sp. 1
Homotrypella n. sp. 2
Leptotrypa ornata Ulrich
Mesotrypa orbiculata Cumings & Galloway
Monticulipora n. sp.
Nicholsonella peculiaris Cumings&Galloway
Peronopora decipiens (Rominger)
Petigopora petechialis ?(Nicholson)
Proboscina auloporoides (Nicholson)
Rhinidictya lata Ulrich
Rhombotrypa subquadrata (Ulrich)
Rhopalonaria venosa (Ulrich)
Stigmatella catenulata Cumings & Galloway
Stigmatella crenulata Ulrich & Bassler
Stigmatella n. sp.
Brachiopoda
Crania scabiosa Hall
Dalmanella meeki
Dinorthis carleyi Hall
Hebertella occidentalis Hall
Hebertella sinuata Hall
Hebertella n. sp.
Leptaena richmondensis praecursor Foerste
Lingula vanhornei Miller
Platystrophia cypha conradi Foerste
Platystrophia ponderosa Foerste
Plectorthis n. sp.
Rafinesquina alternata (Emmons)
Rafinesquina alternata fracta (Meek)
Rhynchotrema dentatum (Hall)

The Arnheim



As noted before, divisions 1 and 2 are essentially devoid of recognizable fossils.

Perhaps the most striking feature of this fossil list is the fauna of division 3. This, the first fossiliferous division of the Arnheim, has a fauna of 37 species, more than half of which are wide ranging and long-lived forms of no special significance.

But practically every one of the remaining species is a fossil characteristic of the Arnheim, or of the Richmond generally, as, for example, *Rhopalonaria venosa, Eridotrypa simulatrix, Mesotrypa orbiculata, Stigmatella catenulata, S. crenulata, Amplexopora pustulosa, Batostoma varians, Leptaena richmondensis* var. *praecursor*, and *Rhynchotrema dentatum*. North of Russellville the first *Rhopalonaria* was found 17' below the *Dinorthis carleyi* horizon, while the first *Rhynchotrema* and *Leptaena* occur over 12' below the *D. carleyi*.

Correlation with Kentucky Exposures

This condition is not peculiar to this general region only, but careful search under favorable conditions of exposure will demonstrate the same thing anywhere in Ohio and Indiana. In Kentucky, where the lower Arnheim or Sunset is much less fossiliferous, the demonstration is naturally difficult or impossible. If the Arnheim be traced along the east side of the arch into Kentucky, the lower or Sunset division rapidly becomes barren, and the upper or Oregonia division much reduced. Traced around the northern outcrops in Ohio and Indiana, the Richmond element in the Sunset becomes reduced, but *Leptaena* appears at or near the base in practically all localities.

The typical Sunset locality at Sunset, Kentucky, shows 2'+ of massive limestones at the base, followed by a 1'6" limestone composed largely of fossil fragments and with an occassional *Platystrophia ponderosa* and with considerable *Stromatocerium*. The same condition is found a half mile below Howards Mill, and at other places in the general region.

At Agawam Station, 8.5 miles below Winchester, Kentucky, on the Winchester-Irvine branch of the L&R Railroad, the cross-bedded basal limestones are absent, but the *Stromatocerium* is abundant enough to constitute a reef 1'9" thick. Following this are 21'3" of fossiliferous Arnheim with fossils few and poorly preserved, but showing *Heterospongia subramosa, Platystrophia ponderosa, Hebertella, Rafinesquina, Lophospira bowdeni*, etc.

There is no doubt of the sharpness of the faunal break between the Mt. Auburn and the Arnheim, and this faunal break is always associated with evidence of a break in sedimentation.

In Jefferson County, Kentucky, at the Railrod trestle west of Fisherville, the Richmond fauna appears as usual at the very beginning of the Arnheim. Below this trestle are 5' of Bellevue topped by resistant limestones which are poorly exposed but which appear to represent the basal Arnheim. The first *Dinorthis carleyi* is 6'8" above these limestones, associated with *Rhynchotrema dentatum* on top of a thin limestone 1' above water level just above the trestle, and 1' below a 3" barren limestone. The interval down to the Bellevue is largely covered. A second occurrence of *R. dentatum*, associated with *Leptaena richmondensis* variety *praecursor* but with *Dinorthis* absent, is 16'6" above the first occurrence. Although no *D. carleyi* was found at this higher level, this is considered to be the regular horizon at which *Dinorthis, Leptaena* and *Rhynchotrema* are associated, since *Platystrophia ponderosa* is found here as far up as the second zone of *Rhynchotrema dentatum*, and in Ohio and Indiana has never been observed to go above the horizon of *Dinorthis, Leptaena* and *Rhynchotrema*.

From this level it is 50.5' all covered except 5' at the top and 5' at the bottom, to the base of the Waynesville coral reef as exposed in the Railroad cut toward Fisherville from the trestle, which reef Butts[4] considers to be the base of the Waynesville in this part of Kentucky. This would give a total thickness to the Arnheim of close to 75', and without showing any distinct division into the Sunset and the Oregonia.

Faunal Relationships

The Richmond fauna came into the Cincinnati Province just as early in the Arnheim as the life conditions became favorable. The Sunset or lower Arnheim has characteristic Richmond species throughout, the Richmond invasions beginning with the first return of life after the disturbances incidental to the Maysville-Richmond break, and not, as is commonly supposed, with *Dinorthis carleyi* and its associates at the base of the Oregonia or upper division of the Arnheim.[5]

Taken as a whole, however, the faunal

chart shows that in addition to the Richmond elements in the lower Arnheim fauna, there are also some very interesting Maysville recurrences, chiefly of Corryville species. It is these recurrent Corryville forms which, because of their relative abundance in parts of the Sunset, give the lower Arnheim in many places in Ohio and Indiana a predominantly Corryville aspect. On the whole, these species seem to have been a hardier lot than the characteristic Richmond species.

Maysville Faunal Relationships

If the Maysville element of this Russellville-Decatur section be sorted out, and to it added Maysville elements from lower Arnheim sections elsewhere in Ohio and Indiana, what is apparently a very good Corryville fauna is obtained. Upon critical examination, however, these resemblances are seen to be more or less superficial, and the forms are mostly seen to be distinct.

Following is a list of forms which have been generally regarded as rather characteristically Maysville, and which have also been found in the lower Arnheim at various places, but mostly in this section.

Agelacrinites cincinnatiensis (Roemer) [=*A. cincinnatiensis* var.]
Streptaster vorticellatus (Hall) [=*S. vorticellatus* var.]
Glyptocrinus dyeri Meek [=*G. dyeri* var.]
Heterocrinus pentagonus Ulrich

Amplexopora filiasa (d'Orbingy) [=*A.* n. sp.]
Atactoporella ortoni (Nicholson)
Bythopora gracilis (Nicholson)
Ceramoporella whitei (James)
Coeloclema oweni (James)
Hallopora andrewsi (Nicholson) [=*H. andrewsi* var.]
Hallopora ramosa (D'Orbingy) [=*H. subnodosa* var.]
Hallopora rugosa (Edwards & Haime) [=*H. subnodosa* var.]
Heterotrypa frondosa (D'Orbingy)
Monticulipora cincinnatiensis (James) [=*M.* n. sp.]
Peronopora dubia Cumings & Galloway
Stigmatella dychei (James)

Platystrophia ponderosa Foerste
Plectorthis jamesi (Hall) [=*P.* n. sp.]

Acrolichas halli Foerste [=*A.* n. sp.]
Ceratocephala anchoralis (Miller) [=*C.* n. sp.] [6]

Stigmatella dychei is generally distributed though usually rare at the base of the Arnheim. The type locality at Lebanon is at the base of the Arnheim. The writer has nowhere found this species in the Mt. Auburn, though superficially identical forms have been found in the Mt. Auburn and Corryville but differ in having thicker walls, beaded mesopores and large acanthopores. It is highly probable that *S. dychei* is not a Maysville species, and in the present light of our knowledge it might safely be removed from the list.

Peronopora dubia is listed as a Maysville species on the authority of Cumings and Galloway,[7] but has not been found outside the Arnheim by the writer.

Coeloclema oweni was considered by Nickles to be the most diagnostic fossil of the Mt. Auburn, but the real horizon is at the base of the Arnheim. Specimens do occur in the Mt. Auburn, but are very rare there.

Hallopora subnodosa shows the same tendency, probably orthogenetic, that crops up in other species of the genus, and in the lower Arnheim the monticules are sometimes as well developed as in *H. ramosa*, and are sometimes transversely elongated, giving a variety indistinguishable externally from *H. rugosa*.

This list does not take into consideration

the fairly long-lived Maysville species which survived until Liberty or later times, such as *Homotrypa flabellaris* and variety *spinifera*, *Leptotrypa ornata*, *Cyrtolites ornatus*, etc., nor does it include species which have survived from the Eden.

Only eight species regarded as more or less distinctly characteristic of the Maysville survived the Mt. Auburn-Arnheim break without modification, and at least half of these are bryozoans that have lived on since the Bellevue, which almost puts them in the same class with *Homotrypa flabellaris*.

Referring again to the faunules of the divisions of this composite section, division four carries a faunule predominantly Richmond, with a slight Maysville representation. The faunule of division five, the first *Glyptocrinus dyeri* bed, shows distinct Maysville affinities, but at the same time it marks the introduction of the very characteristic Richmond species *Cyphotrypa clarksvillensis*, *Anomalodonta alata*, and *A. gigantea*.

Division six is, at most places in Ohio and Indiana, the first obviously Richmond bed, as the faunule is everywhere present where exposed and is easily recognized in the field. *Dinorthis carleyi* and *Leptaena richmondensis praecursor* are found everywhere, but *Rhynchotrema dentatum* has not been found north or west of the great Big Four Railroad cut near Westchester, Ohio, nor as far north as Oregonia, Ohio. At Westchester *Dinorthis* and *Rhynchotrema* are associated 45'3" above the top of the Mt. Auburn, and *Leptaena* occurs just beneath the *Dinorthis* (*[=Retrorsirostra]*).

On Lick Run, a tributary of Todds Fork two miles north of Butlerville, Warren County, Ohio, *Dinorthis* is 40'7" above the base of the Arnheim. No *Rhynchotrema dentatum* was seen. The Sunset bed here is shaly with a few more or less shelly limestones up to 3" thick, and is rather poorly fossiliferous.

On Indian Creek above Reily, Butler County, Ohio, the *Dinorthis* zone is 41' above the base. On Clifty Creek at Madison, Indiana, the zone is 45' above the base.

Division six, then marks the beginning of the Oregonia beds of the Arnheim.

Division seven marks a return of Maysville descendants. The faunule is not abundant. This is the chief source at present for *Glyptocrinus* and *Cyclonema* in symbiotic relationship.

The remaining faunules represent successive waves of Richmond species, each succeeding wave adding some new Richmond element to the fauna. On the whole, however, the Oregonia bed here has neither the profusion of species nor of individuals that is found in Warren and Butler Counties, and the strata here are predominantly even-bedded instead of the lumpy irregularly indurated shales and rough, shaly limestones so characteristic of this horizon as exposed toward the west.

Waynesville Faunal Relationship.

A notable element of the Oregonia fauna here, and one that is so reduced as to be practically absent to the north and west, is the very conspicuous Waynesville element. The following species have been regarded as being more or less characteristically Waynesville or younger, and more especially characteristic of the upper Waynesville.

Waynesville Faunal Element of The Oregonia Section

Streptelasma rusticum (Billings)
Homotrypa communis Bassler
Tetradium huronense Foord
Homotrypella hospitalis (Nicholson)
Bythopora meeki (James)
Rhombotrypa subquadrata (Ulrich)
Constellaria polystomella Nicholson
Lingula vanhornei Miller
Cyphotrypa clarksvillensis Ulrich
Strophomena planumbona (Hall)
Eridotrypa simulatrix (Ulrich)
Strophomena planumbona elongata (James)

Heterotrypa subramosa (Ulrich)
Opisthoptera fissicostata (Meek)
Heterotrypa subramosa prolifica Ulrich
Cyclonema bilix conica Miller

The presence of such a large and characteristic upper Waynesville fauna here, and its almost complete absence to the northwest and west, shows how delicately adjusted the species were to their environment. Whatever the environmental conditions

The Arnheim

were which produced the characteristic lumpy "nodular" shales of the typical Oregonia, they were unfavorable to these Waynesville pioneers, who waited around somewhere, probably to the south, until the conditions became favorable for them to migrate in again during Waynesville times. Meantime a large and conspicuous molluscan fauna was flourishing to the northwest and west under conditions adverse to these Waynesville species.

In the region of this composite section the Arnheim is succeeded by the Blanchester beds of the middle Waynesville, the Ft. Ancient being entirely absent.

Excellent Arnheim exposures are found about Clarksville in Clinton County, and about Oregonia, Ft. Ancient, Lebanon, etc., in Warren County.

Description of The Oregonia Section

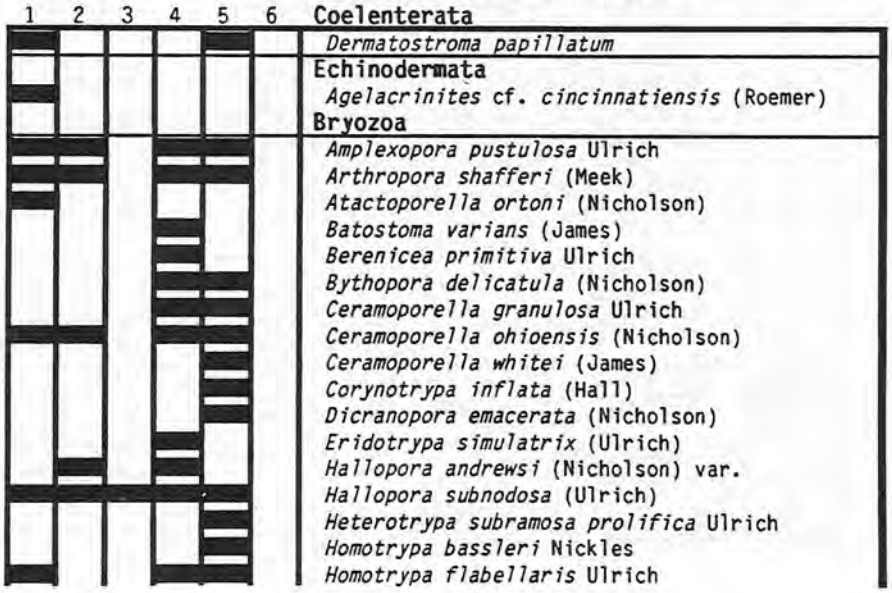
The typical section of the Oregonia was formerly admirably exposed on Longstreths Branch, opposite the village of Oregonia, but it has deteriorated badly under erosion. The following section was taken and most of the faunal collections made while the exposures were at their best, 1907-15. The section follows the straight fork of the creek along the road.

The Oregonia Measured Section

	Thickness
Top of Section.	
7 - Even-bedded shales of the basal Ft. Ancient.	
6 - Heavy but soft and lumpy limestones and thin intercalated shales. . . .	.6'00"
5 - Typical "nodular" and "grainy" limestones and shales of the Oregonia. .	14'05"
4 - *Dinorthis carleyi* and *Leptaena* zone. *Dinorthis* through all but the lower 10", which has many *Leptaena*.	6'04"
3 - Double limestones in floor of creek, forming little waterfalls.	.0'06"
2 - Mostly even-bedded blue clay shales and both regular and rough limestones.	20'09"
1 - Thin, more or less shelly limestones and interbedded shales at the top, 5'6" heavier, rough limestones and shales at the base. From the base of the first exposure to the top of the first waterfall.	

This gives a thickness of 33'5" for the Sunset, and 26'9" for the Oregonia.

- - - Faunal List for the Oregonia Section - - -



Coelenterata

Dermatostroma papillatum

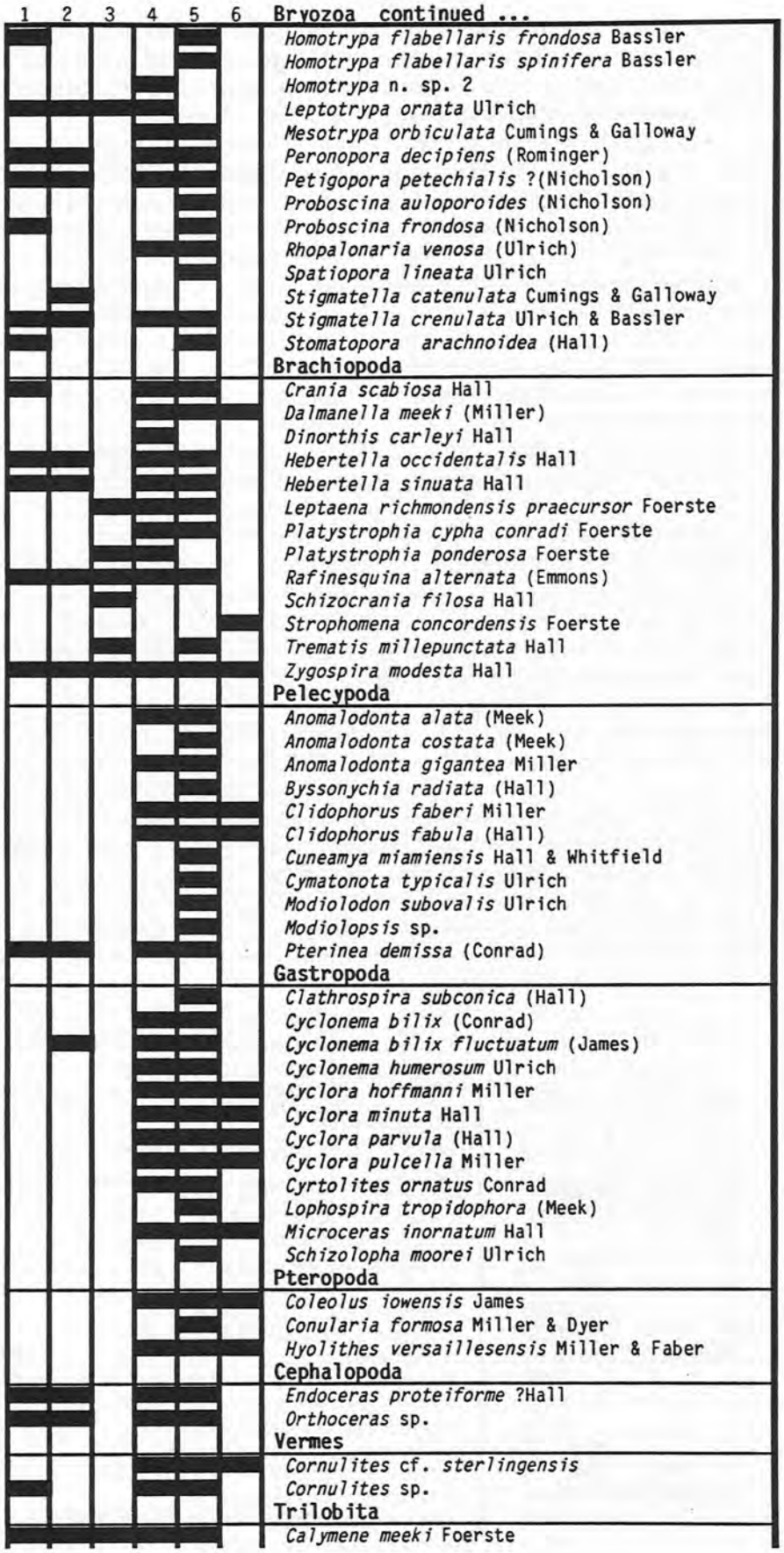
Echinodermata

Agelacrinites cf. *cincinnatiensis* (Roemer)

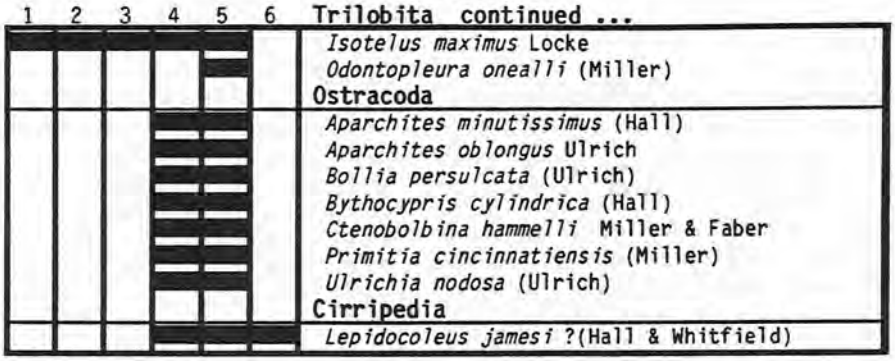
Bryozoa

Amplexopora pustulosa Ulrich
Arthropora shafferi (Meek)
Atactoporella ortoni (Nicholson)
Batostoma varians (James)
Berenicea primitiva Ulrich
Bythopora delicatula (Nicholson)
Ceramoporella granulosa Ulrich
Ceramoporella ohioensis (Nicholson)
Ceramoporella whitei (James)
Corynotrypa inflata (Hall)
Dicranopora emacerata (Nicholson)
Eridotrypa simulatrix (Ulrich)
Hallopora andrewsi (Nicholson) var.
Hallopora subnodosa (Ulrich)
Heterotrypa subramosa prolifica Ulrich
Homotrypa bassleri Nickles
Homotrypa flabellaris Ulrich

The Arnheim


1 2 3 4 5 6
Bryozoa continued ...
Homotrypa flabellaris frondosa Bassler
Homotrypa flabellaris spinifera Bassler
Homotrypa n. sp. 2
Leptotrypa ornata Ulrich
Mesotrypa orbiculata Cumings & Galloway
Peronopora decipiens (Rominger)
Petigopora petechialis ?(Nicholson)
Proboscina auloporoides (Nicholson)
Proboscina frondosa (Nicholson)
Rhopalonaria venosa (Ulrich)
Spatiopora lineata Ulrich
Stigmatella catenulata Cumings & Galloway
Stigmatella crenulata Ulrich & Bassler
Stomatopora arachnoidea (Hall)
Brachiopoda
Crania scabiosa Hall
Dalmanella meeki (Miller)
Dinorthis carleyi Hall
Hebertella occidentalis Hall
Hebertella sinuata Hall
Leptaena richmondensis praecursor Foerste
Platystrophia cypha conradi Foerste
Platystrophia ponderosa Foerste
Rafinesquina alternata (Emmons)
Schizocrania filosa Hall
Strophomena concordensis Foerste
Trematis millepunctata Hall
Zygospira modesta Hall
Pelecypoda
Anomalodonta alata (Meek)
Anomalodonta costata (Meek)
Anomalodonta gigantea Miller
Byssonychia radiata (Hall)
Clidophorus faberi Miller
Clidophorus fabula (Hall)
Cuneamya miamiensis Hall & Whitfield
Cymatonota typicalis Ulrich
Modiolodon subovalis Ulrich
Modiolopsis sp.
Pterinea demissa (Conrad)
Gastropoda
Clathrospira subconica (Hall)
Cyclonema bilix (Conrad)
Cyclonema bilix fluctuatum (James)
Cyclonema humerosum Ulrich
Cyclora hoffmanni Miller
Cyclora minuta Hall
Cyclora parvula (Hall)
Cyclora pulcella Miller
Cyrtolites ornatus Conrad
Lophospira tropidophora (Meek)
Microceras inornatum Hall
Schizolopha moorei Ulrich
Pteropoda
Coleolus iowensis James
Conularia formosa Miller & Dyer
Hyolithes versaillesensis Miller & Faber
Cephalopoda
Endoceras proteiforme ?Hall
Orthoceras sp.
Vermes
Cornulites cf. sterlingensis
Cornulites sp.
Trilobita
Calymene meeki Foerste

The Arnheim



The base of division one is approximately the base of the Arnheim though the contact with the underlying Mt. Auburn was not seen here, but is sometimes exposed in Blacksmiths Hollow, at the north edge of Oregonia. The heavy rains of 1925 cleared out Blacksmiths Hollow completely for the first time in 15 years, and uncovered a practically continuous section from the Mt. Auburn to the Liberty. The basal section is as follows.

Blacksmiths Hollow Section, Oregonia, Ohio.

	Thickness
10 - Waynesville	
9 - Heavy, lumpy limestones.	5'03"
8 - Irregularly indurated shales and irregular limestones.	12'08"
7 - *Dinorthis carleyi* bed.	4'02"
6 - Even-bedded shales and limestones at the base, more "grainy" and irregular at the top.	27'
5 - More or less even-bedded shales and thin limestones, to top of 8" double limestone. Fauna of *Homotrypa flabellaris* and var. *spinifera*, *Peronopora decipiens*, *Hallopora subnodosa*, *Ceramoporella ohioensis*, *Homotrypa libana*, *Stigmatella crenulata* and *Dalmanella meeki*.	7'02"
4 - A 2"-3" limestone of fossil fragments with uneven top and bottom, 5" shale with 1" limestone, topped by 0-4" barren mudstone. Fauna of *Hallopora subnodosa*, *Rafinesquina alternata*, *Zygospira modesta* and *Calymene meeki*. Base of Arnheim.	1'
3 - More prominently shaly, with even-bedded limestones and fewer *Rafinesquina*. Only other fossils are *Hallopora rugosa* and *Zygospira modesta*. Top of Mt. Auburn.	3'
2 - Rough limestones and lumpy shales full of jumbled *Rafinesquina* but with no *Platystrophia ponderosa*. Carries *Ceramoporella ohioensis*, *Hallopora rugosa* and *Heterotrypa frondosa*.	4'07"
1 - *Platystrophia ponderosa* bed, middle Mt. Auburn.	2'09"

The fossils listed from these lower divisions are few because partly of poor conditions of exposure, and partly because the beds are not very prolific of either individuals or species. It may be noted that though the initial Arnheim fauna lacks some of the characteristic Richmond species found at the same horizon in Adams County, yet it is significant that *Homotrypa libana* and *Stigmatella crenulata* appear almost at the base of the Arnheim.

The Lanes Mill Section

Another composite section of the Arnheim has been constructed in the Lanes Mills region on Four Mile Creek, between Dartown and Oxford, Butler County, Ohio. The components of this section are

as follows:

First - Exposures at the base of the high bank just below the bridge across Four Mile Creek, in the southeast corner of Section 31, Range 2 East, Township 5 North. The section continues up the ravine along the road to the south, and shows divisions 1-5 and 10, and most of divisions 6 and 7 of the composite section.

Second - A creek flowing into Four Mile from the west at the ford near the southwest corner of Section 31, Milford Township. The section follows the road, and where the creek branches, follows the left branch. Divisions 8-11 are completely shown, and 7 in part.

Third - Exposures just below the ford ~~(now abandoned) across the Four Mile a mile due west of the first section~~. The section follows up a ravine on the south near the lower end of the long exposure along the creek. Divisions shown are 6-8 and 10, and parts of 9.

Fourth - An exposure along the Four Mile just above the ford. The exposure is practically a continuation of section three. Shows the top of division 6 and about half of division 7.

Fifth - An exposure on Four Mile just around the bend of the creek above section three. Shows divisions 8 and 9, and most of 7 and 10.

Sixth - Martindells Creek, flowing into Four Mile across the northwest corner of Section 36, Oxford Township. Shows divisions 8-11.

The faunules of these divisions do not differ as traced from one locality to another, but the localities vary widely as to favorable conditions of exposure, and the same exposure varies greatly from year to year, so to get a typical complete section and a good faunal list it is necessary to construct a composite section.

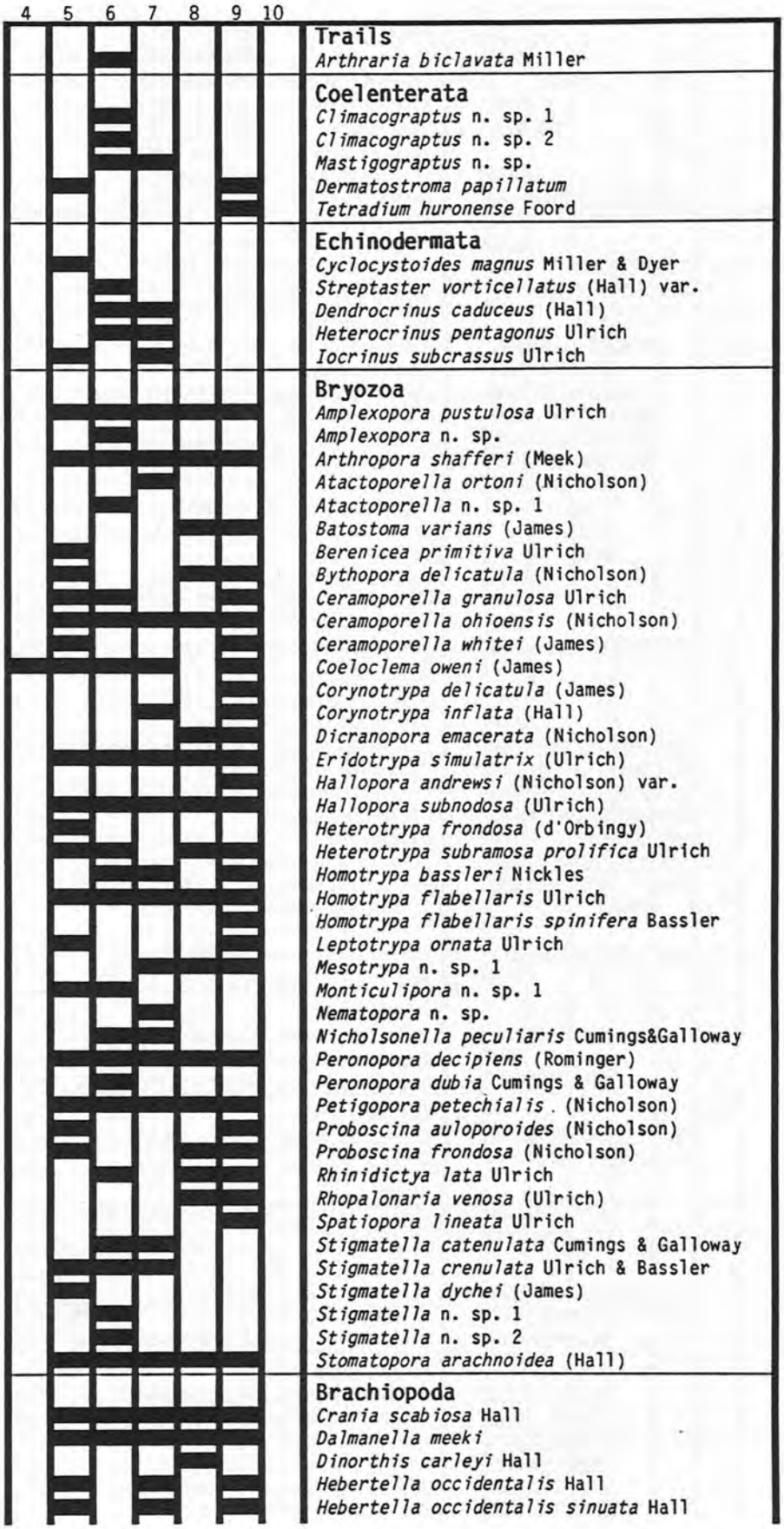
The section follows. (See map, page 19)

The Lanes Mills Composite Section

	Thickness
11 - Even-bedded limestones and shales of the Waynesville.	
10 - Heavy, irregular limestones composed largely of tiny shells of *Cyclora, Microceras* and *Clidophorus*.	5'06"
9 - Typical lumpy Oregonia	6'08"
8 - *Dinorthis carleyi* bed.	2'08"
7 - Mostly even-bedded shales and limestones	28'06"
6 - Even-bedded shales and limestones, from the base of the long, high exposure at the second locality to the top of a ledge forming a little waterfall in the ravine.	6'00"
5 - Thin, rough limestones and grainy shales. *Coeloclema oweni* abundant in lower 4'. *Leptaena* from 6" up to 4' above the base. Top of exposed strata approximately at the horizon of the base of the section a mile west.	5'00"
4 - Rough limestones composed largely of fossil fragments and full of Bryozoa. *Platystrophia ponderosa* on top. *Coeloclema oweni* and *Rafinesquina alternata* common. Basal Arnheim	04"-8"
3 - Grainy shales with *Platystrophia ponderosa*. Top of Mt. Auburn.	1'00"
2 - Very rough limestone, composed largely of finely ground fossil fragments, full of *Cyclora, Microceras*, etc.	4'07"
1 - Apparently typical upper Mt. Auburn.	1'09"

The datum planes used in correlating the various sections which were used as components in the construction of this composite section are the *Dinorthis carleyi* zone and the heavy, lumpy *Cyclora* limestones at the top. The fauna follows:

The Arnheim



Trails
Arthraria biclavata Miller

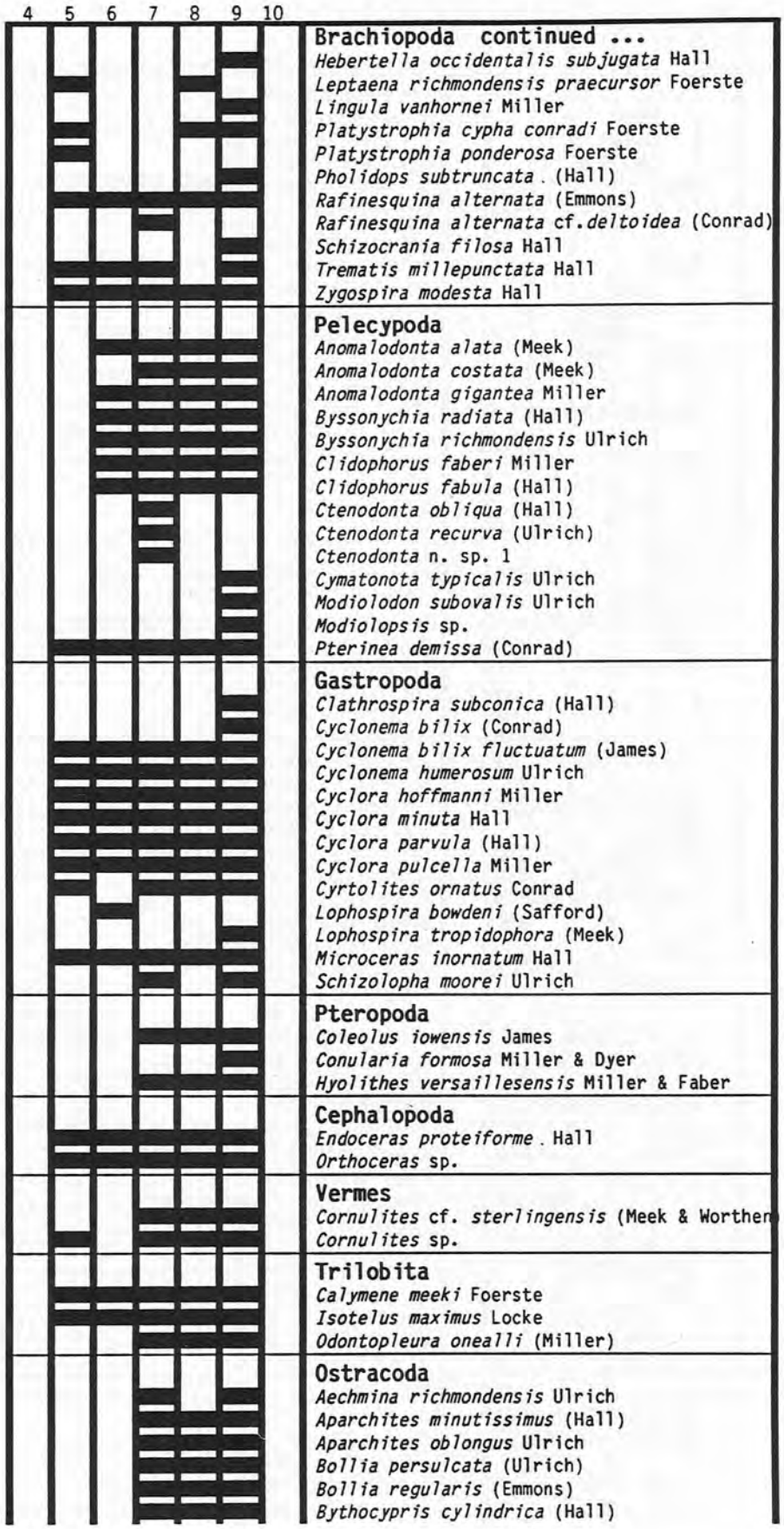
Coelenterata
Climacograptus n. sp. 1
Climacograptus n. sp. 2
Mastigograptus n. sp.
Dermatostroma papillatum
Tetradium huronense Foord

Echinodermata
Cyclocystoides magnus Miller & Dyer
Streptaster vorticellatus (Hall) var.
Dendrocrinus caduceus (Hall)
Heterocrinus pentagonus Ulrich
Iocrinus subcrassus Ulrich

Bryozoa
Amplexopora pustulosa Ulrich
Amplexopora n. sp.
Arthropora shafferi (Meek)
Atactoporella ortoni (Nicholson)
Atactoporella n. sp. 1
Batostoma varians (James)
Berenicea primitiva Ulrich
Bythopora delicatula (Nicholson)
Ceramoporella granulosa Ulrich
Ceramoporella ohioensis (Nicholson)
Ceramoporella whitei (James)
Coeloclema oweni (James)
Corynotrypa delicatula (James)
Corynotrypa inflata (Hall)
Dicranopora emacerata (Nicholson)
Eridotrypa simulatrix (Ulrich)
Hallopora andrewsi (Nicholson) var.
Hallopora subnodosa (Ulrich)
Heterotrypa frondosa (d'Orbingy)
Heterotrypa subramosa prolifica Ulrich
Homotrypa bassleri Nickles
Homotrypa flabellaris Ulrich
Homotrypa flabellaris spinifera Bassler
Leptotrypa ornata Ulrich
Mesotrypa n. sp. 1
Monticulipora n. sp. 1
Nematopora n. sp.
Nicholsonella peculiaris Cumings&Galloway
Peronopora decipiens (Rominger)
Peronopora dubia Cumings & Galloway
Petigopora petechialis (Nicholson)
Proboscina auloporoides (Nicholson)
Proboscina frondosa (Nicholson)
Rhinidictya lata Ulrich
Rhopalonaria venosa (Ulrich)
Spatiopora lineata Ulrich
Stigmatella catenulata Cumings & Galloway
Stigmatella crenulata Ulrich & Bassler
Stigmatella dychei (James)
Stigmatella n. sp. 1
Stigmatella n. sp. 2
Stomatopora arachnoidea (Hall)

Brachiopoda
Crania scabiosa Hall
Dalmanella meeki
Dinorthis carleyi Hall
Hebertella occidentalis Hall
Hebertella occidentalis sinuata Hall

The Arnheim



Brachiopoda continued ...
Hebertella occidentalis subjugata Hall
Leptaena richmondensis praecursor Foerste
Lingula vanhornei Miller
Platystrophia cypha conradi Foerste
Platystrophia ponderosa Foerste
Pholidops subtruncata . (Hall)
Rafinesquina alternata (Emmons)
Rafinesquina alternata cf. *deltoidea* (Conrad)
Schizocrania filosa Hall
Trematis millepunctata Hall
Zygospira modesta Hall

Pelecypoda
Anomalodonta alata (Meek)
Anomalodonta costata (Meek)
Anomalodonta gigantea Miller
Byssonychia radiata (Hall)
Byssonychia richmondensis Ulrich
Clidophorus faberi Miller
Clidophorus fabula (Hall)
Ctenodonta obliqua (Hall)
Ctenodonta recurva (Ulrich)
Ctenodonta n. sp. 1
Cymatonota typicalis Ulrich
Modiolodon subovalis Ulrich
Modiolopsis sp.
Pterinea demissa (Conrad)

Gastropoda
Clathrospira subconica (Hall)
Cyclonema bilix (Conrad)
Cyclonema bilix fluctuatum (James)
Cyclonema humerosum Ulrich
Cyclora hoffmanni Miller
Cyclora minuta Hall
Cyclora parvula (Hall)
Cyclora pulcella Miller
Cyrtolites ornatus Conrad
Lophospira bowdeni (Safford)
Lophospira tropidophora (Meek)
Microceras inornatum Hall
Schizolopha moorei Ulrich

Pteropoda
Coleolus iowensis James
Conularia formosa Miller & Dyer
Hyolithes versaillesensis Miller & Faber

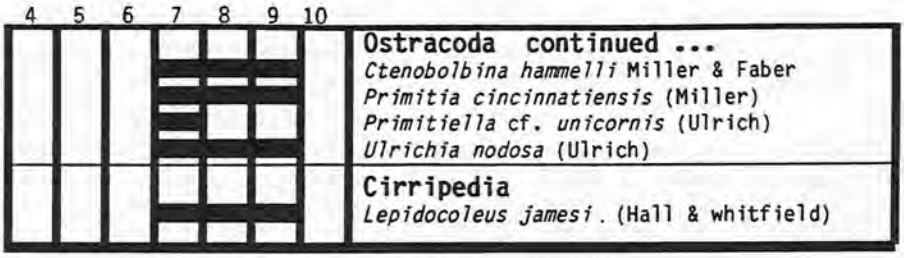
Cephalopoda
Endoceras proteiforme . Hall
Orthoceras sp.

Vermes
Cornulites cf. *sterlingensis* (Meek & Worthen
Cornulites sp.

Trilobita
Calymene meeki Foerste
Isotelus maximus Locke
Odontopleura onealli (Miller)

Ostracoda
Aechmina richmondensis Ulrich
Aparchites minutissimus (Hall)
Aparchites oblongus Ulrich
Bollia persulcata (Ulrich)
Bollia regularis (Emmons)
Bythocypris cylindrica (Hall)

The Arnheim



This composite Arnheim section shows little additional information. The faunal list is longer, but practically all the species are found also at Clarksville and elsewhere. *Coeloclema oweni* is particularly abundant in the lower 4', where it is associated with *Leptaena*. *C. oweni* is practically restricted to this horizon across the north end of the Cincinnati Arch, being generally a rare species in the underlying Mt. Auburn and in the overlying strata of the lower Oregonia.

The Sunset bed shows no essential variation in thickness here, its 38' comparing quite favorably with the figures previously given, 45' at Madison, Indiana, 41' at Reily, Ohio, 40' on Lick Run near Butlerville, Ohio, 33.5' at Oregonia and 22' in Adams County. These figures show a progressive thinning toward the east. On the other hand, the Oregonia shows the exact reverse, thinning down from 54' in Adams County to 26'9" at Oregonia and 15' at Oxford. At Madison, Indiana, it is 16.5'.

These variations apparently have had nothing to do with nearness to shorelines, and probably are due to gently oscillatory warpings of the incipient Cincinnati Arch, such as were discussed by Ulrich[8]

Division ten is a very characteristic horizon across the north end of the Cincinnati Arch, and from Oxford to Oregonia varies but little from a thickness of 5'.

The limestones are distinctly phosphatic, due to phosphatic replacement and filling of countless numbers of minute shells of *Cyclora*, *Microceras*, *Clidophorus*, *Coleolus*, *Hyolithes*, etc. On Martindells Creek the top of the division is almost a solid mass of these shells.

Other good Arnheim sections are shown at or near Scipio, Reily and Jacksonburg in Butler, County, Lebanon and Butlerville in Warren County, and Clarksville in Clinton, County. Fair exposures are shown in Hamilton County at Westwood (corner of Harrison Ave. and Lafveille Ave.) where the *Dinorthis carleyi* horizon is even with the sidewalk on Lafveille Ave, in the C&O Railroad cuts at Bridgetown and just south of Westwood, and just north of the New Burlington (Transit P.O.). At the latter locality the base of the Sunset shows rather abundant *Stigmatella dychei*, a species which is uncommon elsewhere.

A great many detailed sections could be added to the three given, but these three are sufficient to illustrate the main variations, lithologically, faunally and in thickness, of the Arnheim. Indiana has many valuable Arnheim sections but they only yield information supporting statements already made. It is interesting to find, for example, the following section of the Arnheim in Clifty Creek, west of Madison, Indiana.

Madison, Indiana Section

	Thickness
8 – *Dinorthis carleyi* bed	1'06"
7 – To top 3"–6" limestone exposed in the first high bank, opposite house.	45'02"
6 – Lumpy shales and limestones carrying a reduced Mt. Auburn fauna. Up to base 1"–4" smooth, barren, cross-bedded limestone in bed of creek	9'00"

The Arnheim

The most interesting feature is the fact that the basal 4' of division seven, the Sunset bed of the Arnheim, carries the following fauna.

Bryozoa
Amplexopora pustulosa Ulrich
Arthropora shafferi (Meek)
Ceramoporella whitei (James)
Coeloclema oweni (James)
Eridotrypa simulatrix (Ulrich)
Hallopora subnodosa (Ulrich)
Heterotrypa frondosa? (D'Orbingy)
Heterotrypa subramosa prolifica Ulrich
Homotrypa flabellaris Ulrich
Leptotrypa ornata Ulrich
Peronopora decipiens (Rominger)
Stigmatella crenulata Ulrich & Bassler
Stomatopora arachnoidea (Hall)
Brachiopoda
Leptaena richmondensis Foerste
Platystrophia ponderosa Foerste
Zygospira modesta Hall
Mollusca
Anomalodonta alata (Meek)
Byssonychia radiata (Hall)
Cyclonema bilix fluctuatum (James)
Cyrtolites ornatus Conrad
Orthoceras sp.
Cirripedia
Lepidocoleus jamesi ?(Hall & Whitfield)

This fauna, at the very base of the Arnheim and 45' below the *Dinorthis carleyi* fauna, proves again that the Arnheim is typically Richmond from the very base.

Climacograptus n. sp. was found loose 16.5' above the base of this division.

General Conclusions

In all cases the Arnheim begins with evidence of a break in sedimentation, as previously shown, and in all cases the typical Arnheim forms begin to appear in the first fossiliferous strata, while the characteristic Maysville species with but few exceptions fail to pass the break, or if they do pass it, they are recognizably modified. The fact that there may be no essential change in the nature of the sedimentation, when the two sides of the break are compared, has no significance.[9]

There is no doubt that the Arnheim invasions were southern in origin. This is shown by the absence of the characteristic Arnheim species in Canada and New York, and by their presence in the Arnheim of Tennessee. The distribution of *Streptelasma rusticum*, *Rhynchotrema dentatum*, *Strophomena concordensis* and *S. planumbona*, *Platystrophia ponderosa*, etc. within the Arnheim of the Cincinnati Province itself shows that they came from the south, specifically the south-east, since they increase in numbers in that direction and thin out and disappear toward the northwest.

Along the west flank of the Cincinnati Arch in Kentucky, the Arnheim shows a stronger development of less fossiliferous, more or less blocky, argillaceous limestones through Jefferson, Spencer, Nelson, Washington and Marion Counties. Three miles southeast of Lebanon are 42' of Arnheim, beneath which are 34' of barren, ripple-marked and sun- cracked argillaceous limestones which may or may not be Arnheim but probably are, because of the occurrence of similar strata containing characteristic Arnheim species of fossils on the east side of the arch in Madison and Garrard Counties. The fossils collected in the vicinity of Lebanon include many species that have not been found in the Arnheim of the north. The molluscan part of the fauna is notably different, and *Heterospongia subramosa* is common in one zone, associated with an undescribed *Isochilina*.

Along the Cumberland River in the southern part of Russell County, the Arnheim is of uncertain thickness, but is thin, composed of irregularly bedded argillaceous limestones, and is poorly fossiliferous.

Absent from the east side of the Nashville Dome, the Arnheim is variously developed at numerous places along the west side, and at some localities carries, in addition to the usual *Leptaena-Rhynchotrema- Dinorthis carleyi* fauna, a distinctly Waynesville element. Perhaps the best section of this kind is about a mile southeast of Fernvale, Williamson County, on the road across the ridge to Leipers Fork. As the creek along the road is followed up, the Fernvale disappears, but about 300 yards above a little anticline brings it up again and affords the section on the following page.

The Arnheim

Fernvale, Kentucky Section

	Thickness
5 - Chattanooga Black Shale	
4 - Brassfield limestone	0'-5'04"
3 - Fernvale shales and limestones	4'-8'10"
2 - Irregular shaly limestones. Arnheim.	3'09"
1 - A more or less conglomeratic and obscurely cross-bedded stratum of rough, shaly limestone 6" thick, followed by 9" rough limestones less conglomeratic and not cross-bedded. Base of Arnheim?	1'03"

Platystrophia ponderosa is found clear through division one, and *Leptaena richmondensis* occurs near the top. A part of the fauna of division two is -

Tetradium huronense...rare
Dalmanella meeki...common
Dinorthis carleyi...rare
Leptaena richmondensis...casual
Platystrophia ponderosa...common
Plectambonites rugosus...casual
Rhynchotrema dentatum...casual
Strophomena planumbona...casual

The point might be raised that this is an upper Waynesville fauna, and that the supposed Arnheim on the west side of the Nashville Dome is really Waynesville, since with the exception of *Platystrophia ponderosa* all the species are normal to the upper Waynesville of Ohio and Indiana. But we have already seen (p. 9) that with the sole exception of *Plectambonites rugosus* all of these species, and more, generally regarded as more or less characteristic of the upper Waynesville, occur also in the Arnheim deposits of Brown and Adams Counties in Ohio. It seems clear that here we have just one more species, *Plectambonites rugosus*, to add to the list of those species which make a brief appearance in the more southern part of the Arnheim embayment without reaching the northern end. When the southern Waynesville embayment crept up from the Gulf of Mexico and established communication with the northern Waynesville embayment, the freer circulation of water may have produced conditions more congenial to the species than did the relatively stagnant and less saline water at the blind end of the Arnheim embayment.

At Clifton, Tennessee, the Arnheim is but 3' thick, and carries the normal brachiopod fauna, somewhat reduced in numbers. Great numbers of thick, heavy specimens of *Peronopora decipiens* occur, associated with an undescribed species of *Hemiphragma*, a genus hitherto unknown from the Richmond of the Cincinnati-Nashville region.

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Notes:

[1]Jour. Cin. Soc. Nat. Hist., Vol. 20, 1906, pp. 86-8.

[2]Science Vol. 22 N.S., 1905, p. 150.

[3]Note attributed to E.O. Ulrich penciled in at margin. "This awful erosion bugaboo! Very good argument for system"? ??? ????

[4]Note penciled in margin. "Almost universal unless break is very long. If it were to continue there would be but few (?????) breaks anywhere. (?)Butts"

[5]Geol. Jefferson Co., Geol. Surv. Ky., Series IV Vol. 111 Pt. 11 1915 p. 39.

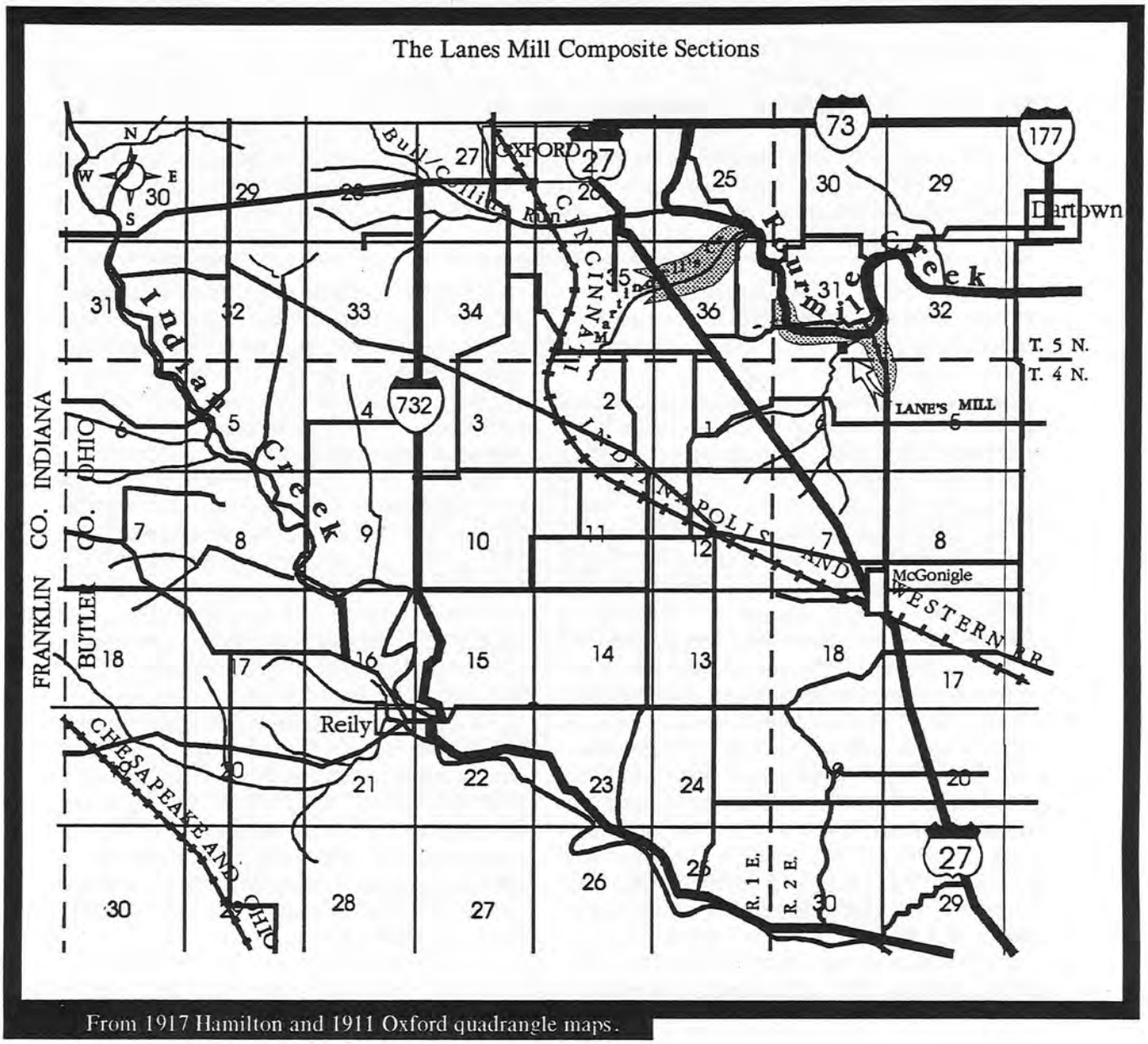
[6]Reviewers note penciled in margin. "9 sp. not differentiated from Maysville sp." "B."

[7]Dept. Geol. & Nat. Res., 37th Ann. Rept. 1912, p. 436.

[8]-Major causes of land and sea oscillations. Wash. Acad. Sci., Vol. 10, No. 3, Feb. 4, 1920, pp.57-78.

[9]-Reviewer's note penciled in margin "Why not? If there were no time break between them and the environment as indicated by character of sediment the same, the species would have persisted without modification. E.O.U" (E.O. Ulrich)

The Arnheim



From 1917 Hamilton and 1911 Oxford quadrangle maps.

The Waynesville

Contrasting strongly with the lumpy, irregularly indurated shales and irregular shaly limestones of the typical Oregonia or upper beds of the Arnheim member, are the even-bedded blue clay shales and thin limestones of the succeeding Waynesville.

The Waynesville is predominantly a shale formation, and instead of the shale weathering into an irregular rubble as do the more or less indurated shales of the Oregonia, the Waynesville shales weather into a blue clay, alternate drying and wetting causing a very rapid and thorough disintegration. Any person who has attempted to wash a dry clam cast preserved in the Waynesville shale will understand the process perfectly.

The Arnheim-Waynesville break constitutes one of the two greatest breaks within the Richmond. Immediately succeeding the heavy, irregular *Cyclora* limestones at the top of the Arnheim is an even-bedded series of 2"-4" limestones, heavily wave-marked, and composed largely of finely ground fossil fragments. These strata represent the material ground up along the shores of the advancing Waynesville sea, and the contact represents a gap or break in sedimentation of considerable extent.

Across the north part of the Cincinnati Arch there is no evidence of post-Arnheim and pre-Waynesville erosion, the contact everywhere being essentially the same. In Adams County, however, the whole basal third of the Waynesville, the Ft. Ancient, typically about 40' thick, is missing. While waterworn *Streptelasma rusticum* and *Dalmanella meeki* at the contact may possibly represent a sort of basal conglomerate, even here there is no evidence of erosion or weathering of the Arnheim deposits before the middle Waynesville sediments were placed upon them. The lack of the lower Waynesville appears to be due to an uplift sufficient to produce [p37] a cessation of deposition rather than to an uplift decided enough to permit erosion.

According to Ulrich, the break between the Arnheim and the Waynesville is, in Tennessee, in part filled in by the Fernvale, which rests upon undoubted Arnheim and is followed by strata regarded as Waynesville. The Waynesville age of the strata following the Fernvale is not fully established however, and, as will be seen later, there is some evidence for another possible correlation of the Fernvale. The fact remains, however, that physical evidences of a break here are plain.

Although there are no distinct evidences of a break between the Arnheim and the Waynesville as exposed across the north end of the arch, the fact that the Waynesville begins as a series of heavily wave-marked limestones composed largely of finely ground fossils indicates the possibility of a break, and at just this point the faunal break is also distinct, particularly in the case of the Bryozoa . Many species rather abundant in the Arnheim fail to appear in the lower Waynesville, but do appear again in the middle or upper Waynesville. If the Waynesville be considered as a whole, however, the faunal lists do not show a very distinct change.

After the initial disturbances of the Waynesville, shale deposition began and continued rather generally without a stratigraphic break until well into the succeeding Liberty. Limestones constitute but a very small part of the thickness and are rarely as much as 3" thick. Lithologically there is but very little variation in the Waynesville as exposed across the north end of the Cincinnati Arch.

While there is no evidence of a stratigraphic break in the interval between the base of the Waynesville and the top of the Liberty, there is abundant evidence that the sea of that time was very shallow, and frequently shoaled to such an extent that the shells and other hard parts (38) of organisms were ground up into a fossil "hash", forming layers of limestone that are commonly wave-marked. Miniature "horses" are occasionally found though not so commonly as in the Liberty. Layers of *Rafinesquina* with the shells jumbled together and frequently packed together standing on edge are another fairly common indication of shoal water.

In Ohio and Indiana there are no sun-cracks and cross-bedding such as are shown on both flanks of the arch in Kentucky. What have been reported as rain-drop impressions[1] from the Oxford region are but impressions of *Ctenodonta* occasionally found on the under side of certain thin

The Waynesville

limestones.

The distribution of the lower Waynesville of the Cincinnati Province is essentially that of the Arnheim, but that the upper Waynesville sea had a much greater extension, at least in a northerly direction, is shown by the great development of the Waynesville in the provinces of Ontario and Quebec, where the Arnheim is absent.

As originally described by Nickles[2] the top was not definitely located, but under Nickles definition of the Liberty the boundary was placed at "the first appearance of *Hebertella insculpta*."

This particular appearance of *H. insculpta* consists typically of several feet of thin limestones full of *Hebertella* followed by 3'-4' of blue clay shale without either *H. insculpta* or *S. planumbona* and that by a 2"-5" limestone which becomes shelly upon weathering, setting free great numbers of *Rhynchotrema capax* and *Hebertella insculpta*.

The base of this horizon shows no evidence of either a sedimentary or faunal break, though a slight faunal break does occur at the top. Then the definition was complicated by Dr. G.M. Austin of Wilmington, Ohio, finding another *H. insculpta* horizon at a lower level, and since then a third horizon has been found at a higher level.

For these reasons Foerste[3] redefined the top boundary of the Waynesville so as to include this middle *H. insculpta* Zone of Nickles with the Waynesville.

This is a highly convenient dividing plane, as it is marked generally in Ohio by a 2"-5" limestone characterized as above, and usually forming a little waterfall due to weathering away of the soft blue clay shale bed beneath, thus insuring exposure. The abundance of *H. insculpta* then makes it an easily recognized horizon. In Indiana, the shale bed thins out so that at Oldenburg *H. insculpta* becomes less abundant, and the horizon though present is difficult to establish at Madison. On the east flank it can easily be traced as far south as the second creek south of Poplar Plains, Fleming County, Kentucky, beyond which it has not been seen.

Although this is a very convenient dividing plane, it must be admitted that it is essentially an artificial division, with no more distinct sedimentary or faunal break here than for 40' above or below. The Waynesville and the Liberty really constitute as much of a stratigraphic and faunal unit as do the three subdivisions of the Waynesville, hence Foerste's term Laughery, including both Waynesville and Liberty, is very well founded. Foerste says[4] "The Waynesville and Liberty taken together, contain that part of the Richmond fauna along the Cincinnati Geanticline which most nearly is related to the Mississippi Valley Richmond. The two formations appear more closely linked together in their fossil content than the other Richmond formations. For that reason the term Laughery is proposed for the Waynesville and Liberty as exposed along Laughery Creek in Ripley County, Indiana."

Exception is taken to Foerste's first statement but extensive field work bears out the truth of the rest.

The Waynesville gets its name from Waynesville, Ohio, but the good exposures referred to by Nickles when he defined the member are no longer in evidence.

On essentially a paleontologic basis, Foerste[5] has divided the Waynesville member into three beds, in ascending order termed the Ft. Ancient, Clarksville, and Blanchester.

The type locality of the Ft. Ancient is on Stony Run, below the road and almost exactly a mile east of the Lower Fort, and is succeeded by a continuous section exposing most of the remainder of the Waynesville. The type section is poor for sectioning, however, since exposures are discontinuous and often more or less obscured by slumps. The Ft. Ancient is characterized by the abundance of *Dalmanella meeki* and numerous species of clams, mostly *Anomalodonta gigantea, Modiolopsis concentrica, Pterinea demissa* and *Pholadomorpha pholadiformis*, and by the absence of *Strophomena, Leptaena, Rhynchotrema,* and all corals and other characteristic Richmond groups. The bed is composed of about 40' of smooth even- bedded shales and thin limestones, and occasional limestones up to 3" thick, commonly composed of finely divided fossil fragments, and more or less distinctly wave-marked. It extends from the top of the Arnheim to the base of a 3'-5' shale bed with *Orthoceras duseri*

The Waynesville

typically abundant, and with *Stromatocerium huronense*, *Tetradium huronense*, *Cyphotrypa clarksvillensis*, abundant *Byssonychia*, *Modiolopsis*, *Anomalodonta*, and *Isotelus*. These *O. duseri* shales were originally classed as the top bed of the Ft. Ancient, but are now considered by Foerste[6] as the basal strata of the Clarksville, which is perfectly logical when one considers the introduction of new forms into the Waynesville.

The Clarksville is typically exposed along Stony Hollow, northwest of Clarksville, Ohio, extends from the base of the *O. duseri* shale bed to the lower *H. insculpta* layer, and is characterized in Warren and Clinton Counties by the prompt appearance of what are regarded as elements of the typical Richmond fauna, which elements had been absent in the Ft. Ancient, though partly present in the Arnheim. These more typical Richmond species are *Streptelasma rusticum*, *Protarea richmondensis*, *Leptaena richmondensis*, *Platystrophia clarksvillensis*, *Plectambonites rugosus clarksvillensis*, *Strophomena planumbona*, *S. sulcata*, *Rhynchotrema capax*, *Rhombotrypa quadrata*, etc. The strata show more but thinner limestones than the Ft. Ancient, and often both limestones and shales are shelly. The lower part of the Clarksville above the *O. duseri* shales shows a series of alternating shales and thin limestones which are almost entirely composed of *Dalmanella meeki*.

Following the Clarksville is the upper division of the Waynesville member, the Blanchester. The strata from which Foerste got most of his information are also on Stony Hollow at Clarksville, but the type locality for the name is a mile west of Blanchester, Ohio. This latter locality has deteriorated very much of late years, and when last seen (1925) was practically all grassed over. The Blanchester includes strata from the base of the first *H. insculpta* zone to the top of the second layer of *H. insculpta*, and is composed of strata much like those of the upper part of the Clarksville, only perhaps more shelly in places, and with several 3'-4' beds of somewhat nodular shales toward the top. The most characteristic fossils besides *H. insculpta* are *Strophomena neglecta*, *S. vetusta precursor*, *S. nutans*, and *Rhynchotrema dentatum*.

The most complete Waynesville section, though it is too steep for extensive collection of fossils, is the one found in Blacksmiths Hollow, at the north edge of Oregonia, and only 5 miles south of the type locality of Waynesville. The section is a continuation of the Arnheim section previously given, and the numbers of the stratigraphic divisions will be made to conform to those previously described. (p. 10)

--- Blacksmiths Hollow, Oregonia Section ---

	Thickness
22 - Liberty	
21 - Shales with few limestones, to top of 4"-6" limestones at top of last falls. *Hebertella insculpta* horizon.	9'03"
20 - Shales and thin limestones to top of 3"-4" limestones forming top of waterfall. *Austinella scovillei*.	0'11"
below top of this limestone.	9'09"
19 - Shelly shales and thin shaly limestones. *Strophomena neglecta* and *S. nutans* bed.	2'10"
18 - Shale bed. Bryozoa abundant. The *Isotelus* bed of Austin.	5'02"
17 - Alternating thin shales and limestones to top of next falls. *H. insculpta* at base. Base of Blanchester.	6'02"
16 - Alternating thin shales and thin limestones, full of *Dalmanella* in lower part, to top of next falls.	17'00"
15 - *Orthoceras duseri* shale bed. Base of Clarksville.	4'09"
14 - Shales and limestones.	3'00"
13 - Shales and limestones to top of next limestone ledge, 3"-4" thick.	8'02"

The Waynesville

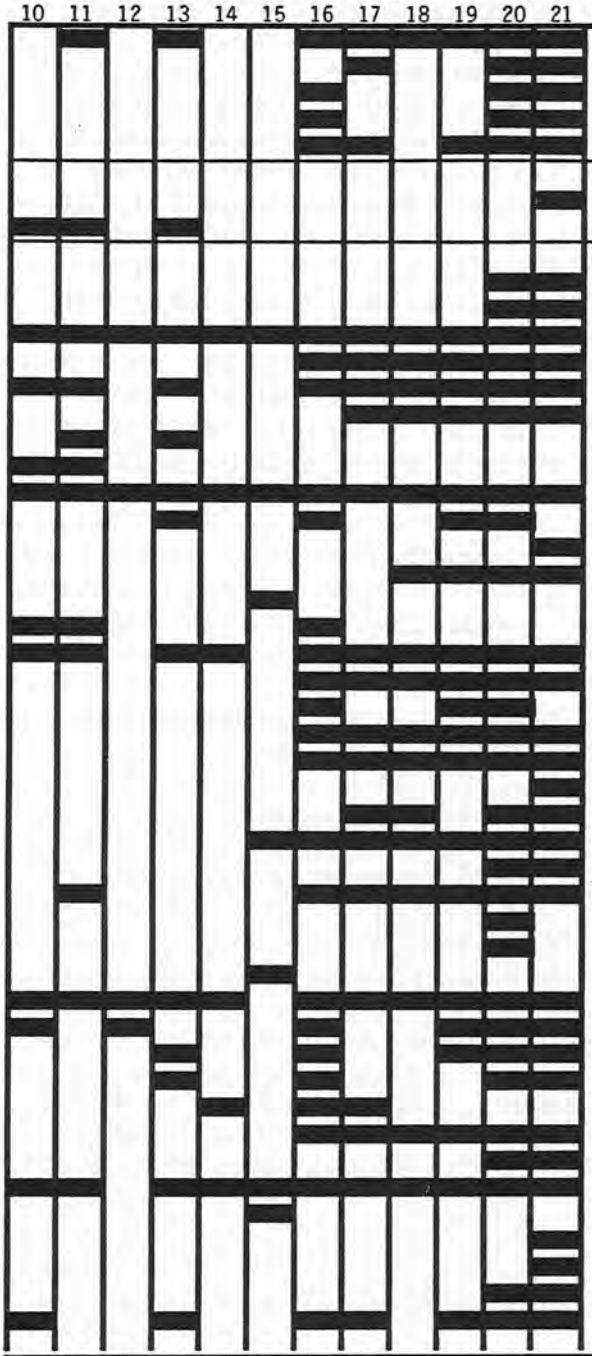
12 - Shale bed with few thin limestones, to top of 3" wave-marked limestone . . . . . 6'00"

11 - At base 3'2" impure shales and thin limestones topped by a 2"-3" barren limestone. Then 2'6" shale bed resembling the *O. duseri* shale bed, to base 2" barren limestone at top of shale bed. . . . . 5'08"

10 - Blue clay shales, with a few rough limestones composed of fossil fragments. To top 3"-4" even-bedded limestone at top of little waterfall . . . . . .13'01"

9 - Arnheim.

--- Waynesville Fauna of the Oregonia Section ---



Coelenterata

Dermatostroma papillatum (James)
Dermatostroma scabrum (James)
Protarea richmondensis Foerste
Protarea papillata Foerste
Streptelasma rusticum (Billings)

Echinodermata

Heterocrinus juvenis Hall
Iocrinus subcrassus (Meek & Worthen)

Bryozoa

Amplexopora pustulosa Ulrich
Arthropora shafferi (Meek)
Atactoporella schucherti Ulrich
Batostoma varians (James)
Bythopora delicatula (Nicholson)
Bythopora meeki (James)
Bythopora striata Ulrich
Bythopora tenuis sp. nov.
Ceramoporella ohioensis (Nicholson)
Corynotrypa delicatula (James)
Constellaria limitaris Ulrich
Constellaria polystomella Nicholson
Cyphotrypa clarksvillensis Ulrich
Dicranopora emacerata (Nicholson)
Eridotrypa simulatrix (Ulrich)
Hallopora subnodosa (Ulrich)
Heterotrypa subramosa (Ulrich)
Heterotrypa prolifica (Ulrich)
Homotrypa communis Bassler
Homotrypa dawsoni (Nicholson)
Homotrypa flabellaris Ulrich
Homotrypella hospitalis (Nicholson)
Homotrypella ramosa sp. nov.
Leptotrypa ornata Ulrich
Monticulipora prominens sp. nov.
Nicholsonella peculiaris Cumings & Galloway
?Paleschara beani James
Peronopora decipiens (Rominger)
Petigopora petechialis (Nicholson)
Proboscina auloporoides (Nicholson)
Proboscina frondosa (Nicholson)
Rhinidictya lata Ulrich
Rhombotrypa quadrata (Rominger)
Rhombotrypa subquadrata (Ulrich)
Rhopalonaria venosa (Ulrich)
Spatiopora aspera Ulrich
Spatiopora corticans (Nicholson)
Spatiopora tuberculata (Edwards & Haime)
Stigmatella crenulata Ulrich & Bassler
Stomatopora arachnoidea (Hall)

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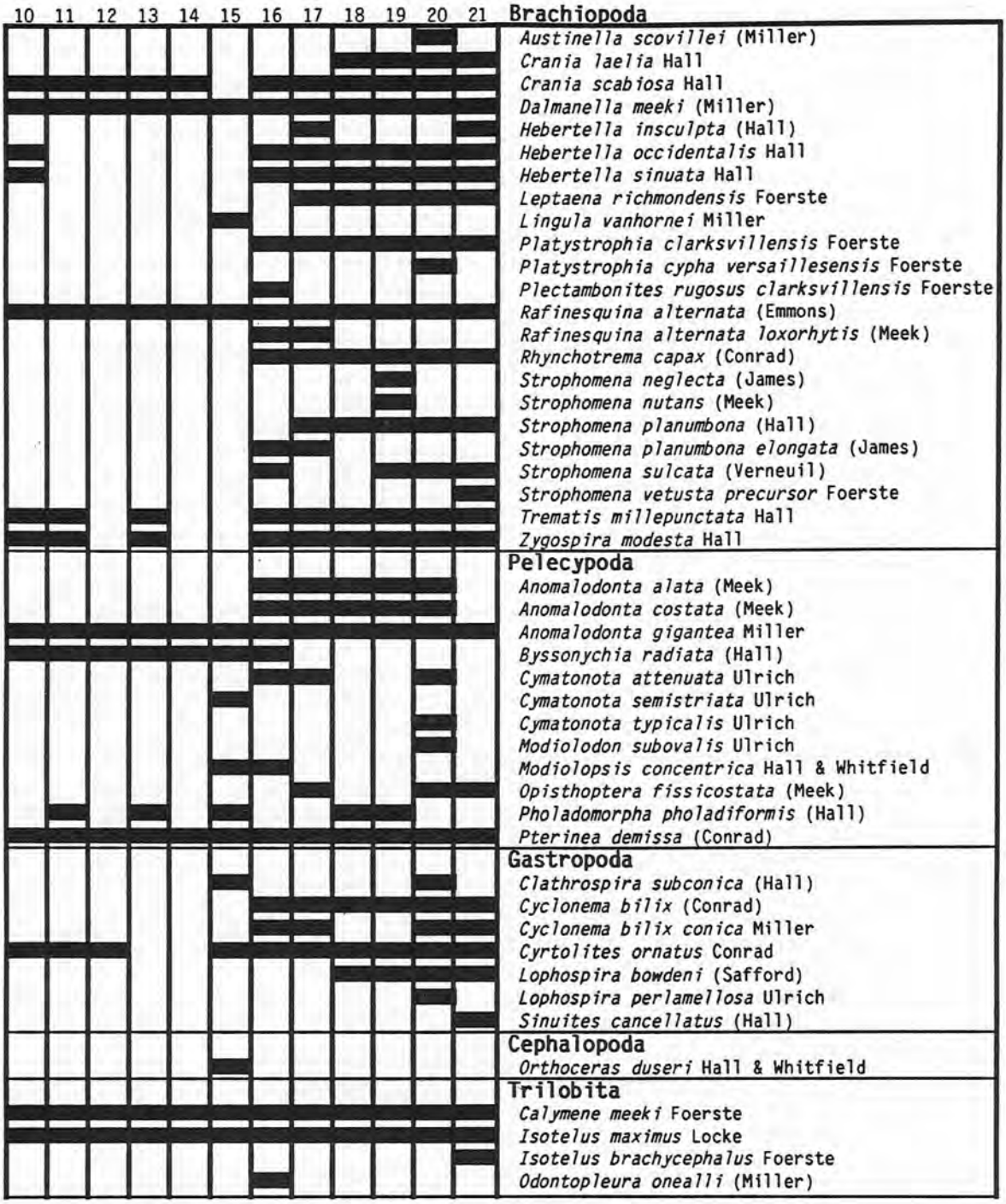


The faunal list here given is far more extensive than can be demonstrated in a casual visit to Blacksmiths Hollow, and represents data collected over a period of seventeen years. The list might have been notably increased by the study of shale washings, since many minute shells of *Cyclora* and other molluscs, and of Ostracoda etc., are found abundantly in the Ft. Ancient and Clarksville wherever samples are taken in Ohio, and undoubtedly could be demonstrated here.

The Blanchester, however has very few specimens of any of these minute fossils, careful examination of shale washings from Clarksville, Jacksonburg and Oxford in Ohio, and Oldenburg in Indiana, failing to show more than a few rare specimens of the

The Waynesville

common and wide- spread species, such as *Microceras inornatum*, *Bythocypris cylindrica*, etc.

In examining the fossil chart, two points stand out rather noticeably. The one is that the Ft. Ancient, aside from its pelecypods, does not carry a very distinctive Richmond fauna. The other is that the Clarksville does initiate a very characteristic Richmond fauna which is added to notably in the Blanchester.

The section as presented gives but little idea of the many little faunules which may be found in the Waynesville, and particularly in the Clarksville and Blanchester. Many faunules occur restricted to a few inches of sediment, and many species occur only in particular narrow zones, as for example, *Austinella scovillei*, which occurs 11" beneath the top of division 20. Here it is not uncommon, but for many years this was the only known locality. In more recent years the species has been found across the valley on Longstreths Branch, and also on Saltlick Creek at the north edge of Casetown, Brown County. This gives promise that ultimately the horizontal range of the species will be materially extended. Its maximum vertical range here is limited to 3".

In the vicinity of Clarksville are a number of excellent exposures of Waynesville strata, notably in Stony Hollow, a half mile northwest of Clarksville, Sewell Run, just east of town, and Penquite Hollow, 2.5 miles below town on the Cincinnati Pike. The Ft. Ancient is best shown in Penquite Hollow, but nowhere is it shown very satisfactorily. The *O. duseri* shales are admirably shown in Stony Hollow and in Penquite, and formerly were shown best of all on Sewells Run, but in this latter place erosion on the soft shales has largely destroyed the exposure. The horizon at these three localities has long been the chief recipient of the attention of trilobite hunters.

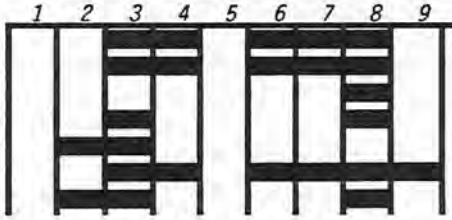
As exposed here, the Ft. Ancient differs in no way from the Ft. Ancient as exposed at Ft. Ancient and at Oregonia, except that the conditions of exposure are far less favorable for examination here. The other two beds are well exposed in an almost continuous series in Stony Hollow. The Stony Hollow section is as follows.

--- The Stony Hollow Section ---

	Thickness
10 - Basal Liberty	
9 - Second *H. insculpta* horizon. Partly covered.	6'06"
8 - Shales and thin limestones.	9'10"
7 - *Strophomena nutans* and *S. neglecta* zone..	2'00"
6 - Alternating thin shales and limestones, to a layer of upturned *Rafinesquina*.	3'02"
5 - Shale bed. *Isotelus* zone..	3'08"
4 - Alternating thin shales and limestones.	5'10"
3 - Thin shales and limestones to base of first *H. insculpta* horizon. Typical Clarksville bed.	15'00"
2 - *Orthoceras duseri* shale bed..	5'00"
1 - Ft. Ancient, mostly covered. Exposures are poor and scattering.	18'00"

The fauna of this section is distributed as shown by the following chart.

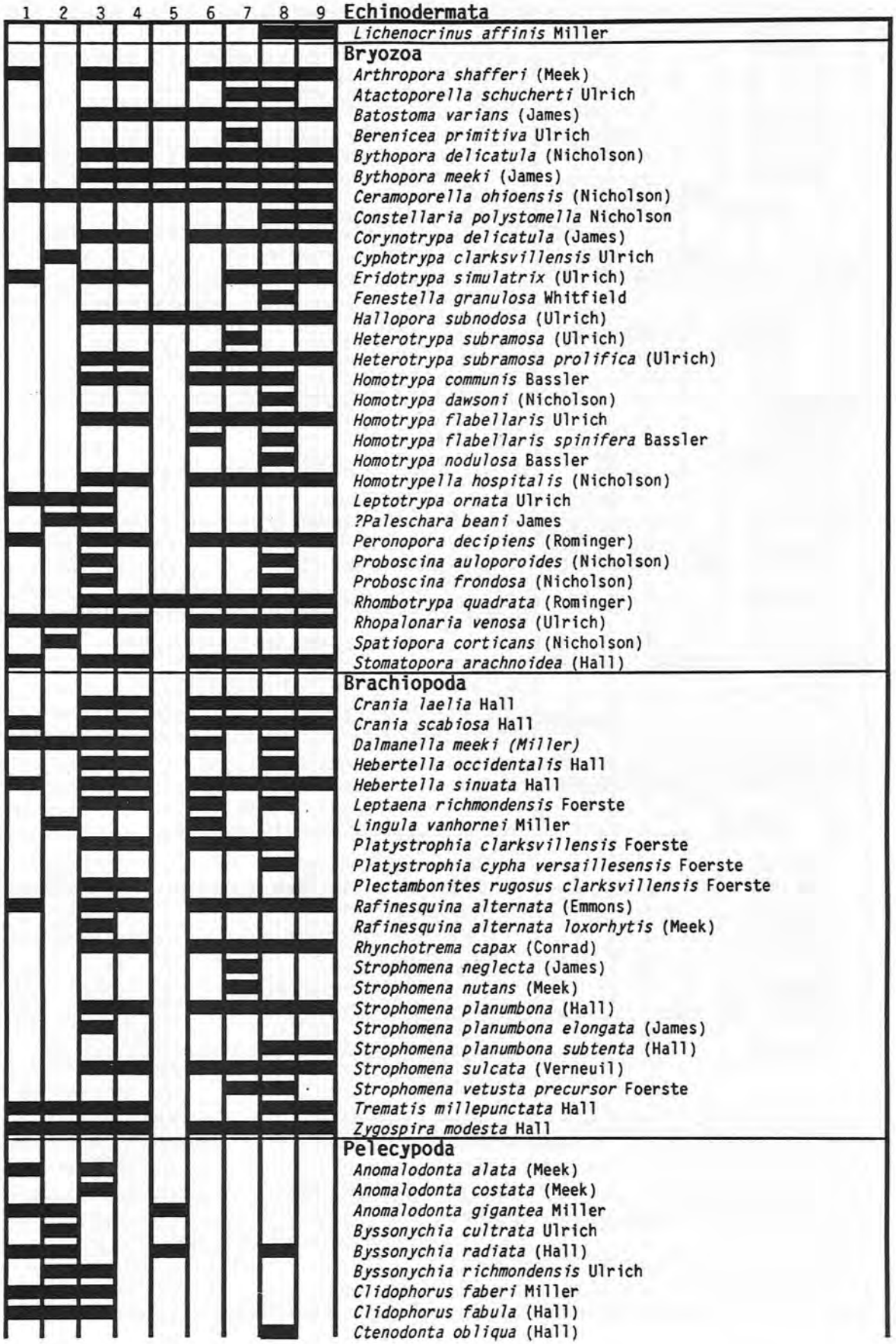
--- Waynesville Fauna of the Stony Hollow Section ---



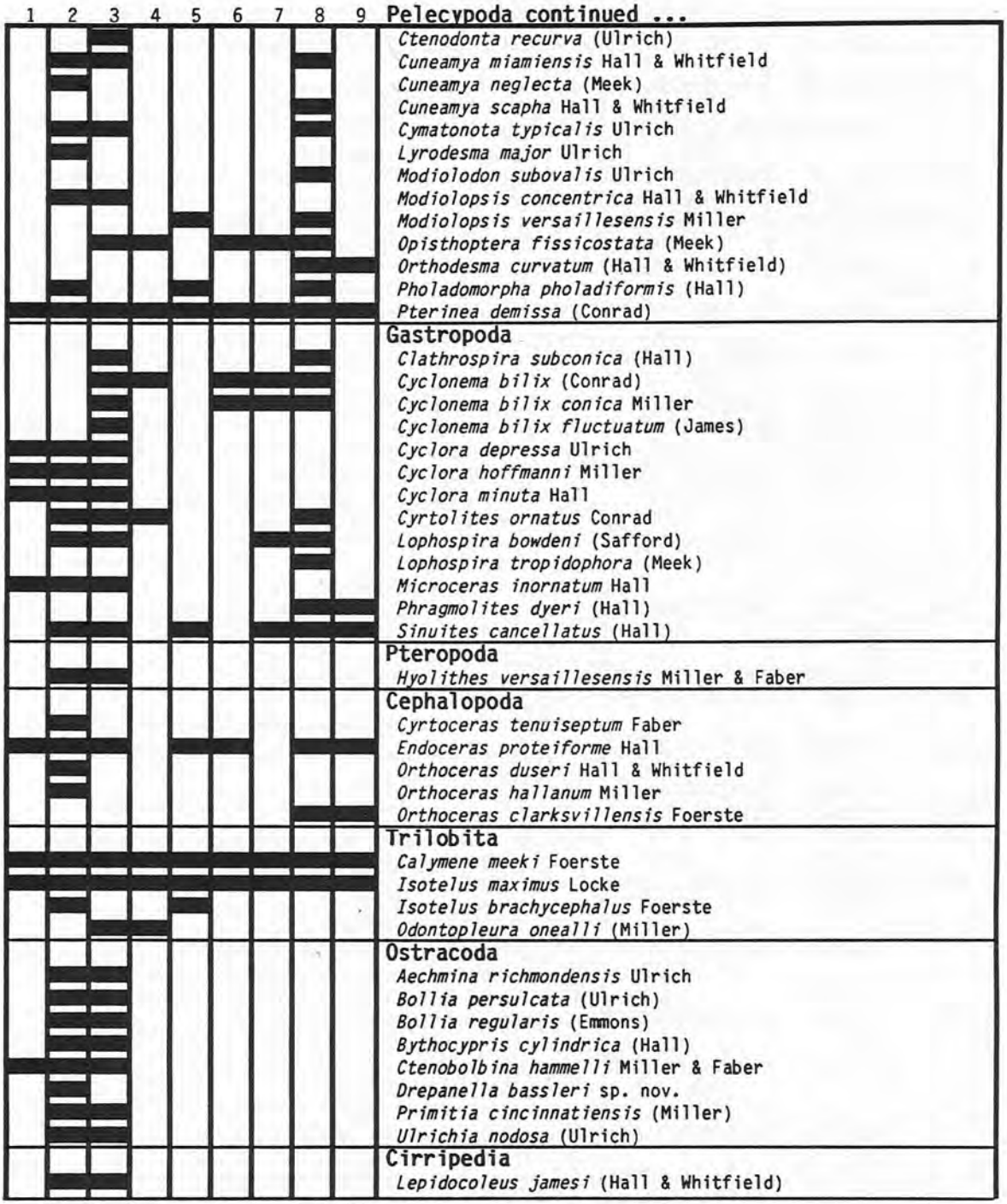
Coelenterata

Dermatostroma papillatum (James)
Dermatostroma scabrum (James)
Lyopora goldfussi (Billings)
Protarea richmondensis Foerste
Stromatocerium huronense (Billings)
Streptelasma rusticum (Billings)
Tetradium huronense Foord

The Waynesville



The Waynesville



As before noted, there is no essential difference when this section is compared with the Oregonia section, the somewhat greater fauna listed being due in part to the examination of shale washings from divisions 2 and 3.

The Ft. Ancient fauna listed from Stony Hollow is but a small part of what might be listed were conditions more favorable. The composite Ft. Ancient fauna of the Clarksville region, however, shows nothing whereby it differs from that of the Oregonia section, and the same may be said regarding the first part of the Clarksville, the *Orthoceras duseri* shale bed.

The Clarksville is characterized by the great abundance of *Dalmanella meeki*. This species, though common in the Ft.

The Waynesville

Ancient, is particularly abundant in the Clarksville, associated with numbers of *Strophomena planumbona* and var. *elongata*. Other common species are *Bythopora meeki*, *Batostoma varians*, *Homotrypella hospitalis*, *Eridotrypa simulatrix*, *Leptaena richmondensis*, *Platystrophia clarksvillensis*, *Streptelasma rusticum*, etc. Just above the *Orthoceras duseri* shales is a zone of *Rafinesquina alternata loxorhytis*. *Catazyga headi* has not been found in Stony Hollow by the writer but elsewhere may sometimes be found at about the level of the first *Hebertella insculpta* layer, usually within a foot either above or below. At an exposure on the creek crossing the road between Clarksville and Penquite Hollow, *C. headi* occurs at a somewhat lower level in the Clarksville.

Neither here or at Oregonia is there any distinct lithologic or faunal break between the Clarksville and the Blanchester. Lithologically shales are perhaps more prominent in the Blanchester, especially toward the top, where they sometimes carry indurated masses resembling small concretions. The limestones are somewhat more argillaceous. Faunally *Strophomena planumbona* is very much in reduced in numbers, except at the top. Only a few individuals represent the hordes of *Dalmanella meeki* in the Clarksville. But *Strophomena nutans*, *S. neglecta* and *S. vetusta precursor* are abundant in division 7. Bryozoa are abundant everywhere except in the shale bed, division 5, and are mostly *Batostoma varians*, *Bythopora meeki*, *Ceramoporella ohioensis*, *Homotrypa communis*, *H. flabellaris*, *Homotrypella hospitalis*, *Heterotrypa*, *Rhombotrypa*, etc. Division 5 is a smooth grained shale bed that has not proven especially prolific to the writer, but it is from this shale bed that Dr. Austin has secured most of his fine specimens of *Isotelus* now in the National Museum.

Scattering Ft. Ancient and Blanchester exposures are found about Blanchester, Clinton County, and Blanchester exposures are shown at Casetown, Brown County. These are all that bridge over the territory between the numerous exposures about Clarksville and Waynesville as exposed in Adams County.

In Adams County some good but scattering exposures of the Clarksville and Blanchester are found along Buck Run, several miles north of Seaman, and on Washburn Run, Ada Run, the East Fork of Eagle Creek, and the three creeks east of Decatur that were discussed under the Arnheim.

Of these two general localities, the region east of Decatur is by far the better, though it is difficult to get the exact thickness of the beds on account of the variable dip of the strata and the discontinuous nature of the exposures. The recent rebuilding (1924) of the Cincinnati Road permitted a section to be made up the road cut from Ada Run to the Sodom School, and here the following section is obtained.

- - Ada Run to Sodom School Section - -

	Thickness
4 - Shales and thin limestones, to top of *H. insculpta* bed.	.24'00"
3 - Covered.	.19'00"
2 - Shales and thin limestones carrying a Clarksville fauna.	.14'00"
1 - More or less lumpy shales from base of second *Strophomena concordensis* zone of the Arnheim, to the even-bedded Waynesville shales and limestones.	.11'09"

The rather scanty fauna listed below was obtained on a single visit, and though conditions of exposure were poor, they are likely to rapidly become much worse, as the strata are practically limited in exposure to the ditch along the road.

The Waynesville

— Decatur, Ada Run - Sodom School Fauna —

2	3	4	
■			*Streptelasma rusticum* (billings)
			Bryozoa
■		■	*Batostoma varians* (James)
■		■	*Bythopora meeki* (James)
■			*Ceramoporella ohioensis* (Nicholson)
■			*Homotrypella flabellaris* Ulrich
■			*Homotrypella hospitalis* (Nicholson)
■			*Peronopora decipiens* (Rominger)
■			*Rhombotrypa subquadrata* (Ulrich)
			Brachiopoda
■			*Dalmanella meeki* (Miller) [Ed. note: No entry]
■			*Hebertella insculpta* (Hall)
■		■	*Leptaena richmondensis* Foerste
■		■	*Platystrophia clarksvillensis* Foerste
■		■	*Plectambonites rugosus clarksvillensis* Foerste
■		■	*Rafinesquina alternata* (Emmons)
		■	*Rhynchotrema capax* (Conrad)
■		■	*Strophomena planumbona* (Hall)
■		■	*Strophomena neglecta* (James)
■			*Strophomena sulcata* (Verneuil)
			Pelecypoda
■			*Opisthoptera fissicostata* (Meek)
■			*Pterinea demissa* (Conrad)
			Trilobita
■		■	*Calymene meeki* Foerste
■		■	*Isotelus maximus* Locke

Scanty as this fragmentary fauna is, it plainly shows that the fauna of division 4 is Blanchester, *Strophomena neglecta* and *Hebertella insculpta* proving the point, and the presence of abundant *Dalmanella meeki* associated with *Strophomena planumbona, S. sulcata, Leptaena richmondensis* and *Plectambonites rugosus clarksvillensis* proves that division 2 is Clarksville. The whole of the Ft. Ancient and at least the basal *Orthoceras duseri* shales of the Clarksville are missing, the 11'9" between the base of the second *Strophomena concordensis* layer and the top of the Arnheim agreeing fairly well with the 8'8" between the same limits as exposed on East Fork a mile and a half farther east, and 12'6" as exposed at the top of the Arnheim section on Washburn Run, one mile west. At this latter place, the new road cut showed exactly the same fauna immediately above the Arnheim as was found in division 2 of the section described, while at the head of the gully along the road the base of the Waynesville was composed of 2' of even-bedded limestones and shales, showing wave-action in that the *Dalmanella* are largely ground up, and the *Streptelasma rusticum* more or less rounded as though waterworn. This is the only indication that the Clarksville might not be perfectly conformable upon the Arnheim, and were the 40' of Ft. Ancient not known elsewhere the break probably would not be suspected. This is an instance of what appears to have been quite common in the Cincinnati Province, an area of such low relief that it constituted an area of non-deposition of sediments rather than an of deposition with subsequent denudation and then deposition again.

The East Fork of Eagle Creek affords a more detailed section, but the long sights with the Locke level, the discontinuous nature of the exposures, and the variability of the dip, make close sectioning impossible. Generally, the strata rise with the stream, though there are exceptions, and leveling over covered intervals where the dip cannot be seen is probably responsible for this section showing a greater thickness of Waynesville than the section up the hill from Ada Run to Sodom School. The section on East Fork is as follows.

— East Fork of Eagle Creek Section —

	Thickness
7 - Shales and thin limestones to top of second *Hebertella insculpta* layer. *Catazyga* common 9'-10' above base.	

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Blanchester bed	22'06"
6 - Shales and thin limestones to thin layer of *H. insculpta*. Top of Clarksville.	3'10"
5 - Series of limestones and shales with *Streptelasma rusticum, Bythopora meeki, Dalmanella meeki, Strophomena planumbona, S. sulcata* and *Plectambonites rugosus* the most characteristic fossils	3'04"
4 - Smooth shales and thin limestones, to top of 3" limestone just above water level at the high exposure on the right below the woods	6'06"
3 - Even-bedded thin limestones and shales full of *Dalmanella meeki*, and with occasional *Streptelasma rusticum, Bythopora meeki, Eridotrypa simulatrix, Plectambonites rugosus clarksvillensis*, etc. Basal Clarksville	4'09"
2 - Lumpy shales and shaly limestones to top of Arnheim and base of 3" limestone full of *Dalmanella meeki*	6'00"
1 - Second *Strophomena concordensis* zone of the Arnheim. Well exposed about 150 yards below the bridge	2'08"

This gives a total Waynesville thickness of 57', or 16' greater than was measured at the Ada Run locality. Though there may be considerable error in the thickness of divisions 3-5, the figures for divisions 6 and 7 were measured directly on a good exposure. This would give an accurate thickness of 22'6" for the Blanchester, which should give about 33' for the Clarksville on the basis of the Ada Run section.

Southward in Kentucky the Waynesville becomes thickened, less calcareous and more argillaceous and arenaceous, and the basal portion becomes cross-bedded, ripple-marked, and sun-cracked, while the fauna is very greatly reduced. Clarksville and Blanchester sediments and faunas may be traced as far south as the southern part of Fleming County, beyond which they rapidly lose their identity.

At Merritts Ferry the Waynesville is almost entirely composed of barren clay shales, sometimes blocky and non-fissile, with some heavy, barren argillaceous limestones. At the top are a few feet carrying a reduced Blanchester fauna with considerable numbers of *Zygospira kentuckiensis*.

Tracing the Waynesville westward from the Oregonia locality good exposures are found at many places, notably the railroad cut at Miamisburg, showing nearly the whole of the Waynesville; Ft. Ancient and Clarksville exposures on the little creek three quarters of a mile north of West Middletown; essentially the whole of the Waynesville along Dry Fork of Elk Creek, south and south-east of Jacksonburg; parts of the Clarksville and Blanchester in Seven Mile Creek Valley between Collinsville and Camden; and essentially the whole Waynesville in numerous exposures about Oxford.

From the Great Miami Valley westward to Oldenburg Indiana, there is very little variation, lithologically and faunally, and usually the same beds and faunules may be traced the entire distance.

Oxford Composite Sections.

Since there is so little variation in the characters of the Waynesville in this territory, one region will be described as being typical of the whole, this is the Oxford region, which is not especially noted for the extent or the quality of its Waynesville exposures, but because the accessibility of these exposures to students of Miami University has resulted in the accumulation of more information about the Waynesville here than elsewhere. Here again the rapidity with which the soft Waynesville shales weather, erode, and slump over, gives rather discontinuous and more or less widely separated exposures, which makes the getting of exact thicknesses of divisions difficult.

In constructing the composite section of the Oxford region, divisions 11-13 constituting the Ft. Ancient were found in Martindells Creek, and since the section is a continuation of the Arnheim section of this region previously described (p. 13), the numbering of the divisions will be made to correspond to the Arnheim section. Practically the whole of the Ft. Ancient occurs here, but the top of the section fails to reach the basal *Orthoceras duseri* bed of the Clarksville.

In the southeast one quarter of section 36, Oxford Township, a small stream heading across the Hamilton Pike and flowing into Four Mile Creek at the upper Lanes Mills ford, shows a continuous section of most of the Arnheim, followed by a practically continuous section of the Ft. Ancient , divisions 11-13. The Ft. Ancient here

The Waynesville

has a total thickness of 34', so that the top of the Martindells Creek section must fail to reach the top of the Ft. Ancient by 1'6". From the base of the *Orthoceras fosteri* zone to the top of the main *Hebertella insculpta* zone, as it is exposed about 100 yards west of the Hamilton road is 75', so that figure represents the combined thickness of the Clarksville and Blanchester.

The exposures on Bull Run and its tributaries give divisions 14-15, and 19-21 completely, most of 16, 18, and 22, and the top of 13. The tributary from the north, cutting across the southwest corner of Oxford and following the road to Bull Run in the southeast one quarter of section 27, and another tributary just west, show parts of division 18.

Divisions 14-15 are also exposed in the bed of Four Mile Creek near the site of the old brush dam at the head of the now abandoned hydraulic, about two miles north of the center of Oxford. Here is where the well known *Isotelus* specimen showing legs was found. In Four Mile Creek at High Banks three miles north of Oxford, are most of division 16, all of 21-25. The section follows.

— Oxford Composite Section —

	Thickness
25 - Basal Liberty.	
24 - Heavy, shelly limestone full of *Hebertella insculpta*, *Rhynchotrema capax*, and *Strophomena planumbona*.	0'04"
23 - Second shale bed showing locally indurated spots resembling nodules or concretions.	*
22 - Smooth shales and even-bedded limestones to base of a second lumpy shale bed	*
21 - Shale beds showing locally indurated spots giving a more or less lumpy, nodular appearance	4'00"
20 - "Grainy" shales, and thin, more or less irregular limestones to base first lumpy shale bed. A 4' zone of *Strophomena nutans* at the base, and a 1" layer of *Rhynchotrema dentatum* 1'6" below the top.	10'04"
19 - *Isotelus* shales, with shales and intercalated limestones above	*
18 - Shales and thin limestones to base of *Isotelus* shales. Base of Blanchester.	*
17 - Shales and thin limestones to base of first *Hebertella insculpta*. Top of Clarksville.	*
16 - *Dalmanella meeki* limestones..	18'06"
15 - Shales and irregular limestones to base of even-bedded limestones of division 16.	3'00"
14 - *Orthoceras duseri* shale bed. Base of Clarksville.	4'06"
13 - Even-bedded shales and limestones, the latter up to 2" thick and often highly argillaceous and barren. To base of *Orthoceras duseri* zone	18'00"
12 - Heavier limestones at the base, shales toward the top. Strata even-bedded, the limestones sometimes composed largely of fossil fragments.	6'06"
11 - Shales and soft, thin limestones at the base, followed by wave-marked limestones composed largely of fragments of *Dalmanella* and Bryozoa, and these by alternating shales and thin limestones. All strata even-bedded, none nodular	9'06"
10 - Irregular, heavy *Cyclora* limestones at the top of the Arnheim.	

[*Editors note... Shideler does not give measurements for strata marked by asterisks. Measurements found in his locality code book are given at the end of this section.]

The Waynesville

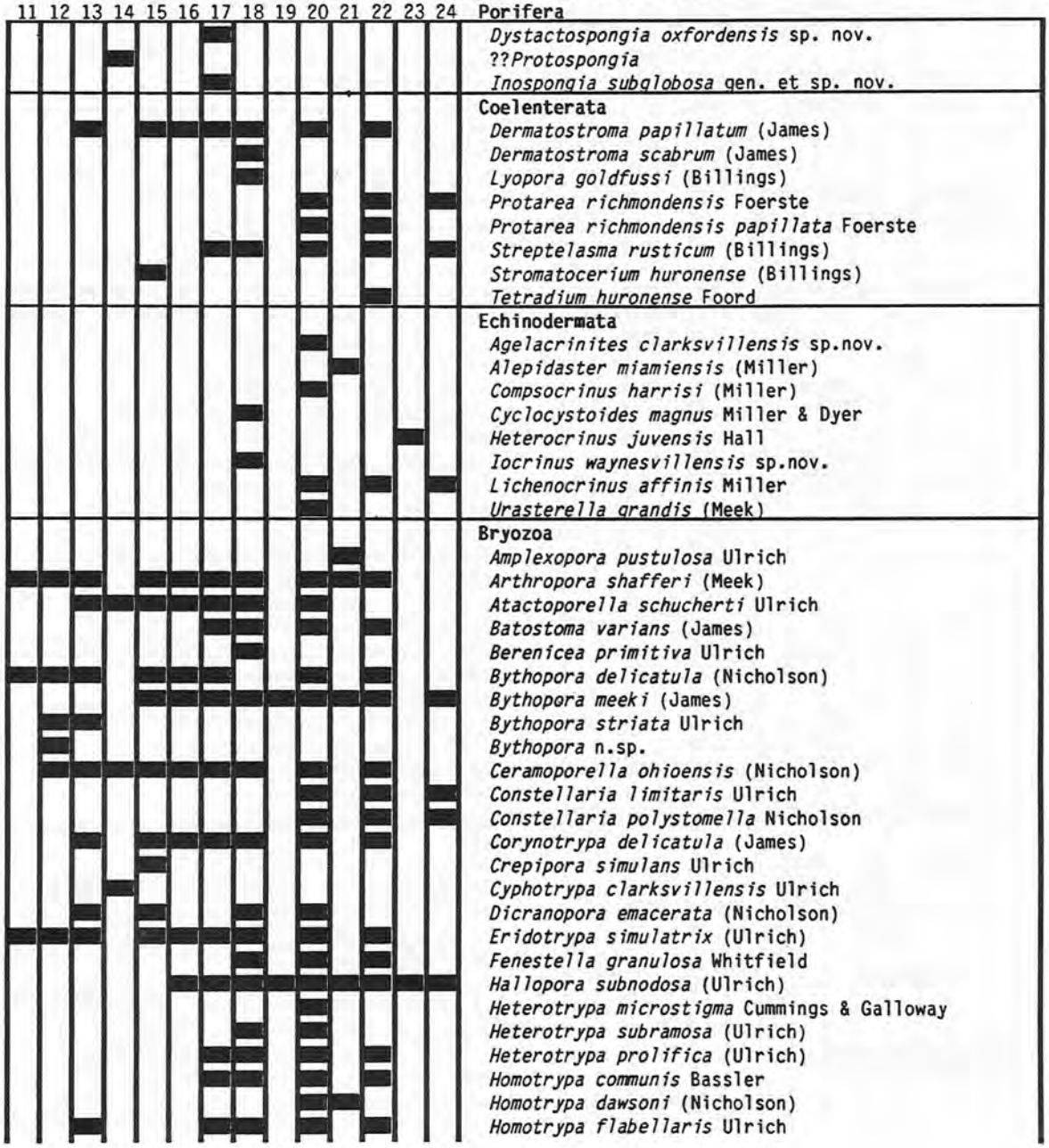
Comparing this with the Clarksville section the following correlation of sections is made.

	Oxford	Clarksville
Division #	14	2
	15-17	3
	18	4
	19	5
	20	6-7, part 8
	21	8 (part)
	22	8-9 (part of each)
	23	9 (part)
	24	9 (part)
	25	10

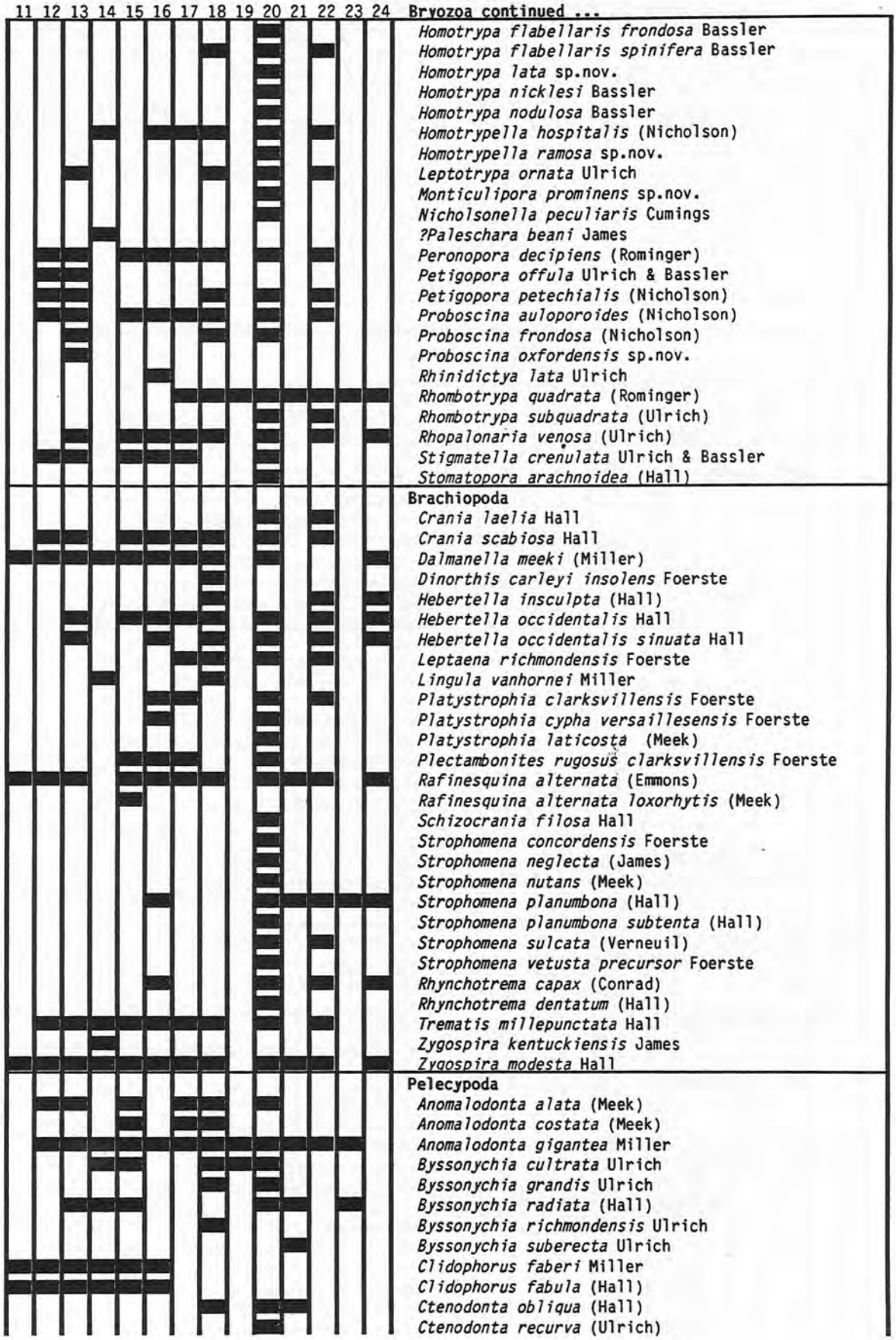
Division 8-9 of the Clarksville section are not very favorably exposed, and are very favorably exposed at Oxford, hence the divisions at Oxford are drawn on a closer and somewhat different basis than those at Clarksville.

The fauna of the Oxford composite section follows.

Oxford Composite Section Fauna



The Waynesville



Bryozoa continued ...

Homotrypa flabellaris frondosa Bassler
Homotrypa flabellaris spinifera Bassler
Homotrypa lata sp.nov.
Homotrypa nicklesi Bassler
Homotrypa nodulosa Bassler
Homotrypella hospitalis (Nicholson)
Homotrypella ramosa sp.nov.
Leptotrypa ornata Ulrich
Monticulipora prominens sp.nov.
Nicholsonella peculiaris Cumings
?Paleschara beani James
Peronopora decipiens (Rominger)
Petigopora offula Ulrich & Bassler
Petigopora petechialis (Nicholson)
Proboscina auloporoides (Nicholson)
Proboscina frondosa (Nicholson)
Proboscina oxfordensis sp.nov.
Rhinidictya lata Ulrich
Rhombotrypa quadrata (Rominger)
Rhombotrypa subquadrata (Ulrich)
Rhopalonaria venosa (Ulrich)
Stigmatella crenulata Ulrich & Bassler
Stomatopora arachnoidea (Hall)

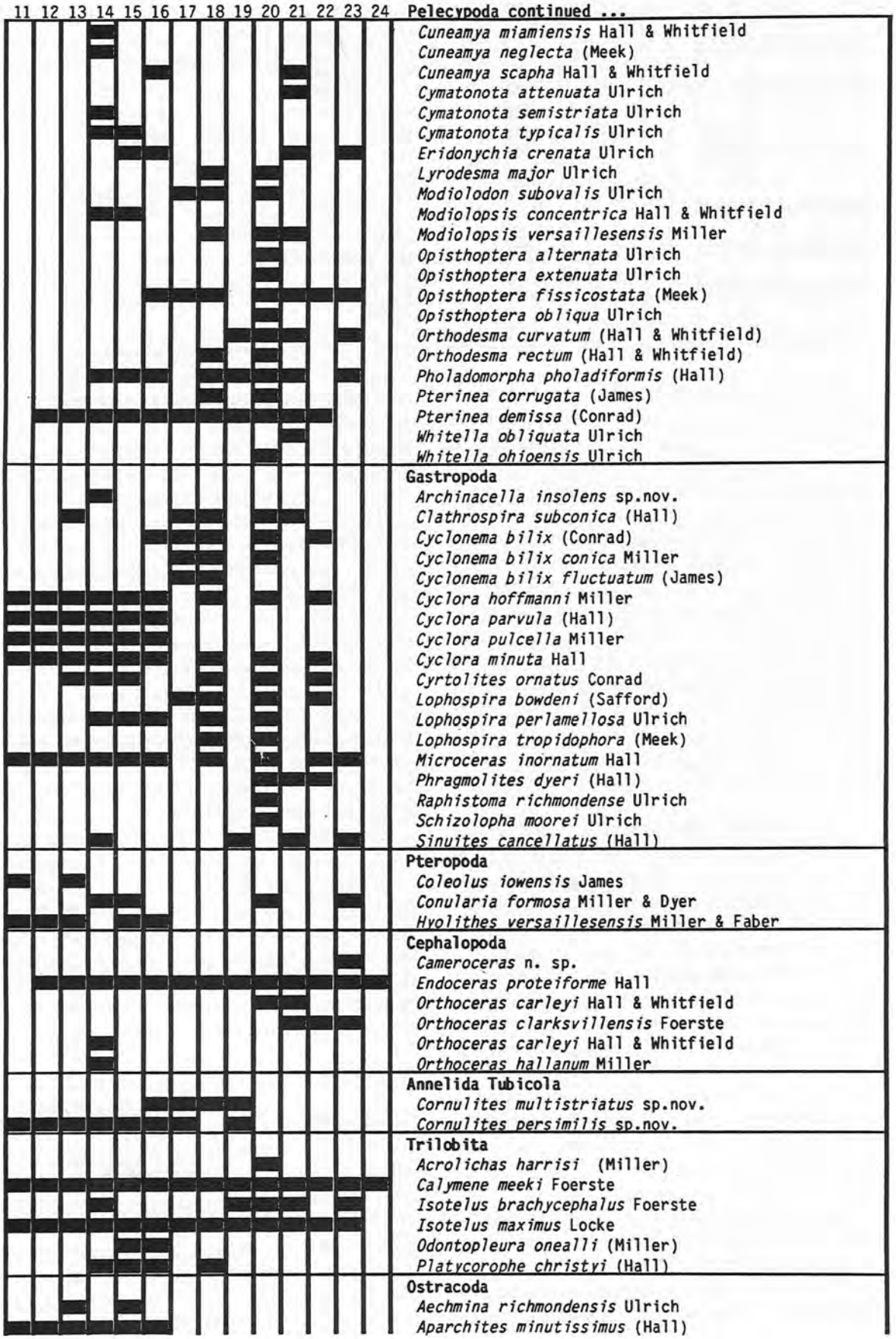
Brachiopoda

Crania laelia Hall
Crania scabiosa Hall
Dalmanella meeki (Miller)
Dinorthis carleyi insolens Foerste
Hebertella insculpta (Hall)
Hebertella occidentalis Hall
Hebertella occidentalis sinuata Hall
Leptaena richmondensis Foerste
Lingula vanhornei Miller
Platystrophia clarksvillensis Foerste
Platystrophia cypha versaillesensis Foerste
Platystrophia laticosta (Meek)
Plectambonites rugosus clarksvillensis Foerste
Rafinesquina alternata (Emmons)
Rafinesquina alternata loxorhytis (Meek)
Schizocrania filosa Hall
Strophomena concordensis Foerste
Strophomena neglecta (James)
Strophomena nutans (Meek)
Strophomena planumbona (Hall)
Strophomena planumbona subtenta (Hall)
Strophomena sulcata (Verneuil)
Strophomena vetusta precursor Foerste
Rhynchotrema capax (Conrad)
Rhynchotrema dentatum (Hall)
Trematis millepunctata Hall
Zygospira kentuckiensis James
Zygospira modesta Hall

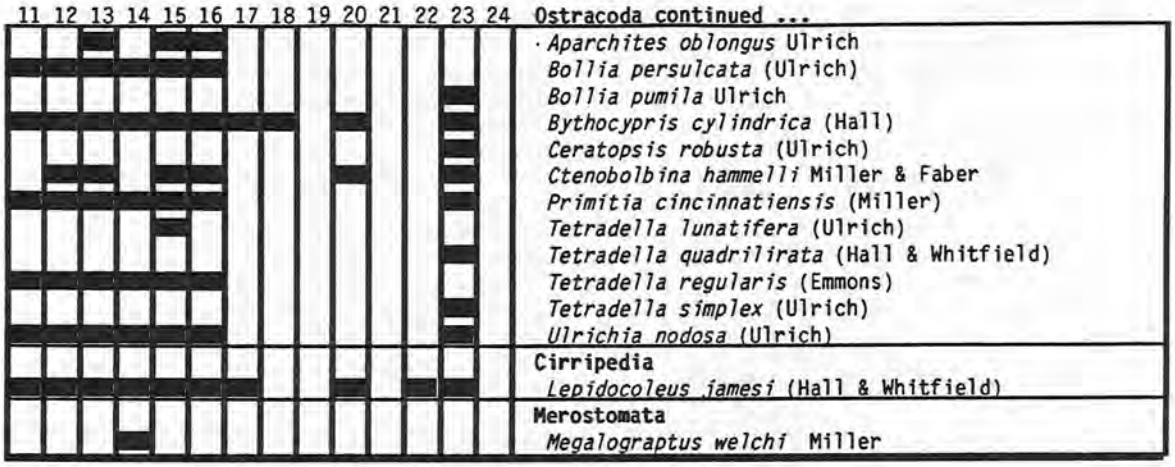
Pelecypoda

Anomalodonta alata (Meek)
Anomalodonta costata (Meek)
Anomalodonta gigantea Miller
Byssonychia cultrata Ulrich
Byssonychia grandis Ulrich
Byssonychia radiata (Hall)
Byssonychia richmondensis Ulrich
Byssonychia suberecta Ulrich
Clidophorus faberi Miller
Clidophorus fabula (Hall)
Ctenodonta obliqua (Hall)
Ctenodonta recurva (Ulrich)

The Waynesville



The Waynesville



The foregoing section and faunal list show that while the various subdivisions of the Clarksville and Oregonia sections can be carried across to Oxford, the characteristic invasion of Richmond species in force is delayed until near the close of the Clarksville, instead of at the beginning. In fact, this is much more so than the chart indicates, since the occurrence of *Stromatocerium huronense* and *Zygospira kentuckiensis* in division 14, and *Rhynchotrema capax* in division 16, are recorded on the basis of one specimen each, while *Streptelasma rusticum* and *Batostoma varians*, fairly common in equivalent beds at Clarksville, are absent in the Oxford section until division 17, and are uncommon there.

Other species more or less common in the Clarksville east of the Great Miami Valley but rare in the Clarksville west of that valley are *Bythopora meeki*, *Homotrypella hospitalis*, *Platystrophia clarksvillensis*, *Strophomena planumbona*, and *S. sulcata*.

The *Orthoceras duseri* shale bed, division 14, shows no *Tetradium* and practically no *Stromatocerium huronense*, *Cyphotrypa clarksvillensis* or *Orthoceras duseri*, quite a contrast to conditions at Clarksville, Ft. Ancient and Oregonia, where these species are common. But *Calymene*, *Isotelus*, *Anomalodonta*, *Byssonychia* etc., are still prevalent, and continue so at least as far west as Oldenburg, Indiana.

These observations show that the conditions which admitted the bulk of the more or less characteristic Richmond elements to the Warren-Clinton-Highland County region did not yet prevail in Butler County and westward into Indiana, and in this latter region only a few rare and scattering individuals became established. The Clarksville species did not become really established here until Blanchester times.

The single specimen of *Zygospira kentuckiensis* found was out of its usual Ohio range. At Clarksville, Blanchester and elsewhere in Ohio it occurs more or less rarely in a thin zone near the base of the Blanchester. At Fisherville, Kentucky, the species ranges through 9.5 feet.

Diligent search has been made for *Catazyga headi* in the Oxford region, but no specimens have been discovered. The species seems to be very erratic in its occurrence, being locally common in a very thin zone, but usually absent.

Generous samples of shale washings have been examined for practically the whole of each division of the Waynesville in the Oxford region, which explains why so many species of minute forms are listed here and not in the other faunas. It is safe to say that the same horizons would show the same species of minute forms wherever they would be searched for in Ohio.

Waynesville in Indiana & Kentucky.

Excellent Waynesville exposures are found in Indiana south of Brookville and at St. Peters, Oldenburg, Weisburg, Versailles, and Madison, and these have mostly been described by Cumings.[7] At Madison the total thickness of the Waynesville is about 110 feet, which is distinctly more than the thickness in the Oregonia-Clarksville region. The fauna of this 110 feet could not be divided into that of the

The Waynesville

Ft. Ancient, Clarksville, and Blanchester beds by the writer, most of the characteristic species of these beds being absent. In fact, only 35 species were listed from the Waynesville of Madison, as compared with 172 species and varieties listed from the Waynesville of the Oxford region.

Southward on the west flank of the arch in Kentucky the Waynesville becomes still less fossiliferous, and impossible to distinguish from the overlying Liberty. In the railroad cut west of Fisherville, Jefferson County, Kentucky, a reef of *Tetradium* marks the base of the Waynesville and this is succeeded by blocky, non-fissile shales and soft limestones carrying a modified Clarksville bryozoa fauna. The Ft. Ancient appears to be lacking. Still further south in Jefferson County, more massive, more or less barren limestones appear in the Waynesville, especially at the base, and show strong wave-markings, cross-bedding, and sun-cracks. The very much reduced Waynesville fauna can be traced as far south as Lebanon, Kentucky, and the most abundant fossil is *Cyphotrypa clarksvillensis*.

No Waynesville has been identified in the southern part of Russell County, where a good section is shown along the Cumberland River. The only Richmond beds identified here are those of the Arnheim, which are followed by the Chattanooga, and below Shinbone Cliff, possibly some basal Liberty. During Arnheim times this area seems to have been very close to shore, and during the Waynesville must have been elevated above the Waynesville sea.

Just what was the exact path of migration of the southern Arnheim and Waynesville faunas into the Cincinnati region is not clear, but the Arnheim sea apparently extended up the west side of the Nashville dome, thence eastward across the saddle between the Nashville dome and the Cincinnati Arch, both of which had been in existence in an incipient condition since early in the Mohawkian, and thence into the Cincinnati area from the southeast. The Ft. Ancient and the southern Clarksville faunas probably followed the same path, except that they came up the east side of the Nashville dome instead of the west, where Waynesville sediments are absent.

The Ft. Ancient fauna is essentially a reduced southern fauna of long-lived and wide-ranging types, which probably were the first to migrate in because of their adaptability to all sorts of conditions. Typical Richmond elements are conspicuous by their almost entire absence.

The Clarksville fauna seems to be composed of two elements, one southern and one northern. The southern element includes those species listed as having previously occurred in the Arnheim (p. 21). The northern element includes *Protarea richmondensis*, *Rhombotrypa quadrata*, *Rhynchotrema capax*, and *Strophomena sulcata*. The Blanchester fauna appears to be northern, and includes such northern species as *Catazyga headi*, Hebertella insculpta, *Strophomena neglecta*, *S. nutans*, and *S. vetusta*. The upper Waynesville in Canada is widely distributed from Manitoulin Island on Georgian Bay at least to the Nicolet River, almost half way between Montreal and Quebec[8], and the faunas, excepting the southern element, are arctic and not Atlantic in their relationships.

**Notes: **

[1] N.W. Perry, American Geologist, Vol. IV No. 6, (1885), pp. 326-36.
[2] American Geologist, Vol. 32, 1903, pp 205-7.
[3] Bull. Sci. Lab. Den. Univ., Vol. 14, 1909, p. 290.
[4] Bull. Sci. Lab. Den. Univ., Vol. 17, 1912, p. 22
[5] Bull. Sci. Lab. Den. Univ., Vol. 14, 1909, pp. 291-3
[6] Geol. Surv. Can., Mem. 138, 1924, p. 75.
[7] 32nd Ann. Rept. Ind. Dept. Geol. & Nat. Res., 1907.
37th Ann. Rept. Ind. Dept. Geol. & Nat. Res., 1913.
[8] Foerste, A.F. Upper Ord. Formats. in Ont. & Quebec, Can. Dept. Mines, Geol. Surv., Mem. 83, pp. 97-155.

The Waynesville

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Shideler Locality Code-book Section For High Banks

Locality 1.1CC
"High Banks." NE 1/4 NW 1/4, Sec. 11, T06N, R01E, Wash bank along Four Mile Creek.

1. 2' 9" Water level to top last ls. with crowded *Dalmanella meeki* in top. Below in west bank are ^5' of *Dalmanella* lss., thin & even bedded, with smooth blue clay shales between.

2. 15' 2" to base 1" stratum of *H. insculpta*. {±} lumpy & irregular shales & irregular argillaceous lss. *Dalmanella*.

3. 15' 11" to base *Isotelus* shale bed. Strata more even-bedded than #2. *Dinorthis carleyi insolens* 7"-8" above *H. insculpta* both in bank & in creek. In bank *D. carleyi* is ^1' below top exposed lss.

4. 1' 7" Smooth, blue clay shales. *Isotelus* zone of Austin. Occasional ls. lenses carry the bulk of the fauna.

5. 1' 7" Four to five lss. with intercalated shales, to base shelly zone of *Strophomena nutans*.

6. 1' 1" *Strophomena nutans* zone.

7. -

The Liberty

The Liberty member of the Richmond formation was described by Nickles[1] as beginning with the main *Hebertella insculpta* layer. Dr. G.M. Austin proposed to raise the base of the Liberty to the base of a series of heavy argillaceous limestones, well developed about Clarksville, thus restricting the predominantly limestone beds to the Liberty, and the shales to the Waynesville. But, this would not serve that purpose, as there is another shale bed above the heavy limestones, and the boundary might just as well be placed at the base of the next limestone series above. As a matter of fact, to repeat the substance of what has already been said, any separation of the Waynesville from the Liberty is on primarily an artificial basis and for a distance of 40' either above or below the boundary as redefined by Foerste, there is in the typical Liberty region, no outstanding line of division that is any better than numbers of other possible division lines.

As for the upper limit, Nickles says "On the east side a layer in which *Streptelasma rusticum* (Billings) is very abundant marks about this horizon and may be considered the upper boundary."[1]

For reasons before stated, the base of the Liberty has been raised to the top of the main *Hebertella insculpta* layer.

As for the *Streptelasma* layer mentioned by Nickles, this is a very distinct marker in Warren and Clinton Counties, Ohio, and is characterized by the great abundance of large *Streptelasma rusticum*, associated with more or less numerous *Batostoma variabile*, *Rhombotrypa quadrata*, *Pachydictya fenestelliformis*, *Strophomena vetusta* and *Rhynchotrema capax*. This layer is just above the *Charactoceras baeri* zone, which introduces the Whitewater fauna. Just beneath the *C. baeri* zone are several heavy, barren, fine-grained blue limestones which occur everywhere in Ohio and in places in Indiana. While the basal heavy limestones tend to fail southward in Indiana, the *C. baeri* zone can be traced as far west as Laurel and as far south as Versailles. Somewhere between Versailles and Madison the layer wedges out.

Faunally, this dividing line at the base of the heavy limestones, or at the base of the *C. baeri* zone where the heavy limestones are absent, marks one of the two greatest breaks in the Richmond, the Arnheim-Waynesville boundary previously discussed being the other. Both above and below as well as in the *C. baeri* zone may be found filled erosional channels or miniature "horses" up to 2' thick, and in Adams County a veritable conglomerate occurs. Isolated pebbles may be found as far west as the Indiana state line. All indications point to this as the logical place at which to draw the Liberty-Whitewater boundary.

Nickles originally described the Liberty as the *Strophomena planumbona* beds, and though most of his information regarding the member was derived from the Clarksville area, he took as his type locality a series of exposures along a little tributary of Silver Creek about a mile west of Liberty, Indiana. These exposures are continued into a small quarry toward the top of the hill.

This is an unfortunate choice, since it shows but little of the real characters of the Liberty, the base is not exposed at all, and the top but pooorly. The quarry at the top is mostly if not wholly in the Whitewater, including the *Charactoceras baeri* zone and 7 feet of the strata above, the layers quarried being the heavy limestones at the base of the Whitewater beneath the *C. baeri* zone, and including possibly also some other heavy limestones at the top of the Liberty, the deterioration of the long abandoned quarry obscuring this point.

Nickles' *Streptelasma* layer does not occur here, but the *Charactoceras baeri* zone does, and it, together with the heavy barren limestones beneath constitute a good datum plane. Following is a section of the locality, with fanual lists.

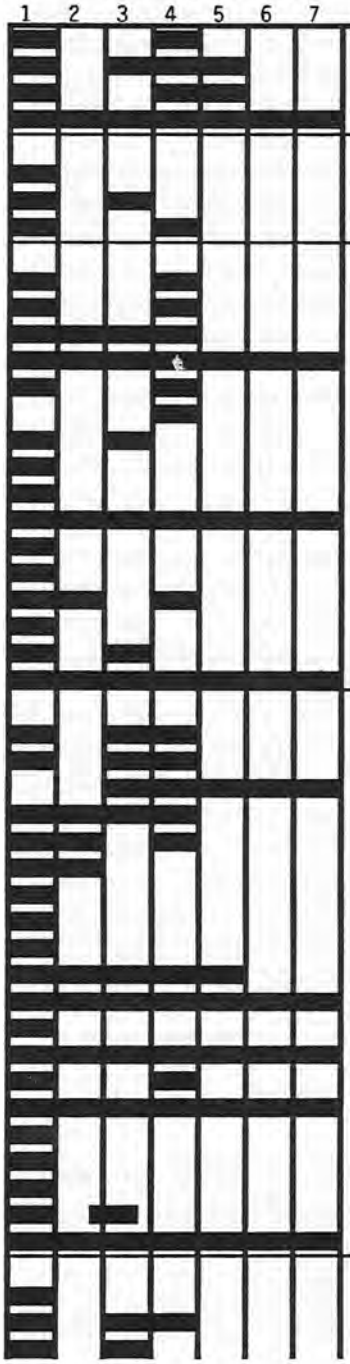
Liberty Type Section (Silver Creek)

	Thickness
9 - *Charactoceras baeri* zone	02'
8 - Barren limestones. Base of Whitewater	02'
7 - Limestones like division 6	07'

The Liberty

6 - Series of wave-marked, obscurely cross-bedded and more or less barren "hash" limestones and shales..... 03'02"
5 - Rather shelly limestones and thin, intercalated shales. *Plectambonites* bed.....05'
4 - Rather shelly limestones and thin shales. Highly fossiliferous..05'06"
3 - Shale with few thin limestones, some of which are in lenses..... 03'03"
2 - Even-bedded limestones 2 - 6 inches thick with intercalated shales. Limestones wave-marked and composed largely of fossil fragments..... 04'
1 - Shales with few thin limestones..... 03'

--- Liberty Fauna of the Liberty Type Section (Silver Creek) ---



Coelenterata
Dermatostroma papillatum (James)
Protarea richmondensis Foerste
Streptelasma divaricans (Nicholson)
Streptelasma rusticum (Billings)

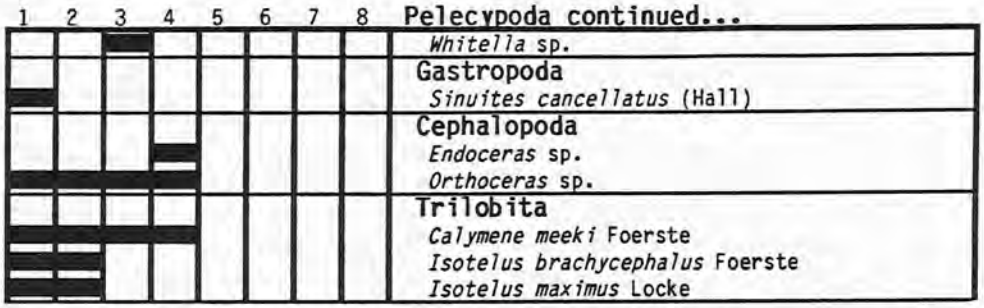
Echinodermata
Dendrocrinus casei? Meek
Heterocrinus juvenis ?Hall
Lichenocrinus affinis Miller

Bryozoa
Arthropora shafferi (Meek)
Batostoma prosseri Cummings & Galloway
Bythopora delicatula (Nicholson)
Bythopora meeki (James)
Ceramoporella ohioensis (Nicholson)
Constellaria polystomella Nicholson
Corynotrypa inflata (Hall)
Dicranopora emacerata (Nicholson)
Eridotrypa simulatrix (Ulrich)
Hallopora subnodosa (Ulrich)
Heterotrypa subramosa prolifica Ulrich
Helopora harrisi James
Homotrypa flabellaris Ulrich
Lioclemella subfusiformis (James)
Proboscina auloporoides (Nicholson)
Rhombotrypa quadrata (Rominger)

Brachiopoda
Crania laelia Hall
Crania scabiosa Hall
Dinorthis subquadrata (Hall)
Hebertella occidentalis Hall
Hebertella sinuata Hall
Leptaena richmondensis Foerste
Platystrophia cumingsi McEwan
Platystrophia cypha versaillesensis Foerste
Platystrophia annieana Foerste
Plectambonites rugosus clarksvillensis Foerste
Rafinesquina alternata (Emmons)
Rafinesquina alternata fracta Meek
Rhynchotrema capax (Conrad)
Rhynchotrema capax perlamellosum (Whitfield)
Strophomena planumbona (Hall)
Strophomena planumbona subtenta (Hall)
Strophomena sulcata (Verneuil)
Strophomena vetusta (James)
Trematis millepunctata Hall
Zygospira modesta Hall

Pelecypoda
Byssonychia radiata (Hall)
Pterinea demissa (Conrad)
Pterinea corrugata (James)

The Liberty



Favorable conditions of exposure undoubtedly would more than double the faunal list from this locality.

Disregarding the faunal evidence, the base of the Liberty might be drawn at the base of division 2, as advised by Austin. But that would leave a number of other horizons equally as good where the line might just as logically be drawn. The point the writer wishes to emphasize is that the upper Waynesville and the Liberty are distinctly shallow water formations, and if we take the wave-marked limestone series largely composed of fossil fragments finely ground, and the obscure cross-bedding, the presence of miniature "horses", etc. as evidence of breaks in the sedimentary record, without checking up with the fossils, plenty of breaks can be found. How to distinguish the genuine breaks from what appear to be breaks can only be done by finding faunal changes which are correlated with the suspected break, and by finding that the evidences of the break are more than local.

Excellent Liberty exposures abound, chiefly because the more resistant limestones stand up better under erosion than do the soft shales of the underlying Waynesville.

As exposed across the north end of the Cincinnati arch, the basal part of the Liberty is lithologically and in part faunally but a continuation of the sedimentation and the life of the Waynesville, with two shale beds separated by a series of 2 to 4 inch limestones, the limestones with intercalated shales and the shale beds with thin limestones. The upper Liberty, however, is dominantly limestone, the 2 to 4 inch limestones being separated by thin shales.

Localities noted for the excellence of their exposures of the Liberty member are Oldenburg, Weisburg, and Versailles in Indiana, and Oxford, College Corner, Jacksonburg, Flat Fork, Clarksville, and Harshaville in Ohio.

Oxford Composite Section.

(See map on page 50)

One of the most satisfactory Liberty sections is that found along Dodges Creek just outside Oxford to the north-west, though a section equally good is found on Little Four Mile Creek, about three miles east of College Corner and six miles north of Oxford. The following section is a composite of the Dodges Creek section, supplemented by the Little Four Mile section, and by a small exposure on Addisons Creek midway between the two. Of the composite section, all divisions are exposed on Dodges Creek, though divisions two through four are not completely shown. On Addisons Creek one and two are shown, and on Little Four Mile all but one and the basal part of two are admirably exposed. The thickness of divisions one and two are as measured on Addisons Creek, three through nine as measured on Little Four Mile.

— Oxford Composite Liberty Section —

	Thickness
9 - *Charactoceras baeri* zone.....	06'
8 - Barren blue limestone with trails on top. Base of Whitewater.....	07'
7 - Limestones 2"-4" thick with intercalated shales.	

The Liberty

Limestones are less fossiliferous, are wave-marked, and show lines of mud flowage toward the north and north-east. Equivalent of divisions 6-7 of the Liberty, Indiana section..... 09'07"

6 - Mostly thin limestones and shales to top conspicuous 3" to 4" ledge which limestone is the *Dendrocrinus casei* zone/*Plectambonites* zone. Equivalent of division 5 of the Liberty, Indiana section..... 04'08"

5 - Rather shelly limestones characterized by great numbers of *Rhynchotrema capax*, *Dinorthis subquadrata*, Bryozoa, etc. To top of 3"-4" limestone forming floor of creek 1' below the *Plectambonites* zone..... 06'04"

4 - Shale bed, with some thin limestones, and some "horses" up to 10" thick. Division 3 of the Liberty, Indiana section..... 04'10"

3 - Series of wave-marked limestones composed largely of fossil fragments..... 06'05"

2 - Shale bed with a few thin limestones with abundant *Bythopora delicatula*. Top of division equals division 1 of the Liberty, Indiana section..... 08'

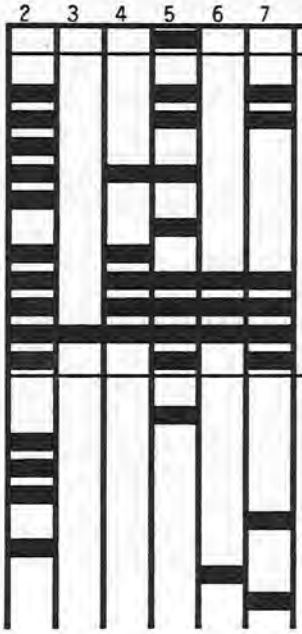
1 - *Hebertella insculpta* bed. Top of Waynesville..... 04'05"

The divisions of this section retain their lithological and faunal characters over practically the whole of the exposed area of the Liberty in Ohio, though they may vary somewhat in thickness, variation in total thickness of the Liberty being primarily due to variations in thickness of the divisions above the *Plectambonites* bed.

Like the Waynesville, the Liberty is exceedingly prolific as regards specimens of fossils, though there are fewer species here than in the Waynesville.

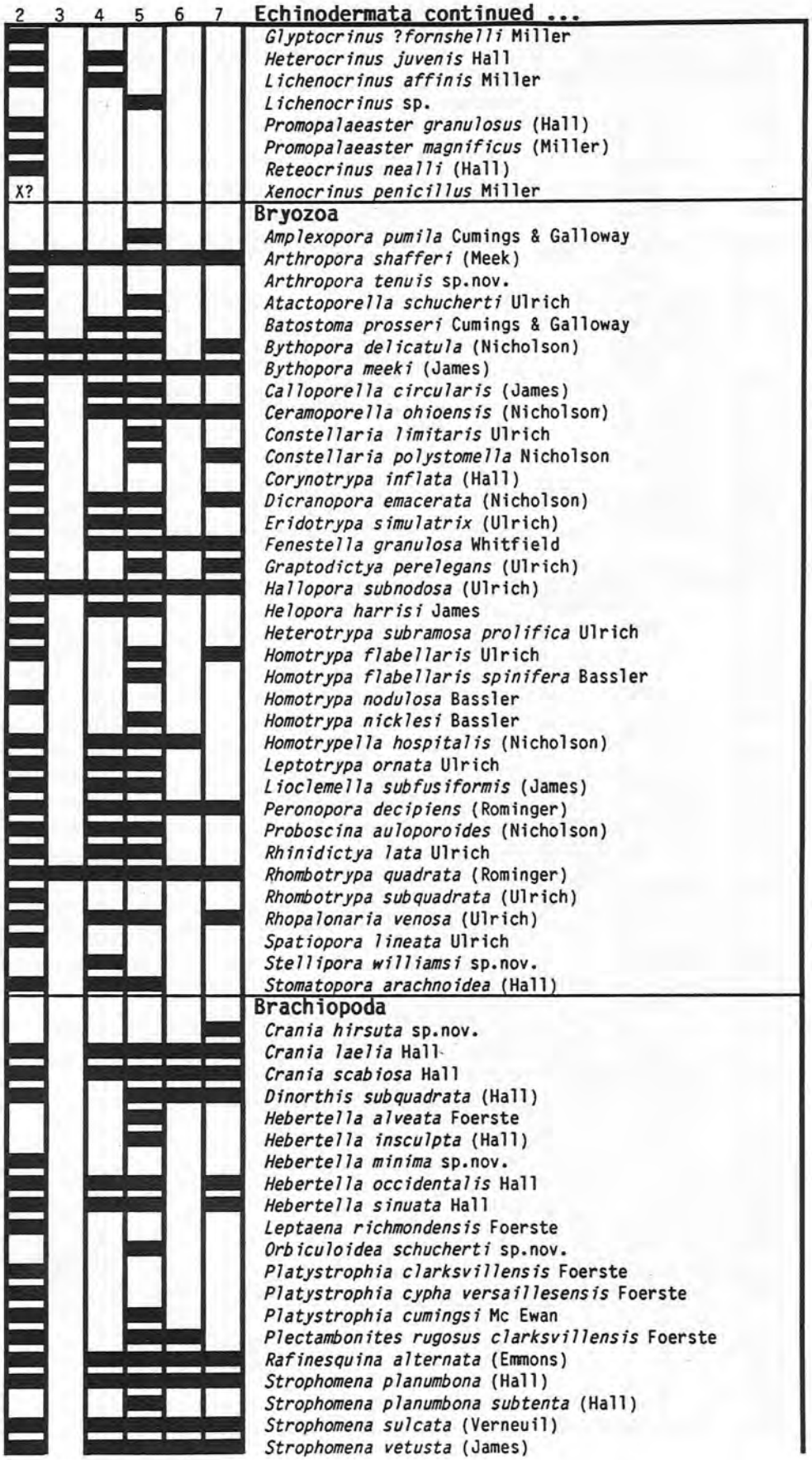
For the same reasons stated in the case of the earlier Richmond members, the Oxford section has yielded a far greater faunal list than any other region. Shale washings have been examined for practically the entire thickness. When other localities are kept under close observation for a considerable period of time they should prove as good and possibly better. The fauna by divisions follows.

— Liberty Fauna of the Oxford Section —



2	3	4	5	6	7	
						Porifera
						Hindia subrotunda James
						Coelenterata
						Calapoecia cribiformis (Nicholson)
						Columnaria alveolata Goldfuss
						Columnaria vacua Foerste
						Dermatostroma papillatum (James)
						Dermatostroma scabrum (James)
						Graptolite gen. et sp.nov.
						Mastigograptus sp.nov.
						Protarea richmondensis Foerste
						Streptelasma divaricans (Nicholson)
						Streptelasma rusticum (Billings)
						Tetradium huronense Foord
						Echinodermata
						Agelacrinites clarksvillensis? sp.nov.
						Agelacrinites hemicystiformis sp.nov
						Compsocrinus harrisi (Miller)
						Compsocrinus miamiensis (Miller)
						Cupulocrinus polydactylus (Schumard) n.var.
						Dendrocrinus caduceus (Hall)
						Dendrocrinus casei Meek
						Dendrocrinus posticus? (Hall)

The Liberty



Echinodermata continued ...

Glyptocrinus ?fornshelli Miller
Heterocrinus juvenis Hall
Lichenocrinus affinis Miller
Lichenocrinus sp.
Promopalaeaster granulosus (Hall)
Promopalaeaster magnificus (Miller)
Reteocrinus nealli (Hall)
Xenocrinus penicillus Miller

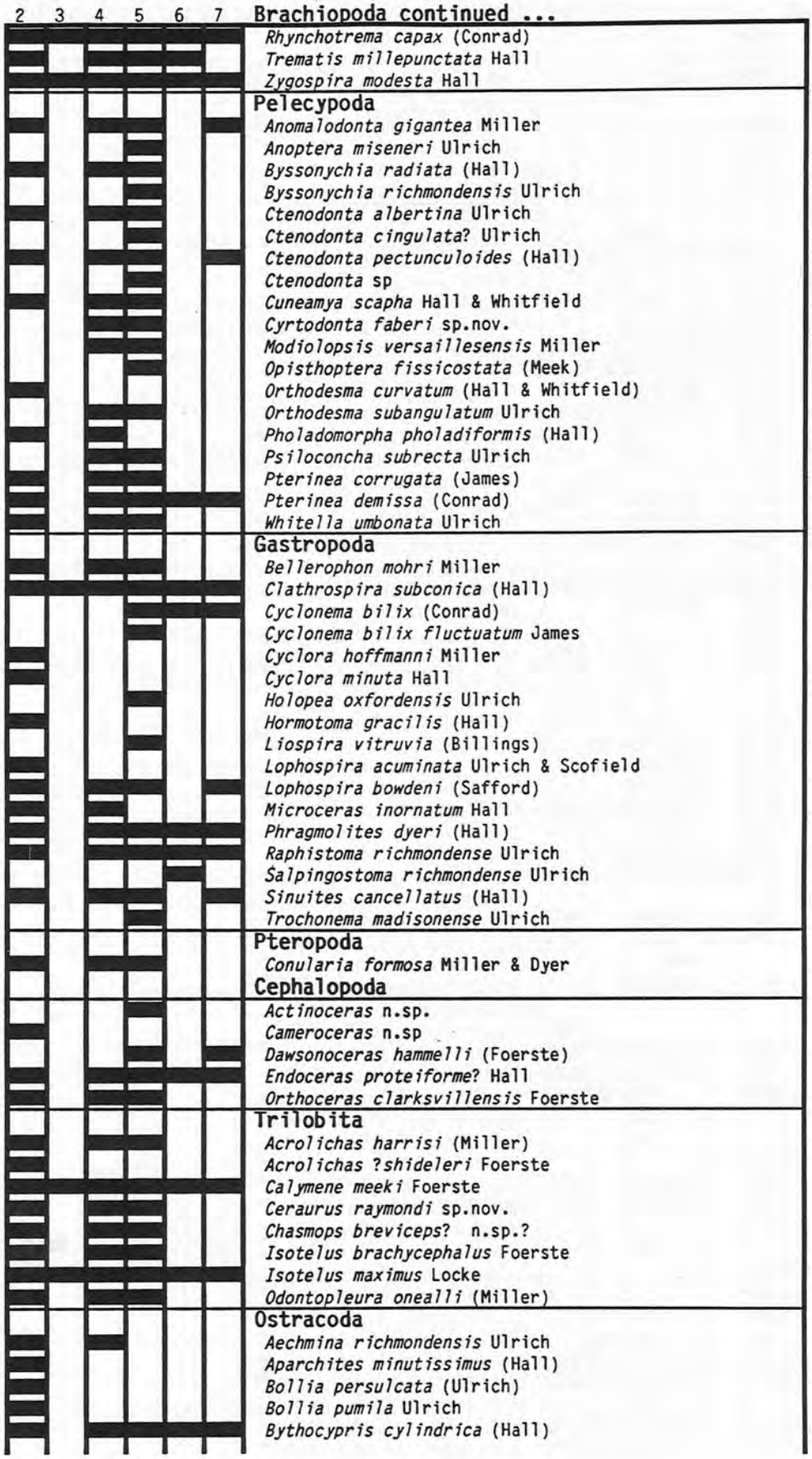
Bryozoa

Amplexopora pumila Cumings & Galloway
Arthropora shafferi (Meek)
Arthropora tenuis sp.nov.
Atactoporella schucherti Ulrich
Batostoma prosseri Cumings & Galloway
Bythopora delicatula (Nicholson)
Bythopora meeki (James)
Calloporella circularis (James)
Ceramoporella ohioensis (Nicholson)
Constellaria limitaris Ulrich
Constellaria polystomella Nicholson
Corynotrypa inflata (Hall)
Dicranopora emacerata (Nicholson)
Eridotrypa simulatrix (Ulrich)
Fenestella granulosa Whitfield
Graptodictya perelegans (Ulrich)
Hallopora subnodosa (Ulrich)
Helopora harrisi James
Heterotrypa subramosa prolifica Ulrich
Homotrypa flabellaris Ulrich
Homotrypa flabellaris spinifera Bassler
Homotrypa nodulosa Bassler
Homotrypa nicklesi Bassler
Homotrypella hospitalis (Nicholson)
Leptotrypa ornata Ulrich
Lioclemella subfusiformis (James)
Peronopora decipiens (Rominger)
Proboscina auloporoides (Nicholson)
Rhinidictya lata Ulrich
Rhombotrypa quadrata (Rominger)
Rhombotrypa subquadrata (Ulrich)
Rhopalonaria venosa (Ulrich)
Spatiopora lineata Ulrich
Stellipora williamsi sp.nov.
Stomatopora arachnoidea (Hall)

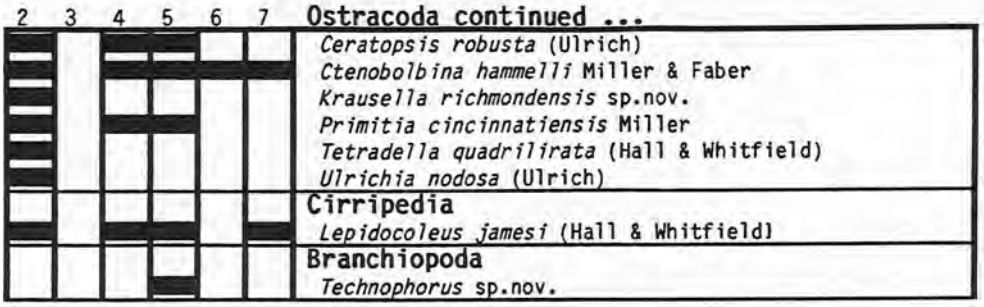
Brachiopoda

Crania hirsuta sp.nov.
Crania laelia Hall
Crania scabiosa Hall
Dinorthis subquadrata (Hall)
Hebertella alveata Foerste
Hebertella insculpta (Hall)
Hebertella minima sp.nov.
Hebertella occidentalis Hall
Hebertella sinuata Hall
Leptaena richmondensis Foerste
Orbiculoidea schucherti sp.nov.
Platystrophia clarksvillensis Foerste
Platystrophia cypha versaillesensis Foerste
Platystrophia cumingsi Mc Ewan
Plectambonites rugosus clarksvillensis Foerste
Rafinesquina alternata (Emmons)
Strophomena planumbona (Hall)
Strophomena planumbona subtenta (Hall)
Strophomena sulcata (Verneuil)
Strophomena vetusta (James)

The Liberty


2 3 4 5 6 7
Brachiopoda continued ...
Rhynchotrema capax (Conrad)
Trematis millepunctata Hall
Zygospira modesta Hall
Pelecypoda
Anomalodonta gigantea Miller
Anoptera miseneri Ulrich
Byssonychia radiata (Hall)
Byssonychia richmondensis Ulrich
Ctenodonta albertina Ulrich
Ctenodonta cingulata? Ulrich
Ctenodonta pectunculoides (Hall)
Ctenodonta sp
Cuneamya scapha Hall & Whitfield
Cyrtodonta faberi sp.nov.
Modiolopsis versaillesensis Miller
Opisthoptera fissicostata (Meek)
Orthodesma curvatum (Hall & Whitfield)
Orthodesma subangulatum Ulrich
Pholadomorpha pholadiformis (Hall)
Psiloconcha subrecta Ulrich
Pterinea corrugata (James)
Pterinea demissa (Conrad)
Whitella umbonata Ulrich
Gastropoda
Bellerophon mohri Miller
Clathrospira subconica (Hall)
Cyclonema bilix (Conrad)
Cyclonema bilix fluctuatum James
Cyclora hoffmanni Miller
Cyclora minuta Hall
Holopea oxfordensis Ulrich
Hormotoma gracilis (Hall)
Liospira vitruvia (Billings)
Lophospira acuminata Ulrich & Scofield
Lophospira bowdeni (Safford)
Microceras inornatum Hall
Phragmolites dyeri (Hall)
Raphistoma richmondense Ulrich
Salpingostoma richmondense Ulrich
Sinuites cancellatus (Hall)
Trochonema madisonense Ulrich
Pteropoda
Conularia formosa Miller & Dyer
Cephalopoda
Actinoceras n.sp.
Cameroceras n.sp
Dawsonoceras hammelli (Foerste)
Endoceras proteiforme? Hall
Orthoceras clarksvillensis Foerste
Trilobita
Acrolichas harrisi (Miller)
Acrolichas ?shideleri Foerste
Calymene meeki Foerste
Ceraurus raymondi sp.nov.
Chasmops breviceps? n.sp.?
Isotelus brachycephalus Foerste
Isotelus maximus Locke
Odontopleura onealli (Miller)
Ostracoda
Aechmina richmondensis Ulrich
Aparchites minutissimus (Hall)
Bollia persulcata (Ulrich)
Bollia pumila Ulrich
Bythocypris cylindrica (Hall)

The Liberty



This list of 151 forms constitutes the best faunal expression of the Liberty, and includes practically all forms found during this investigation elsewhere in Ohio and in Indiana. Most of the species however are quite rare. Undoubtedly the list will be materially extended as future work is done.

The bulk of the fauna is seen to occur in the beds below the *Plectambonites* bed. Divisions three and seven, as would be expected in times of very shallow water with the consequent strong action and the shifting of sediments, have greatly reduced faunules, particularly so in the case of division three, where the grinding action of the waves seems to have been rather thorough.

Although divisions two and four are shale formations showing miniature "horses", wave-action seems to have been distinctly mild, essentially absent, and division two is the most prolific of species of any Liberty bed, though division five is the more prolific as regards specimens. In this respect division five is probably the most prolific of any zone in the Richmond.

Ostracods and other microscopic species are abundant in certain layers in division two, but above this become greatly reduced. Locally there are occasional spots containing great numbers and a great variety of the jaws of annelid worms.

The greater number of Liberty species of Echinodermata is found in division two, and *Dinorthis subquadrata* appears near the top, but is rare until division five, where it is very abundant, associated with great numbers of well preserved *Rhynchotrema capax*, *Strophomena planumbona*, *Plectambonites rugosus* and other brachiopods, and bryozoans.

Flat Fork Section.

The next Liberty section to be described is that on Flat Fork three miles north-east of Oregonia, Ohio. Just below the road bridge and dipping down stream for a half mile are the basal beds of the Whitewater. Below this is exposed practically the entire thickness of the Liberty, and still further downstream most of the Waynesville. The basal portion of the Liberty is poorly exposed, the *Hebertella insculpta* layer at the top of the Waynesville being usually covered by talus or by stream wash.

Liberty Section at Flat Fork, Oregonia, Ohio

	Thickness
6 - Dense, hard, barren blue limestone, top covered with a series of linear impressions averaging 15 mm long, 3 mm across and up to 4 mm deep, known locally as "turkey tracks". Base of Whitewater.....	11'
5 - Limestones 1" to 3" thick with intercalated shales. 5'2" to top of 5' cascade plus 6" to base of 11" hard limestone.....	05'08"

The Liberty

4 - Shales and limestones to top of 8' waterfall which is caused by a 3" to 5" strongly wave-marked limestone overlying the soft shales and thin limestones..... 04'04"

3 - Shale bed..... 04'

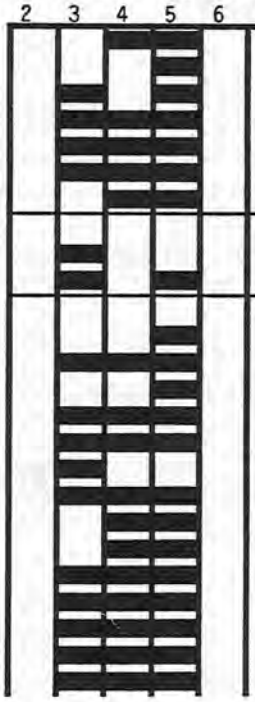
2 - Covered..... 07'

1 - *Hebertella insculpta* layer. Top of Waynesville..... 00'04"

As far as it can be told from the poorly exposed basal part of this section, division two of the Oxford section is greatly reduced, or possibly entirely absent. Division three of this section is equivalent to division four of the Oxford section, and is more prolific of fossils, especially Mollusca, and the transition into the more distinctly limestone phase of the middle Liberty is more gradual. Division four of this section equals the basal part of division five of the Oxford section. Division five of this section represents the rest of five plus six and seven of the Oxford section, there being no convenient dividing plane between them here. The very fossiliferous division five at Oxford is much less fossiliferous here, and the specimens are not so well preserved. Division six at Oxford is represented here by a few thin limestones carrying but a small proportion of the great numbers of *Plectambonites* so characteristic of the zone at Oxford and westward, while the 9'7" of division seven at Oxford are essentially absent here.

Undoubtedly the faunal list suffers in comparison with that of the Oxford section on account of the lack of exposures of the very fossiliferous basal part of the Liberty. But even at that, there is a considerable reduction in the fauna that is not altogether due to this, or to the fact that the Oxford exposures are more available and hence better worked. Although well exposed, (except at the base), and repeatedly examined, the Liberty here is distinctly less fossiliferous than it is farther westward.

--- Liberty Fauna of the Flat Fork (Oregonia, Ohio) Section ---



Coelenterata

Calapoecia cribiformis (Nicholson)
Columnaria alveolata Goldfuss
Dermatostroma papillatum (James)
Protarea richmondensis Foerste
Streptelasma divaricans (Nicholson)
Streptelasma rusticum (Billings)
Tetradium huronense Foord

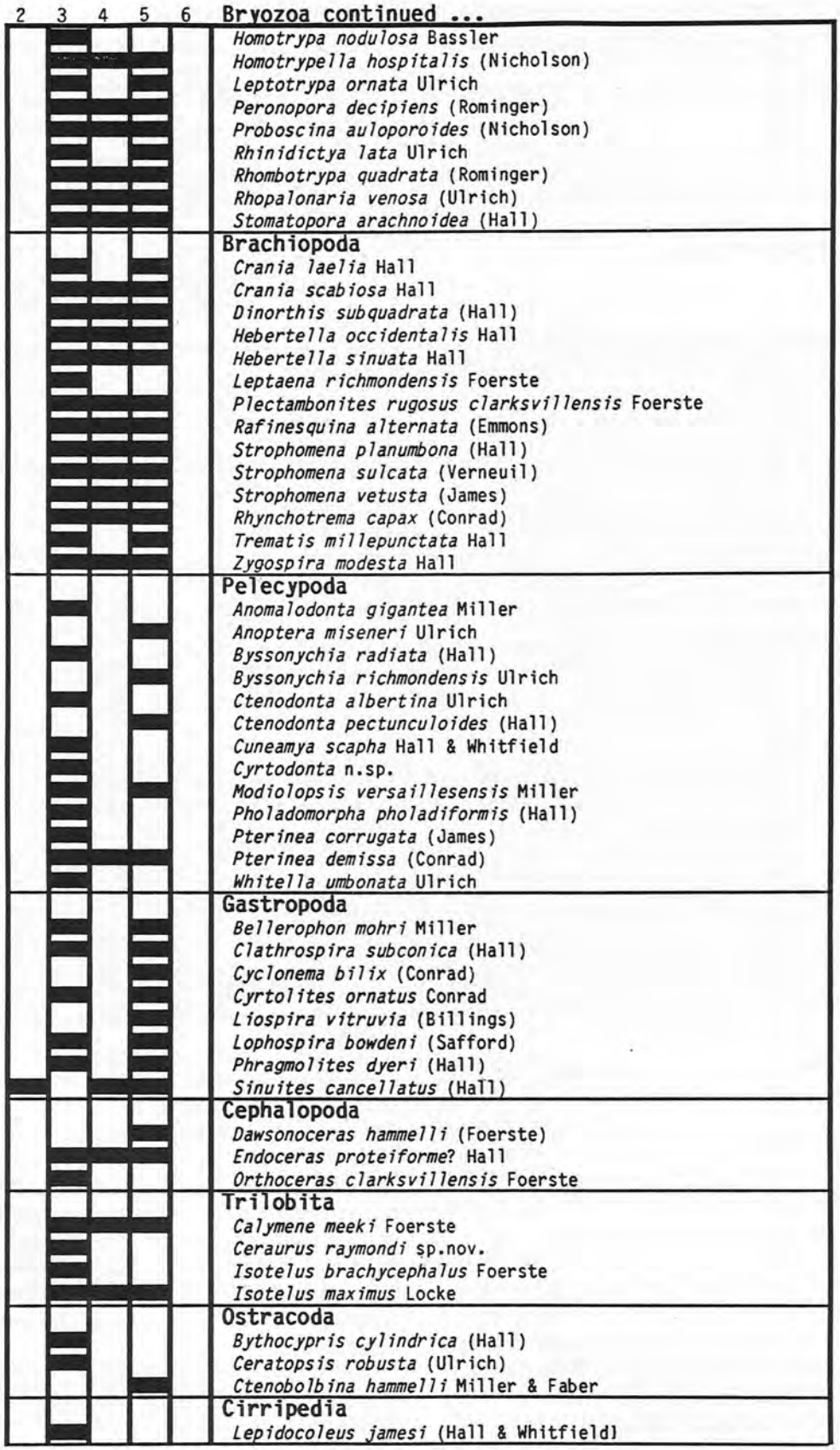
Echinodermata

Heterocrinus juvenis Hall
Lichenocrinus affinis Miller

Bryozoa

Amplexopora pumila Cumings & Galloway
Arthropora shafferi (Meek)
Batostoma prosseri Cumings & Galloway
Bythopora delicatula (Nicholson)
Bythopora meeki (James)
Calloporella circularis (James)
Ceramoporella ohioensis (Nicholson)
Constellaria limitaris Ulrich
Constellaria polystomella Nicholson
Dicranopora emacerata (Nicholson)
Eridotrypa simulatrix (Ulrich)
Fenestella granulosa Whitfield
Hallopora subnodosa (Ulrich)
Homotrypa flabellaris Ulrich

The Liberty



Bryozoa continued ...

Homotrypa nodulosa Bassler
Homotrypella hospitalis (Nicholson)
Leptotrypa ornata Ulrich
Peronopora decipiens (Rominger)
Proboscina auloporoides (Nicholson)
Rhinidictya lata Ulrich
Rhombotrypa quadrata (Rominger)
Rhopalonaria venosa (Ulrich)
Stomatopora arachnoidea (Hall)

Brachiopoda

Crania laelia Hall
Crania scabiosa Hall
Dinorthis subquadrata (Hall)
Hebertella occidentalis Hall
Hebertella sinuata Hall
Leptaena richmondensis Foerste
Plectambonites rugosus clarksvillensis Foerste
Rafinesquina alternata (Emmons)
Strophomena planumbona (Hall)
Strophomena sulcata (Verneuil)
Strophomena vetusta (James)
Rhynchotrema capax (Conrad)
Trematis millepunctata Hall
Zygospira modesta Hall

Pelecypoda

Anomalodonta gigantea Miller
Anoptera miseneri Ulrich
Byssonychia radiata (Hall)
Byssonychia richmondensis Ulrich
Ctenodonta albertina Ulrich
Ctenodonta pectunculoides (Hall)
Cuneamya scapha Hall & Whitfield
Cyrtodonta n.sp.
Modiolopsis versaillesensis Miller
Pholadomorpha pholadiformis (Hall)
Pterinea corrugata (James)
Pterinea demissa (Conrad)
Whitella umbonata Ulrich

Gastropoda

Bellerophon mohri Miller
Clathrospira subconica (Hall)
Cyclonema bilix (Conrad)
Cyrtolites ornatus Conrad
Liospira vitruvia (Billings)
Lophospira bowdeni (Safford)
Phragmolites dyeri (Hall)
Sinuites cancellatus (Hall)

Cephalopoda

Dawsonoceras hammelli (Foerste)
Endoceras proteiforme? Hall
Orthoceras clarksvillensis Foerste

Trilobita

Calymene meeki Foerste
Ceraurus raymondi sp.nov.
Isotelus brachycephalus Foerste
Isotelus maximus Locke

Ostracoda

Bythocypris cylindrica (Hall)
Ceratopsis robusta (Ulrich)
Ctenobolbina hammelli Miller & Faber

Cirripedia

Lepidocoleus jamesi (Hall & Whitfield)

The Liberty

Good Liberty exposures are found about Clarksville, mostly showing the basal portion of the member, but between these and Adams County there are no exposures of any importance. A few poor exposures south of Fayetteville show portions of the lower Liberty, and this horizon is also well shown on West Fork of Ohio Brush Creek just south of Fincastle, near the eastern edge of Brown County.

Harshaville Section.

In Adams County are quite a number of good Liberty sections, but the most complete, the most accessible, and the most favorably exposed for examination, is the section along Cherry Fork, the section beginning beneath the bridge over the creek at Harshaville. Another very good section begins just below this same bridge and follows up Grace Run, a tributary coming in from the west. The section up Cherry Fork follows.

The Liberty section at Cherry Fork, Harshaville, Ohio

	Thickness
7 – Limestone series. Base of the Whitewater.....	05'02"
6 – Limestones at base, shales with limestones at top.....	05'10"
5 – Two shale beds separated by 6" thin limestones. To base of a 4" to 7" limestone full of *Rhynchotrema capax*, *Dinorthis subquadrata*, etc., all jumbled together.....	05'
4 – Limestones with interbedded shales. The first *Dinorthis subquadrata* appears in the middle of this section.....	05'04"
3 – Shales.....	02'04"
2 – Three limestones with intercalated shales. Bottom limestones are more or less strongly wave-marked. Form floor of creek above and below the bridge.....	01'
1 – Shales exposed in a sharp little anticline about 100 yards above the bridge and in the west bank. The *Hebertella insculpta* layer was not seen, but must have been just beneath.....	03'

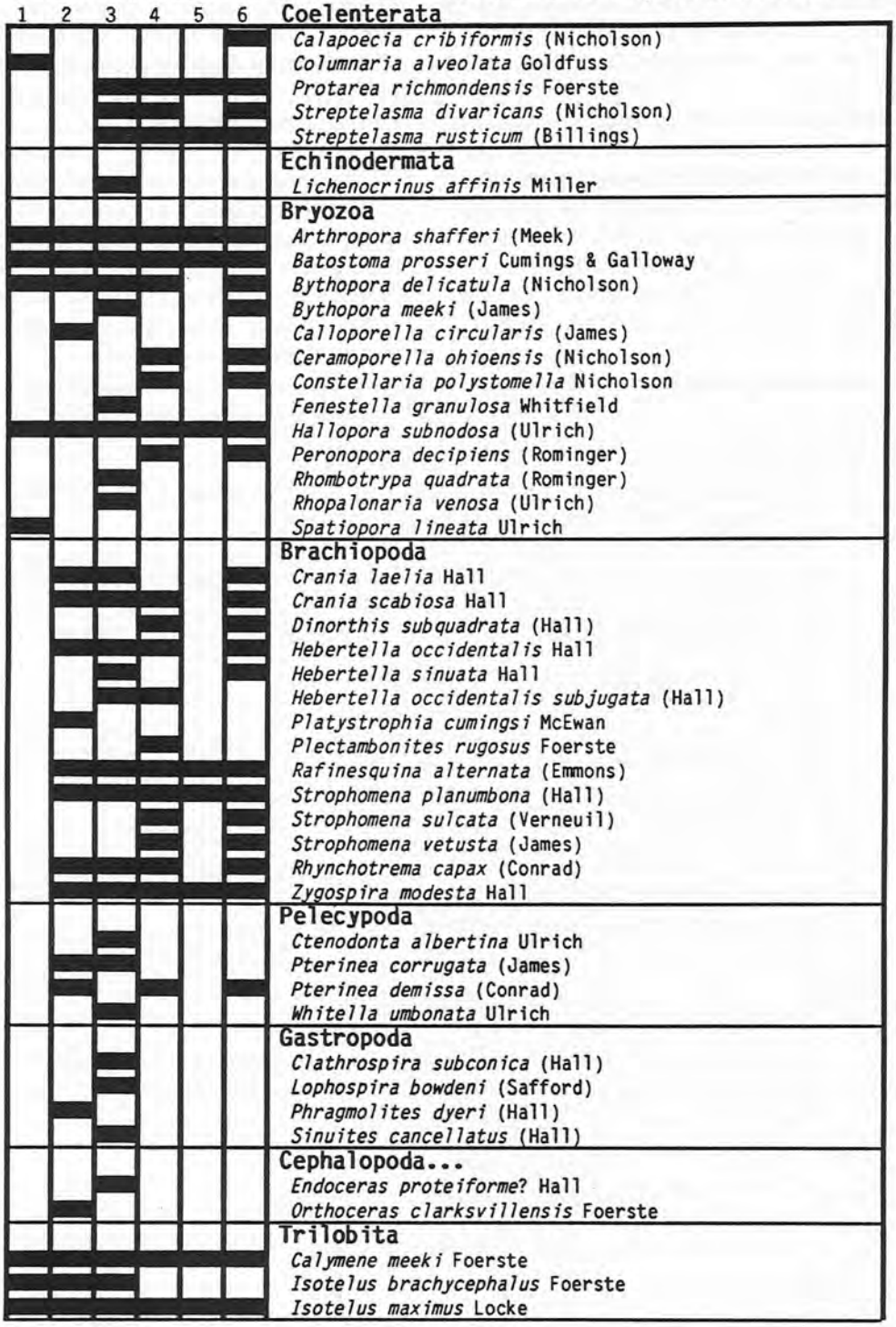
This section gives a thickness of 22'6" to the Liberty here which agrees very closely with the 21' of the Flat Fork section. Here, as is the case in the Flat Fork section, the thinning down as compared with the Oxford section is due to the reduction or absence of the uppermost divisions.

Divisions one through three appear to be equivalent to division two of the Oxford section, and division four is probably equivalent to division three at Oxford, though showing little evidence of wave action as at Oxford. Division five appears to correlate with four at Oxford, though this cannot be proven from the fauna since on account of this division being exposed only in a very short and vertical exposure, but little of its fauna could be seen. Division six appears to be equivalent to divisions five and six, and possibly seven at Oxford.

Repeated careful examinations of this section have given but a meager fauna as compared with that of the Oxford section, but each visit has added to the total, and ultimately a fair fauna will be derived from these strata.

The shales carry a greater proportion of barren mudstones than they do in Warren and Butler Counties.

— Liberty Fauna of the Cherry Creek (Harshaville, Ohio) Section —



A good Liberty section is found on Georges Creek, a mile west of Lawshe, and another on Trebers Run, a mile west of Duncanville. At the former locality *Lyopora goldfussi* was found near the top of the Liberty and at the latter locality a *Stellipora* was found at the same horizon. Several specimens of *Hudsonaster incomptus* were found in the basal Liberty as exposed on Brush Creek just above its junction with

The Liberty

West Fork at Lawshe. These occurrences justify the expectation that eventually a much more complete Liberty fauna will be derived from the Harshaville section, though it never will equal the fauna of the Oxford region.

Scattering Liberty exposures are found at various places in Adams Co. on western tributaries of Brush Creek, but show nothing additional to the Harshaville section, except that by the time the strata are traced as far down the east flank of the arch as a tributary of Brush Creek along the Blue Creek Pike, six miles east of West Union, the whole of the upper Liberty appears to be missing. The decrease in thickness of the Liberty, the increase in proportion of barren mudstones, and the decrease in the abundance of fossils, is continued into Kentucky.

Poplar Plains Section.

As the Liberty is traced southward the strata becomes also gradually arenaceous. These points are well shown by a section along a little creek crossing the Owingsville road south of Hillsboro. The creek is part of the headwaters of Locust Creek, and is the second creek showing exposures below Poplar Plains.

Poplar Plains Liberty Section

	Thickness
6 – Barren Shales and mudstones to top of exposure. Probably Whitewater. From base of this division to base of lowest exposed Brassfield limestone in side of hill to south is 63', all covered above the top of this division. May possibly be slightly more on account of the possible creep of the Brassfield outcrop.....	11'
5 – Barren shales, with stronger limestones up to three inches thick toward top. To top six inch limestone at ford below covered bridge. On top of top limestone a few poorly preserved *S. planumbona*, *R. capax*, *Rafinesquina* and *Protarea*. Probably top of Liberty.....	14'06"
4 – Rather barren shales and thin limestones with few poorly preserved *Bythopora delicatula*, and an occasional *Streptelasma rusticum* and *Rhynchotrema capax*.....	5'
3 – Rather barren shales to top of a layer of *Rafinesquina* on edge. Poorly preserved and rare *Rhynchotrema capax*, *Strophomena planumbona*, *Bythopora meeki*?, *B. delicatula* and *Rafinesquina alternata*.....	6'06"
2 – *Hebertella insculpta* zone. Most specimens of *H. insculpta* and associated *Streptelasma rusticum* and *Rhynchotrema capax* in a four inch sandy shale. One *Calapoecia*. Top of Waynesville.....	1'
1 – Shales and limestones carrying an abundant and typical Blanchester fauna.....	10'

South of this section the Liberty cannot be differentiated from the rest of the Richmond, the disappearance of the *Hebertella insculpta* bed and the absence of Liberty fossils removing the basis of distinction between the Waynesville and the Liberty, while the distinction between the Liberty and the Whitewater is lost some-

where between the Ohio River and Flemingsburg.

West Flank of Cincinnati Arch.

Tracing the Liberty from Oxford, Ohio, down the west flank of the Cincinnati arch, it is found that while there is no notable thinning down, the characteristic Liberty fauna becomes progressively reduced. At Fisherville, Jefferson County, Kentucky, a somewhat different kind of Liberty fauna begins to appear, and prevails southward at least as far as Lebanon. This modified Liberty fauna contains species such as *Platystrophia moritura*, characteristic of the Elkhorn in Ohio, *Platystrophia acutilirata*, and *Hebertella alveata*, normally characteristic of the Whitewater, and *Beatricea undulata*, characteristic of the Saluda in Indiana and the Elkhorn in Indiana and Ohio. With these are undescribed species of *Aulopora*, *Dermatostroma*, and various genera of Bryozoa.

At the base of the Liberty over a considerable area centering about Bardstown is the well known Bardstown coral reef. This reef does not extend into Ohio, but it is at this level that *Columnaria alveolata* and *C. vacua* are most likely to be found in the Liberty of Ohio. At Bardstown the fauna introduced with the reef is quite distinct from that below, and the change in sedimentation is also distinct.

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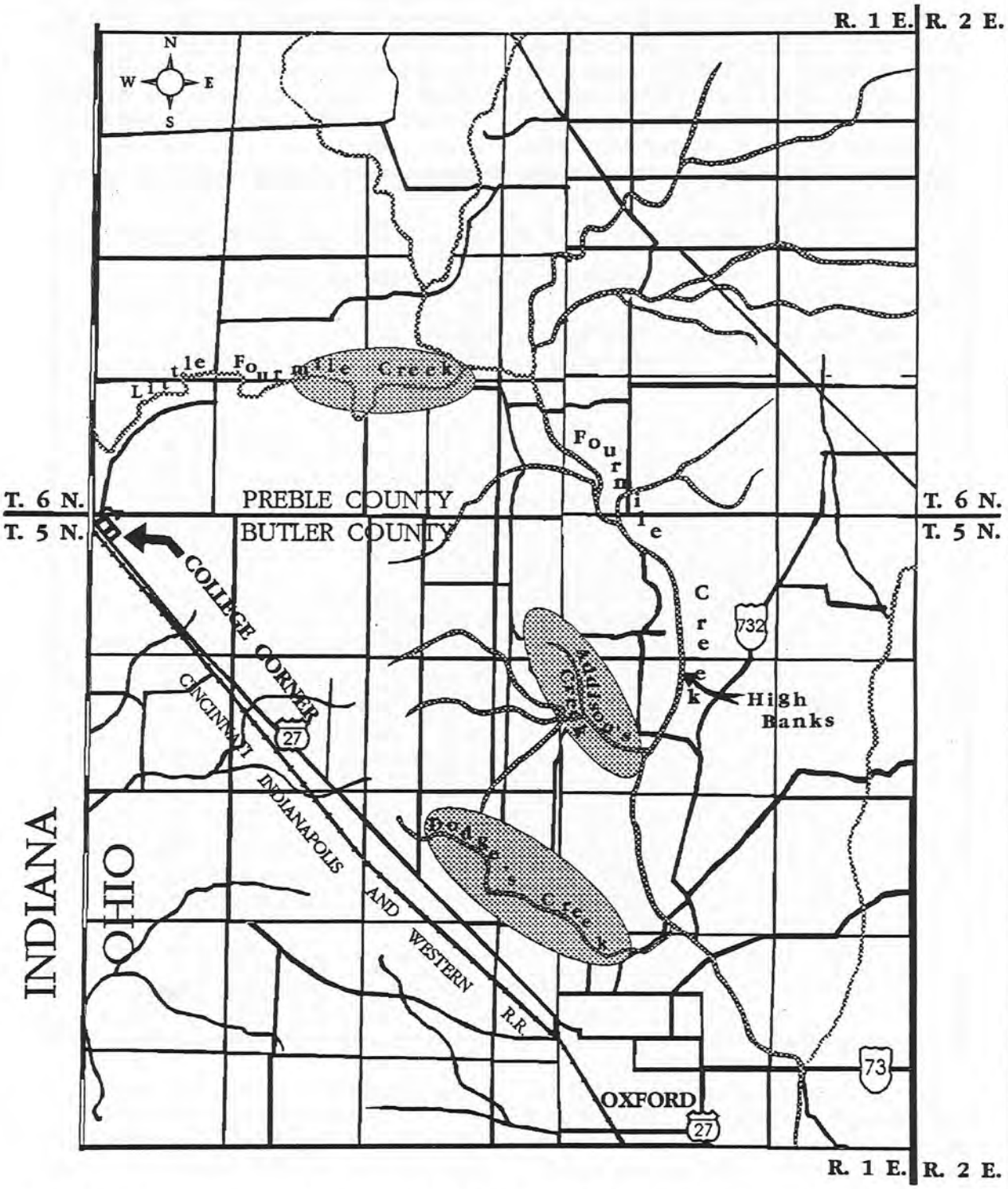
NOTES:

[1] - Amer. Geologist, Vol. 32, 1903, pp. 207-8

Oxford Composite Section Liberty Localities



Map based on Oxford Quadrangle of 1911 and College Corner Quadrangle of 1918.

The Whitewater

Far more complicated than the sediments and the faunules of the Liberty are the sediments and the contained faunules of the Whitewater, since there is a great variation in both respects.

Originally described by Nickles[1] as the "Whitewater or *Homotrypa wortheni* beds", the base of the member was placed, when he was placing the top boundary of the Liberty, as approximately at the level where a limestone occurs in which *Streptelasma* is very abundant. While the top was not specifically defined, *Rhynchotrema dentatum* was stated to be in the upper Whitewater and close to the top. On the other hand, Nickles placed the "Madison Beds" above the Whitewater, The relationship between these "Madison" or Saluda beds and the typical Whitewater has proven very confusing, and as it is impossible to understand the Whitewater without dealing with the Saluda, the Saluda will be briefly dealt with here, even though the member is barely found in Ohio.

The *Streptelasma* layer referred to by Nickles is a one to two inch limestone characterized by the abundance of specimens of *S. rusticum* which are usually embedded in the rock just enough to hold them, the individual specimens standing above the general surface of the stone by about half their diameter. Associated with these *Streptelasma* are considerable numbers of *Batostoma variabile*, *Bythopora meeki*, *Rhombotrypa quadrata*, *Dinorthis subquadrata*, *Strophomena vetusta*, and *Rhynchotrema capax*. *Pachydictya fenestelliformis* is common on this limestone in Clinton and Warren Counties, decreases in abundance westward, and is not found west of Jacksonburg, Butler County.

As before stated, this limestone is just above the *Charactoceras baeri* bed, which shows the first invasion of the characteristic Whitewater fauna. Beneath the *C. baeri* bed are one or several heavy limestones, quite devoid of fossils, and the bottom one is hard and fine-grained. These limestones are found everywhere in Ohio and in places in Indiana. Where these occur, they mark the base of the Whitewater, and in their absence, the *C. baeri* bed marks the beginning of the Whitewater. The basal one of these limestones is usually, at least in Clinton and Warren Counties, more or less distinctly marked by peculiar linear impressions, rather uniformly 15 mm long, 3 mm wide, and 4 mm deep, known locally as "turkey-tracks".

These heavy limestones and the overlying *C. baeri* zone are both everywhere present in Ohio, but both disappear as the horizon is traced southward into Kentucky along the east side of the axis. In Indiana the basal barren limestones may be locally absent, but the *C. baeri* zone is everywhere present at the proper level as far south as Versailles, but wedges out and disappears somewhere between Versailles and Madison. On Big Sains Creek, about two miles out of Laurel, Indiana, are three feet of hard, rough, barren limestones and barren shales, above which are one foot of lumpy shales with the characteristic fauna of *C. baeri*, *Whitella obliquata*, *Endoceras proteiforme*?, *Strophomena planumbona*, *S. vetusta*, etc.

This dividing line marks one of the two greatest breaks in the Richmond, the other one being the Arnheim-Waynesville break. Primarily because of the importance of this break, the Maqouketa has been correlated by Ulrich and Bassler with the Richmond of the Cincinnati province by placing it in this gap between the Liberty and the Whitewater. As the Maqouketa did not seem to be able to be correlated directly with any Cincinnati member of the Richmond, and as this seemed to mark the greatest break in the upper part of the Richmond, it seemed probable that the Maqouketa belonged here. However, as will be seen later, additional evidence has been developed more recently which gives more logical reasons for establishing a different correlation of the Maqouketa with the typical Richmond. The evidences of a break are various. First the thinning of the upper layers of the Liberty as previously described. Second is the series of barren limestones, more or less wave-marked, and always present in Ohio and most of the Indiana Richmond at the base of the Whitewater. Third is the not uncommon presence of miniature "horses" or sediment filled erosion channels up to 18" thick, and ranging in position from the base up to three to four feet above the *C. baeri* zone. Fourth the occurrence of intraformational

pebbles in the same zone as the "horses", forming a distinct conglomerate in parts of Adams County, and being occasionally found as far west as the Ohio-Indiana line. And fifth, one of the two most distinct breaks in the Richmond fauna is found here.

With respect to the upper boundary of the Whitewater Nickles merely says[2] "The *Rhynchotrema capax* (Conrad) is still abundant in the lower strata of this division, but gradually diminishes in numbers. As it appears near the top, *Rhynchotrema dentatum* (Hall) takes its place." The *Rhynchotrema dentatum* form a very distinct zone across the north edge of the Cincinnati Arch, and constitutes a very constant marker. Cumings[3] accepts the top of the *Rhynchotrema dentatum* zone as the top of the Whitewater and the base of the Elkhorn. However, as will be seen later the top of this zone averages close to 12' below the base of the Elkhorn as here defined.

The Saluda Question.

As before noted, the Whitewater cannot be adequately discussed without including a discussion of the Saluda. This member was originally described as the "Madison beds" by Foerste.[4] "Beneath the Clinton layer at Madison is a banded, brown and blue rock which forms the steep walls at the side of the Michigan and Telegraph roads, and at many of the waterfalls for miles around. Here the layers for a vertical distance of 40' to 55' present essentially the same color, grain and chemical composition. These layers are grouped under the name 'Madison beds'." The name Madison being preoccupied by a Cambrian formation in Wisconsin, Foerste proposed[5] as a substitute the name Saluda, from Saluda Creek, a small stream cutting through these beds as it drops from the upland down to the Ohio River some six miles south of Hanover, Indiana. Foerste qualifies his first statements by describing the Madison on pages 220-3[6] as being composed of eight feet of softer shales with a reef of *Columnaria* at the base, followed by 30 to 32' of "argillaceous limestones, weathering on long exposures to light brown, more or less banded with darker brown and even purplish tinted layers," mostly devoid of fossils, and few occurring being confined to a few layers. Following the weather-resisting banded limestones are several feet of fossiliferous blue limestones with shale partings, which Foerste did not seem to include in his typical Madison bed, and which contain a very distinct fauna known generally as the "Hitz fauna".

At that time Foerste was unable to trace the Saluda further north than Osgood, but definitely correlated the "Madison" with the Ohio strata as follows.[7] "In Ohio the Madison beds are replaced by clays and clayey shales which are at times mottled with purple and reddish purple and are usually devoid of recognizable fossils. Near the crest of the anticline, from the Miami River westward to the Indiana state line, the clays are less often mottled, are more calcareous, and contain more fossils." This can only mean a correlation of the Saluda with the beds which Cumings later called the Elkhorn,[8] a correlation which Foerste has long since abandoned.

Cumings has repeatedly contended[9] that the Saluda came beneath the Whitewater. The writer once held that "all of the Elkhorn and nearly all of the Whitewater are but the deeper water equivalents of the shoal water Saluda to the south."[10] Ulrich[11] agrees only with the last half of the immediately foregoing statement, holding that the Saluda represents in part a wedge into the Whitewater and in part the equivalence of certain parts of the upper Whitewater.

Before there can be any intelligent discussion of the merits of these different correlations of the Saluda, the testimony of some of the sections must be presented.

Because it agrees almost perfectly, faunally and lithologically, with the typical Whitewater sections about Richmond, Indiana, and because it has been more closely studied than any other region, the Oxford region is chosen as a typical expression of the Whitewater of Ohio.

A composite of three of the most profitable Whitewater sections about Oxford has been constructed. Since two of these three sections are continuations of two of the Liberty sections previously given, the numbering of the divisions of the composite section will be made to conform to the generalized Liberty section, and will continue the section through the Whitewater of this region.

The Whitewater

Oxford Composite Whitewater Section

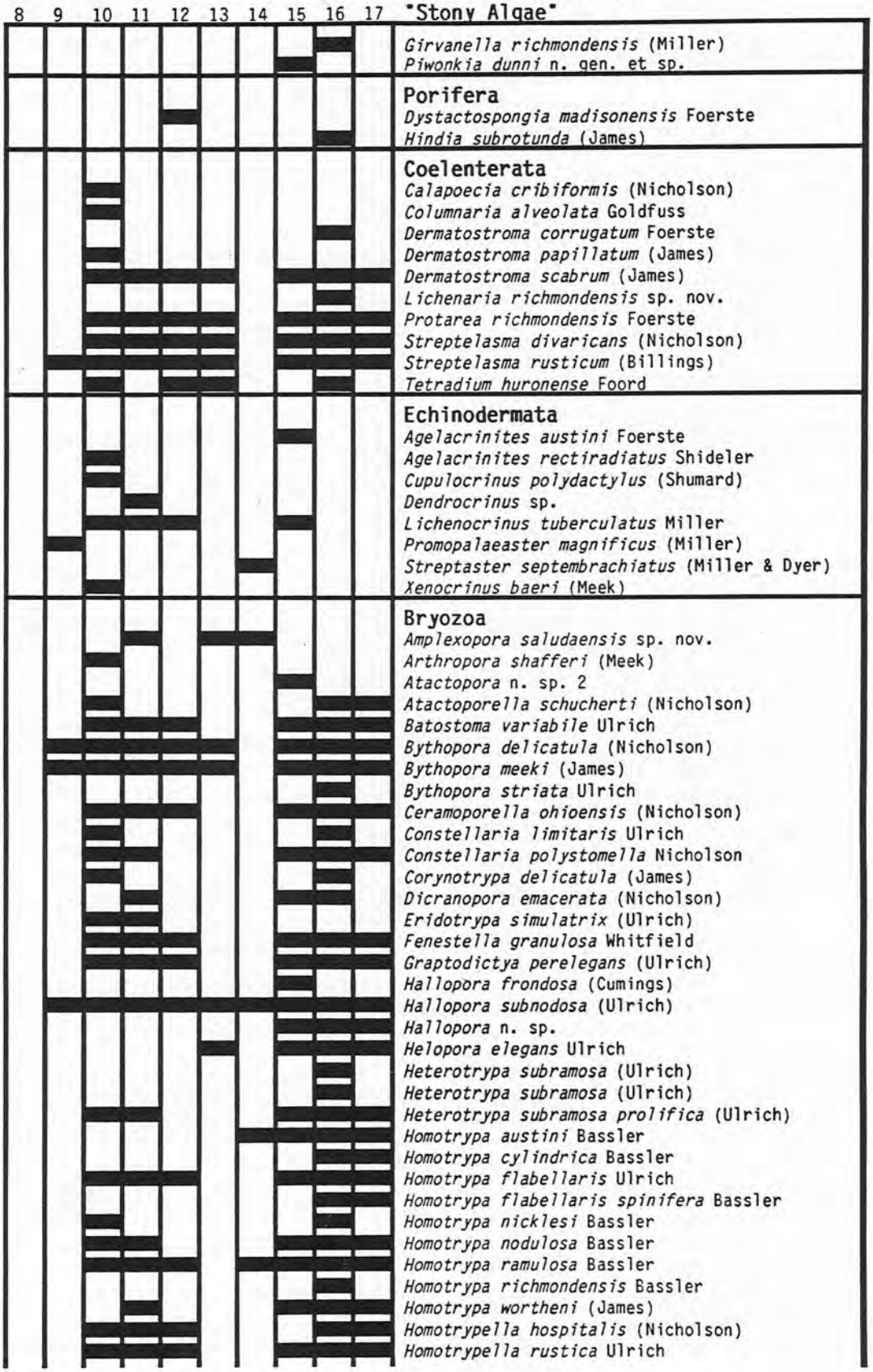
		Thickness
17 -	Lumpy shales and irregular limestones to top of exposure. *Rhynchotrema dentatum* zone.....	10'00"
16 -	More or less irregularly indurated shales and soft, irregular, lumpy limestones, giving much the same type of lithology as is characteristic of the typical Oregonia bed of the Arnheim member. Typical Whitewater to base of *Rhynchotrema dentatum* zone.....	13'
15 -	More or less even-bedded, thin limestones and shales with great numbers of bryozoa, mostly *Homotrypa*.....	05'06"
14 -	Heavy limestones at the base, dove-colored when weathered, more bluish when fresh. Upper portion of alternating thinner dove-colored limestones and interbedded shales, transitional to the next division. Typical Saluda sediments and fauna.....	06'02"
13 -	*Tetradium* reef. At base is a 14" rather barren limestone with little *Tetradium*. Above this is a zone averaging 1'4" thick which is largely a mass of *Tetradium* colonies.....	02'06"
12 -	Mostly blocky shales with thin limestones. Locally this division shows zones of irregular thickness up to 1' which appear distinctly arenaceous, the fossils being more or less covered with a rather tenacious sandy looking coating. This apparent arenaceous character is due to the development of dolomite crystals.....	06'03"
11 -	Thinner limestones and thicker shales.....	19'
10 -	Limestones 1" to 3" thick with inter-bedded shales as in the upper part of the Liberty.....	06'10"
9 -	Soft, blocky claystones and non-fissile shales, with a few harder limestones. *Charactoceras baeri* zone.....	06'
8 -	A 4" barren, blue limestone with trails, followed by 8" barren argillaceous limestone. Base of Whitewater.....	01'
7 -	Upper Liberty.	

The components of this composite section are Dodges Creek and Little Four Mile, discussed under the Liberty, and McDills Mill, a post-glacial gorge on the Four Mile Creek one and one quarter miles north of Little Four Mile. Dodges Creek shows all divisions of the composite section except parts of 12, 16, and 17. McDills Mills shows the entire section without a break though most of the locality is too vertical to show much of the contained fossils. Little Four Mile shows well only divisions 8 and 9, but these are exposed very favorably for study and have yielded most of the fauna credited to these divisions in the faunal charts.

Faunal chart follows on next page.

The Whitewater

Oxford Composite Section Whitewater Fauna



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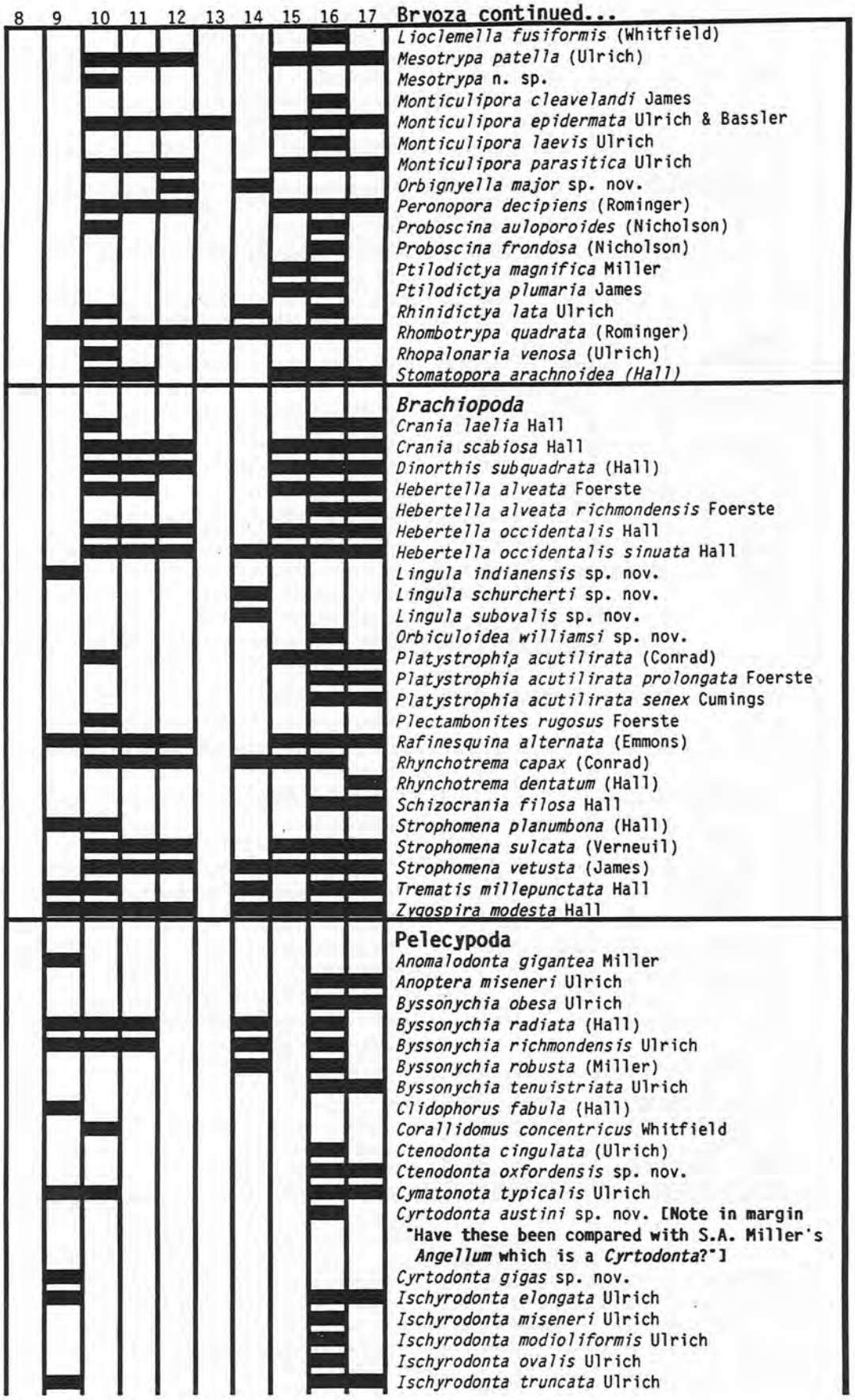

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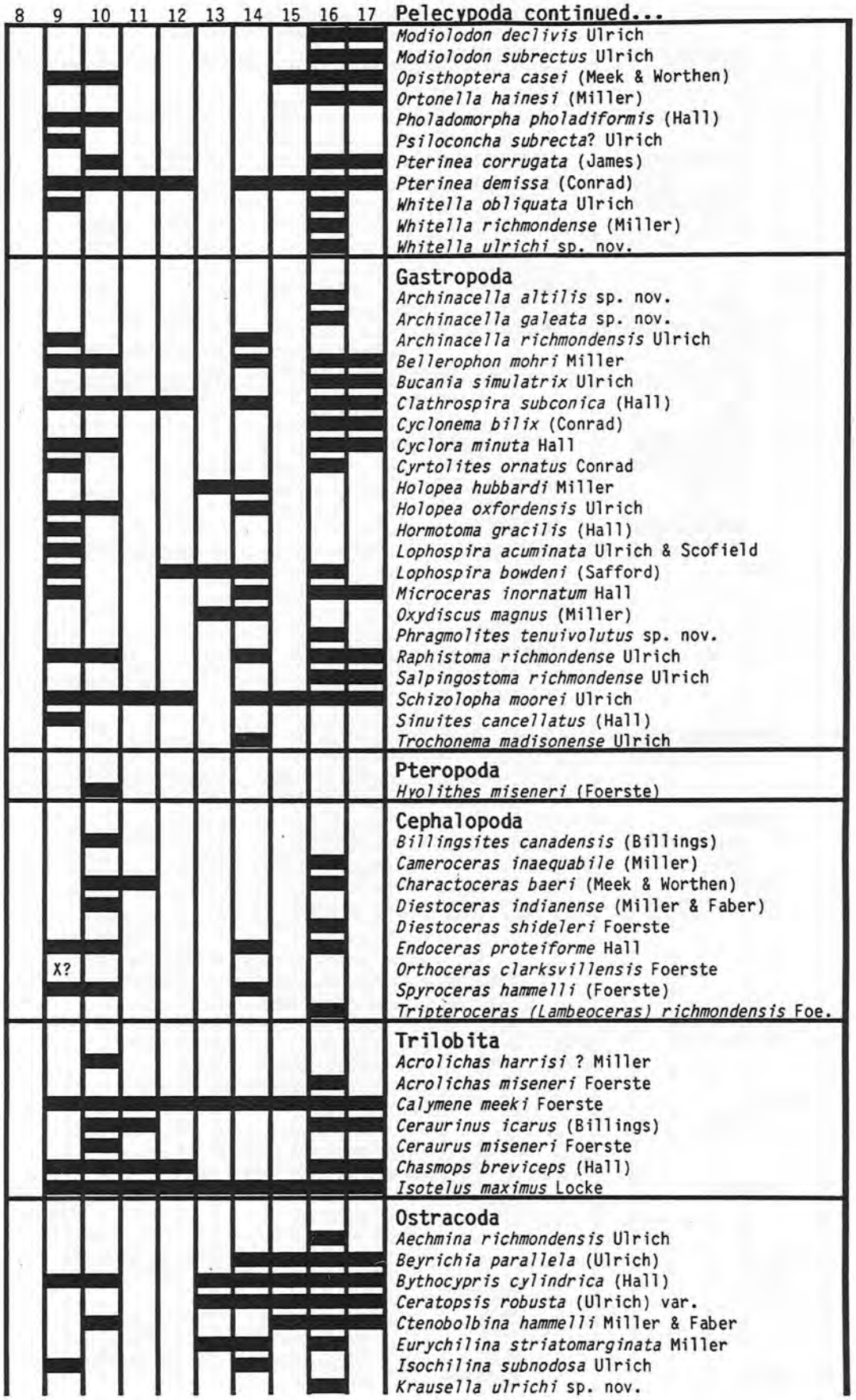
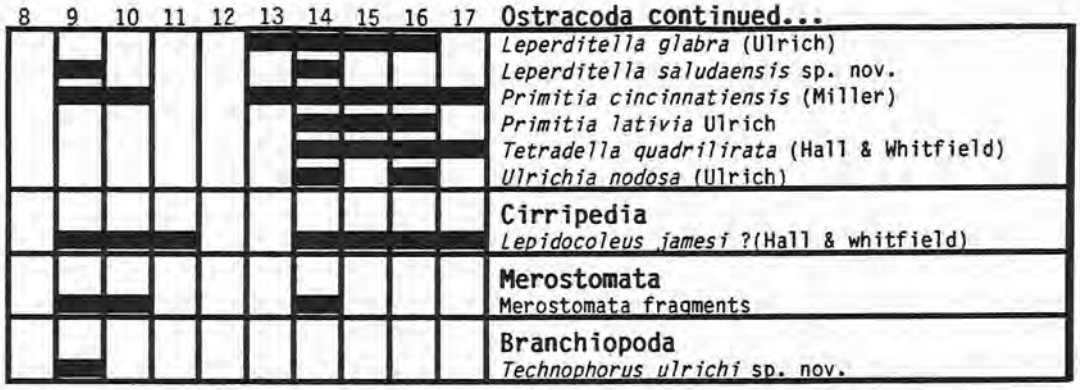




Regional Correlations.

As previously noted the *Charactoceras baeri* horizon, division 9, is everywhere present at the proper level between the southern part of Adams County in Ohio and Versailles, Indiana. Casual examination will not lead to any appreciation of the importance of this zone, but persistent study will, in time, accumulate a wealth of molluscan material, chiefly cephalopod and largely undescribed. The fauna appears to represent a distinctly northern invasion. In fact, before this the faunules of the various divisions of the Richmond were either distinctly southern in origin, or were predominantly southern but with northern elements, as for example some of the Blanchester faunules. But from this zone on the faunules which invade the Cincinnati province seem to be entirely northern in origin, excepting only certain elements in the upper Whitewater and Elkhorn which seem to have gotten into the Cincinnati region directly from the Upper Mississippi province.

Notable though rare elements of the fauna of this division are the first appearance of such characteristic Whitewater species as *Ischyrodonta elongata* and *Ischyrodonta truncata*, and such Saluda species as *Isochilina subnodosa* and *Leperditia saludaensis*. *Opisthoptera fissicostata* is replaced by *Opisthoptera casei*. *Strophomena planumbona*, which was characteristically so abundant in the top of the Waynesville and through the Liberty is represented by a few individuals which do not go above the base of division 9. *Batostoma prosseri* of the Liberty is replaced by *Batostoma variabile*. *Ptilodictya flagellum* and *Ptilodictya nodosa*, though not found in the Oxford region occur just above this zone in Clinton County, as also does *Pachydictya fenestelliformis*. In brief, the faunal chart of the Oxford section of the Whitewater, when compared with the faunal chart of the Liberty of the same region, shows that judged either by the disappearance of old types or by the appearance of new ones this division marks one of the most important zones in the Richmond. Division 9, then, introduces the first Whitewater fauna, and includes also certain Saluda elements.

Agelacrinites rectiradiatus was found near the base of division 10, which is exactly the same level at which it has been found in Warren and Adams Counties. Division 10 is a return to upper Liberty conditions of sedimentation but with the characteristic Liberty species absent. The fauna is still further reduced by the absence or rarity of most of the characteristic Whitewater species.

Division 12 represents the sediments which accumulated here during the time of development of the basal coral reefs of the Saluda in the Madison, Indiana region. In the Madison region the Saluda begins with a reef of *Columnaria* up to 3'6" thick, followed by 2'4" to 4'6" of dolomitic shales and thin limestones with *Dystactospongia madisonensis*, etc., then a second *Columnaria* reef up to 1' thick with *Dystactospongia* just above it.

Going north from Madison, *Tetradium* appears through the seven feet of soft, blocky strata immediately above the second *Columnaria* reef, and the basal part of this zone becomes the more or less solid reef that can be traced as far north as Liberty, Indiana, and as far into Ohio as Camden. But the *Columnaria* gradually disappears,

becoming "spotty" north of Versailles, and showing only a few isolated specimens at this horizon north of where the West Branch of Laughery Creek crosses the pike south of Ballstown, where the last semblance of a reef is seen. The general horizon can be recognized however by the prevailingly sandy appearance of certain portions, and by the occurrence of *Dystactospongia madisonensis*.

Division 13 is a continuation of the *Tetradium* zone at Madison, becoming a definite reef toward the north.

Division 14 is typical Saluda, both lithologically and faunally. In the typical Madison region the Saluda carries one fauna in the basal portion, and one materially different at the top. The top fauna disappears south of Versailles, but the lower one is found well developed here. So it may readily be seen that either the Dodges Creek or the McDills components of the composite Oxford section shows that there are at least 32' 10" of Whitewater below the northern equivalent of the basal *Columnaria* reef at Madison. The difference between the interpretation of Cumings and that of the writer is due to Cumings' failure to recognize either the horizon mentioned by Nickles as being approximately the base of the Whitewater, or the importance of the *Charactoceras* zone, the result being that he consequently raised the base of the Whitewater of the typical section to the position of the base of the Saluda.

Cumings attaches importance to the continuation of the Liberty type of lithology up toward the base of the Saluda, and to the radical change in both lithology and fauna at that point[12]. This is highly convenient but hardly logical, seeing, first, that the base of the Whitewater as defined by Nickles and recognized everywhere where exposed in Ohio, is also present in Indiana as far south as Versailles; second, that the fact that the first 30' or so of the Whitewater is lithologically similar to the strata of the upper Liberty has no significance in a region where there are only normal blue clay shales and limestones; and third, that the sudden incursion of the dense, fine grained, massive buff limestones which are more or less dolomitic and somewhat arenaceous toward the south, may appear to be highly significant when one considers the Indiana area alone, but is of much less significance when one considers that in Kentucky there was sedimentation of this general type going on somewhere or other during the whole of the Richmond. In the Arnheim[13] it was limited to the east side of the arch south of Fleming County. In the Waynesville it[13] was deposited on both sides of the arch, and in the lower Waynesville on the west side as far north as Oldham County. In the Liberty this type is restricted to the more southern exposures on the west side, about Bardstown and on south. In the Saluda these sediments were drifted farther north again, going as much farther north as those of the Waynesville were north of those of the Liberty. It is these sediments, distinctly sandy in Kentucky, sandy and dolomitic in southern Indiana, and more calcareous and argillaceous farther north in Indiana and in Ohio, that invaded Indiana and Ohio in the middle of the Whitewater and are known as the Saluda.

When one considers Indiana alone, the[14] sudden incursion of these sediments and of[14] the shoal water fauna associated with them seems to make this a perfectly natural division surface, but when one considers the Richmond of the whole Cincinnati province the significance of this becomes much less. If the accepted Liberty-Whitewater boundary means anything from Adams County, Ohio, entirely around the north end of the Richmond outcrops in Ohio, where the Saluda facies is absent and its position cannot be determined[15], the accepted boundary should mean just as much where it is carried from Butler and Preble Counties in Ohio, west and south beneath the Saluda to Versailles, Indiana, where the boundary is still distinct.

This Oxford section, then, is complete justification for the statement that at least 32' of Whitewater are below the Saluda.

Six miles west of Oxford three little streams flowing into Indian Creek from the east show sections which throw additional light upon the relationship of the Saluda and the Whitewater. The exposures on the small stream just to the north of the road across the south edge of section 30, R.IE., T.5N., gives the following section.

The Whitewater

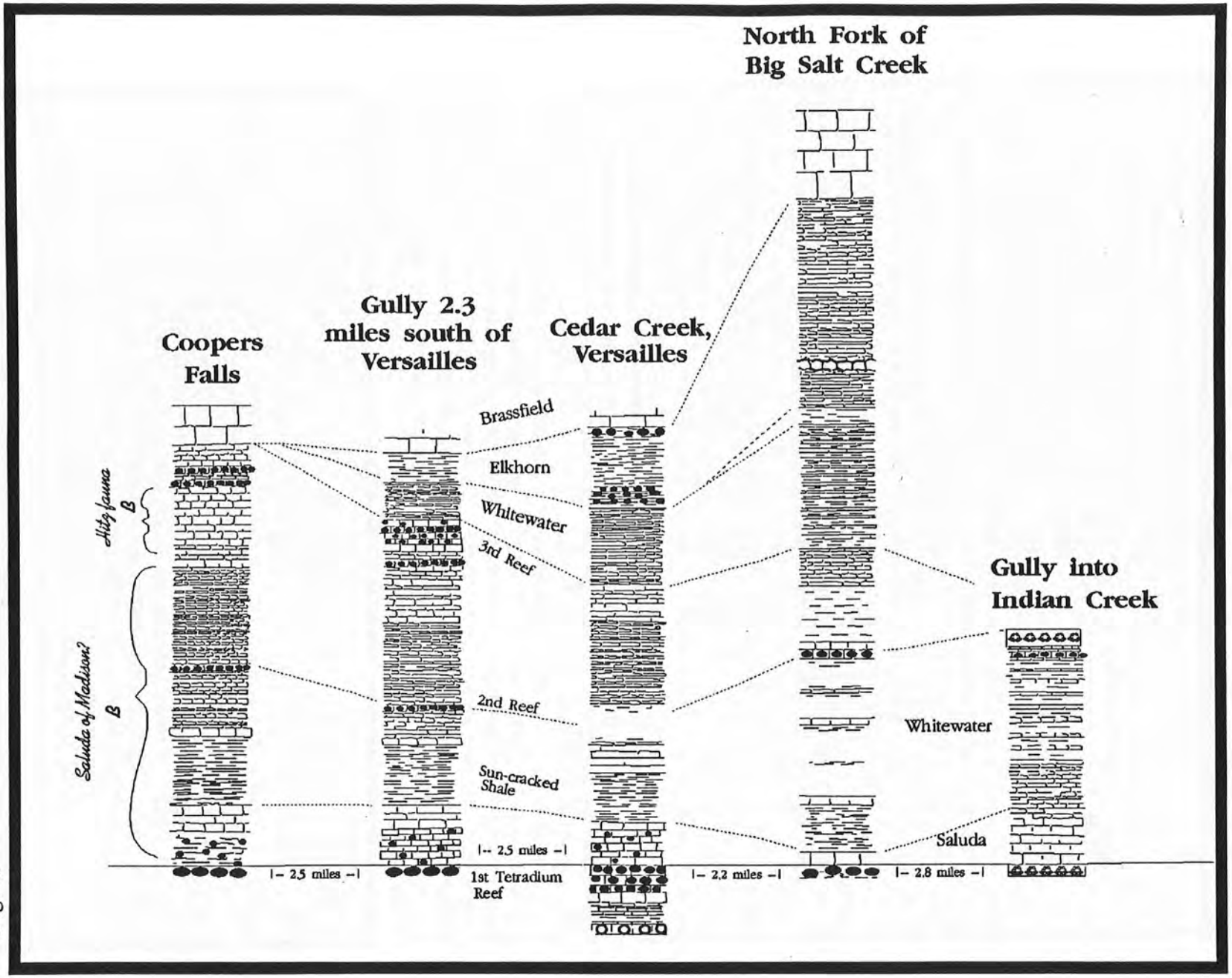
Tributary into Indian Creek Section

6 - 10"-2'2" Massive upper Tetradium reef. Not present in Oxford section.
5 - 1'8"[16] Characteristic lumpy Whitewater strata with characteristic Whitewater fauna. A 14" zone of abundant *Tetradium* has its top 2'5" below the top of the division, but the *Tetradium* does not form a reef. Equals division 16 of Oxford section.
4 - 6'6" Thin limestones and shales. Bryozoan bed. Equals division 15 of Oxford section.
3 - 8' Saluda and transition. At base 6' of typical Saluda, grading into rather heavy limestones of the common blue type. Division 14 of Oxford section.
2 - 1' Tetradium reef, hard and massive, with calcite-lined cavities. Division 13 at oxford.
1 - Lower Whitewater.

The full significance of this section is appreciated only after it is compared with the Saluda section at Coopers Falls, about four miles south of Versailles, (Sect. 1.60F of Cumings)[17], with the section up the gully 2.3 miles south of Versailles, (Sect. 1.60D of Cumings),[17] with the section along the headwaters of the West Fork of Cedar Creek, including the road cuts where the Osgood pike crosses the creek (1.60H of Cumings),[17] and with the section along the North Fork of Big Salt Creek, 2 miles west of Hamburg, supplemented by the road cut on the west side of the valley (1.64B of Cumings).[17] Cumings, interpretation of these sections is seen in his correlation charts opposite page 637.[17] The interpretation of the writer is seen on the accompanying chart (Fig. 1) followed by the Coopers Falls and West Hamburg sections.

Coopers Falls Section

	Thickness
10 - Brassfield.	
9 - Whitewater. Thin limestones and shales	3'2"
8 - Thinner limestones and shales. At base is a 6"-8" layer of *Tetradium*, *Stromatocerium*, *Labechia* and *Beatricea*, and at the top is a 6" layer of the same fossils. (3rd reef)	3'
7 - Heavy, hard limestones up to 14" thick, with intercalated shales. Limestones carry *Leperdia caecigena* and other elements of the "Hitz" fauna of Madison	12'3"
6 - Thin, irregular, shaly limestones. Top of "mottled bed"	14'
5 - Layer with abundant *Stromatocerium*, and with *Tetradium* and Bryozoa. (2nd reef)	1'
4a- Rough limestones and shales, ending with 2' of more or less barren, mottled, blocky, arenaceous limestones. Base of the "mottled bed" of Cumings	8'4"
4b- Limestone topping falls	1'
3 - Ripple-marked and sun-cracked shale bed	10'
2 - Heavy limestones	3'6
1 - Lumpy, shaly limestones with *Tetradium*. This division is soft and has weathered back under the watfall. The base is covered by talus, but on the basis of other exposures in the vicinity, there should be a 4' massive *Tetradium* reef below the part exposed here, below the reef a 1'4" hard limestone, and several feet lower the remnants of the basal *Columnaria* reef exposed at Madison	5'


North Fork of
Big Salt Creek
Coopers
Falls
Gully 2.3
miles south of
Versailles
Cedar Creek,
Versailles
Gully into
Indian Creek
Hitz fauna
B
Saluda of Madison?
B
Brassfield
Elkhorn
Whitewater
3rd Reef
2nd Reef
Sun-cracked
Shale
1st Tetradium
Reef
Whitewater
Saluda
|– 2.5 miles –|
|– 2.5 miles –|
|– 2.2 miles –|
|– 2.8 miles –|

(Fig. 1)

The Whitewater

Section 2.1 miles west of Hamburg, Indiana.[18]

		Thickness
12 -	To top of Elkhorn (base of Brassfield)	23'5"
11 -	Irregular layer, rather sandy and cherty	1'4"
10 -	Much like lithologically. Bryozoan bed	5'6"
9 -	Smooth blue shales and a few thin limestones. Base of Elkhorn	2'2"
8 -	Thin, rough limestones and lumpy, grainy shales. Characteristic Whitewater sediments and abundant Whitewater fauna. Layer of *Rhynchotrema dentatum* 6"-1' thick, based 1' above bottom of division	18'
7 -	More resistant, barren limestones and shales, distinctly ripple-marked and sun-cracked	6'6"
6 -	A 1' even-bedded, hard, resistant limestone forming floor of creek for some distance, topped by 8'6" soft, blocky, shaly bed with a few harder strata in middle	9'6"
5 -	Second *Tetradium* reef. Much *Stromatocerium*	1-2'
4 -	Limestones and shales, poorly exposed and poorly fossiliferous	20'
3c-	A 3'4" ledge weathering into a lumpy outcrop, seperated by a 4" shale from a 1'10" hard, massive, barren limestone	5'6"
b-	Ripple-marked and sun-cracked shale bed	2'2"
a-	A 10" black, carbonaceous shale plus 1'6" massive limestone	2'4"
2 -	Massive limestone with very irregular top. Full of *Tetradium*. First *Tetradium* reef	1-1'6"
1 -	Poorly fossiliferous, lumpy, sandy, buff limestones. A few *Tetradium* colonies	4'

These and numerous other sections about Versailles, Osgood, Bardstown, Oldenburg, Hamburg, Weisburg, etc., show a very persistent coral reef of *Tetradium*, with or without *Stromatocerium* and *Labechia*, a short distance above the sun-cracked and ripple-marked shale bed or its equivalent wherever the appropriate horizon is exposed.

Along the Ohio-Indiana state line road about half way between Mixerville and Philanthropy, south-west of Oxford, the reef is massive and up to 18" thick. At the locality 5 miles west of Oxford the reef is massive and up to 2'2" thick, but is not found close about Oxford nor south or east of that region.

The first point to this digression is just this, that if the 27'10" between the very persistent first and second reefs as exposed at Coopers Falls is Saluda, then the 32'6" between the same two persistent reefs as exposed 5 miles west of Oxford must be either Saluda or its equivalent. Since only 8' of strata above the basal reef can possibly be called Saluda, either lithologically or faunally, and since the remaining 24'6" are Whitewater both lithologically and faunally, it logically follows that 24'6" of the Whitewater of the Oxford region is neither above nor below the Saluda as a whole, but represents, together with the 8' of undoubted Saluda below, deeper water sediments accumulated at the same time that the shoal water equivalents were accumulating between the horizons of the two reefs in the Versailles region.

Returning to the Versailles region, a thin wedge of upper Whitewater is seen to appear at the section 2.3 miles south of Versailles. Absent at Coopers Falls, 5'6" thick here, and 11' thick where the Osgood pike crosses the West Fork of Cedar Creek, it increases up to 18' at the Hamburg section. At this latter locality a zone of *Rhynchotrema dentatum* 6"-1' thick begins 1' above the base, thereby identifying this particular part of the Whitewater occurring above the Saluda with a fair degree of accuracy. Whether this 1' of *Rhynchotrema dentatum* represents the whole, the base, or the top of the *Rhynchotrema dentatum* zone

of the Richmond and Oxford regions cannot be told certainly, but judging by the rapidity with which the zone thickens above the Saluda as one goes north to Big Sains Creek at Laurel, it is either the base or the whole of the zone as it occurs at Richmnond and Oxford. In either case the part of the standard Richmond, Indiana and Oxford sections of Whitewater that is ahove the base of the *Rhynchotrema dentatum* zone is in no way the equivalent of any part of the typical Saluda, but is above it. The second point to this digressian into the geology of Indiana, then, is that to this extent Cumings is correct when he places the whole of the Saluda beneath the Whitewater.

There remains the correlation of that part of the Saluda between the horizons of the second and third reefs as exposed at Coopers Falls, with the Ohio sections. As this interval is traced northward, the separate beds become more or less modified and progressively thinner. At Coopers Falls 32'5" thick, the interval is only 16' thick at the Hamburg locality and 10' on Big Sains Creek ten miles farther north. At the latter place the second reef is 18" thick, and the 10' between it and the typical Whitewater shows 1'8" of Saluda type limestone carrying a Saluda fauna at the base, and the rest of the interval up to the undoubted Whitewater is composed of rather barren and more or less sandy shales, carrying a few rare amd poorly preserved fossils of no diagnostic value. Evidently this section of the Saluda wedges out northward and ultimately disappears. That the same thing happens toward the east is indicated by the fact that in the region five miles west of Oxford the second *Tetradium* reef is within a few feet of the base of the *Rhynchotrema dentatum* bed, as determined by levelling up a parallel stream a half mile farther north.

The third reason for the digression into Indiana, then, is to demonstrate that the upper part of the typical Saluda wedges out into the Whitewater, and, excepting for a few feet of strata along the Ohio-Indiana state line, is not represented in the Ohio section.

A glance at the chart will help to explain why the writer made the mistake of interpreting the whole of the Elkhorn as being included beneath the third coral reef as exposed at Coopers Falls, and consequently as equivalent to part of the Saluda. When the writer first investigated the Versailles region, the the top the section 2.3 miles south of Versailles was covered. The third reef, which extends from at least as far south as Oldham Co., Ky., is everywhere found at this horizon as far north as the locality 2.3 miles south of Versailles. Since this association of *Tetradium*, *Stromatocerium* and *Labechia*, and sometimes also *Beatricea*, is so very persisten at this position just beneath the Brassfield, it was correlated with the zone containing these same species just beneath the Brassfield on the West Fork of Cedar Creek, only 2.5 miles from the gully south of Versailles. This latter "reef" is found wherever this horizon is exposed almost as far north as Batesville. No reef is found in this position at Hamburg or at Laurel, but a persistent "reef" of the same fossils is found close under the Brassfield in Fayette and Wayne Counties in Indiana, and in Preble, Montgomery and Warren Counties in Ohio. Because of the identical fauna and the identical position with respect to the Brassfield, it was assumed that they represented parts of the same continuous "reef", which assumption is 'now shown by the uncovering of Whitewater strata carrying a characteristic Whitewater fauna above the top "reef" of the Saluda to be a gross error.

Summary.

To summarize, the Saluda represents an influx from the south, where it is probably continuous with the Cumberland sandstone, of more or less dolomitic and arenaceous material into the middle of the Whitewater. From its base to the horizon of the second *Tetradium* reef the Saluda gradually grades into characteristic lumpy Whitewater to the north, and the horizon of its base is, at Oxford, 33' above the top of the Liberty. From the horizon of the second *Tetradium* reef to the top, the Saluda wedges out beneath the *Rhynchotrema dentatum* layer.

Returning to the Oxford section, divison 15 is an easily recognized horizon in the western parts of Butler and Preble Counties, but is not so distinct elsewhere. The great numbers of *Homotrypa*, chiefly *Homotryapa ramulosa*, are distinctive.

Division 16 carries the bulk of the Whitewater fauna in this region. The most

abundant and characteristic species are the *Streptelasmas*, *Homotrypa flabellaris* and Var. *spinifera*, *Homotrypa nodulosa*, *Homotrypa ramulosa*, *Homotrypa wortheni*, *Homotrypella rustica*, *Monticulilpora epidermata*, *Monticulipora parasitica*, *Batostoma variabile*, *Rhombotrypa quadrata*, *Hebertella alveata*, *Platystrophia acutilirata*, *Strophomena sulcata*, *Strophomena vetusta*, *Rhynchotrema capax*, *Ischyrodonta elongata*, *Ischyrodonta truncata*, *Modiolodon subrectus*, *Ortonella hainesi*, *Pterinea demissa*, *Salpingostoma richmondense*, *Schizolopha moorei*, *Bellerophon mohri*, etc., etc.

Division 17 is nowhere completely exposed in the Oxford region, and the characters of the horizon will be discussed later under another section.

Camden Section.

The entire section of the Whitewater-Saluda is seen in the region of Camden, Ohio at the Devil's Backbone, a mile west of town, the section beginning on Paint Creek and following up along the road toward the west begins in the middle Liberty and ends near the top of the *Rhynchotrema dentatum* zone; including the Saluda which is thinner-bedded and more argillaceous and is without the basal *Tetradium* reef but still carries its characteristic ostracod fauna. Following up Paint Creek for 1.5 miles above the Backbone practically the same section is seen, though not so completely exposed. These sections agree very closely with the Oxford sections as regards lithology, faunules and thickness, so to describe them would be but to duplicate what has already been said. But on Beasley Run a section begins about 150 yards below the bridge at the cross road two miles due north of Camden, at about the horizon of the base of division 16 of the Oxford section. From here up there is an unbroken succession into the base of the Elkhorn, with most of the Elkhorn in discontinuous exposures above that.

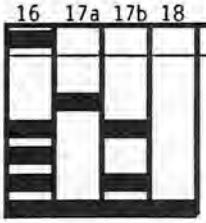
Since this section is essentially a continuation of the composite Oxford section, and only eight miles from the McDills Mills component of that section, the numbering of the divisions will be made to conform to the Oxford Whitewater section.

Beasley Run Section

	Thickness
19 - Basal "barren" shales of the Elkhorn.	
18 - Series of 1"-3" even-bedded limestones and shales, *Tentaculites oswegoensis* is found occuring in great numbers just above the middle of the section. The middle of the section is more or less "sandy" (dolomitic) zone with rather abundant bryozoa and brachiopods.....	15'
17b - Strata as in division 16, to base of smoother, harder and more even-bedded limestones and shales. *Rhynchotrema dentatum* to within 18" of top.....	7'
a - *Rhynchotrema dentatum* zone to floor of east fork at its mouth, a short distance above the bridge. Slightly less shaly than division 16, otherwise much the same.....	3'8"
16 - Soft, lumpy, grainy, shales and limestones, to base of a zone less shaley and of more resitant and even-bedded limestones. These limestones form floor of creek below bridge.....	13'6"

Beasley Run Composite Section Whitewater Fauna

16 17a 17b 18



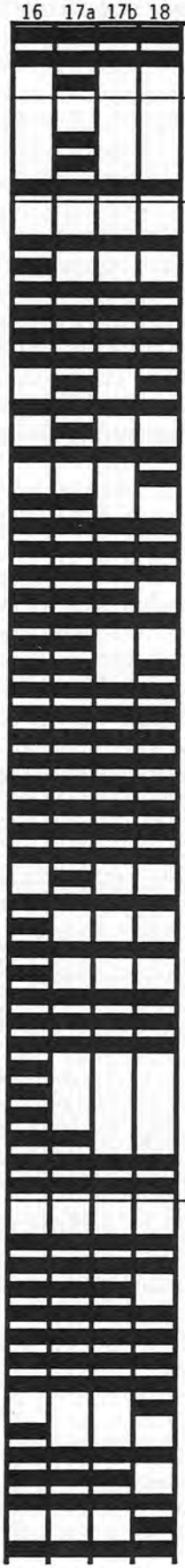
Porifera

Hindia subrotunda (James)

Coelenterata

Columnaria alveolata Goldfuss
Dermatostroma corrugatum Foerste
Dermatostroma papillatum (James)
Dermatostroma scabrum (James)
Protarea richmondensis Foerste

The Whitewater



16 17a 17b 18 **Coelenterata continued...**

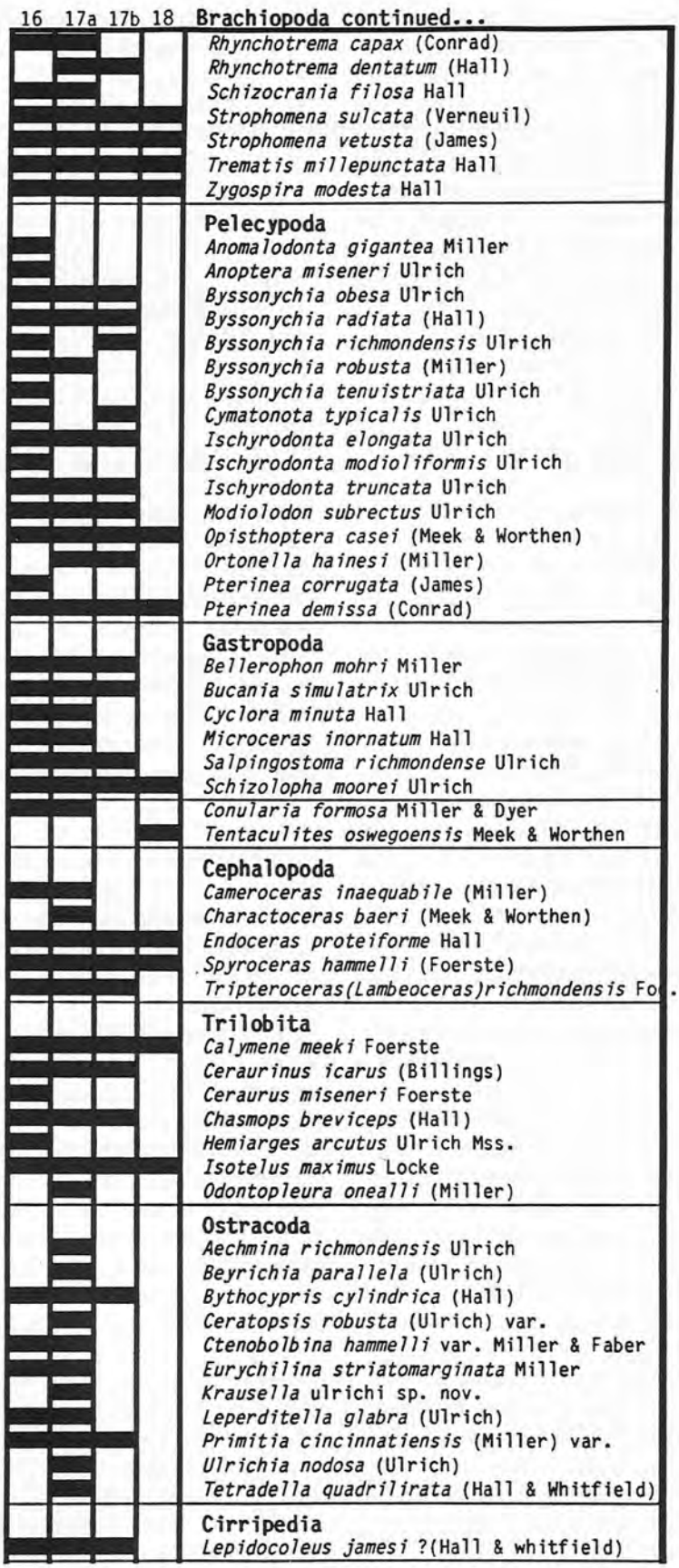
Streptelasma divaricans (Nicholson)
Streptelasma rusticum (Billings)
Tetradium huronense Foord

Echinodermata
Cyclocystoides sp.
Lepadocystis sp.
Lichenocrinus tuberculatus Miller

Bryozoa
Arthropora shafferi (Meek)
Atactopora n. sp.
Atactoporella schucherti (Nicholson)
Batostoma variabile Ulrich
Bythopora delicatula (Nicholson)
Bythopora meeki (James)
Bythopora striata Ulrich
Ceramoporella ohioensis (Nicholson)
Constellaria limitaris Ulrich
Constellaria polystomella Nicholson
Corynotrypa delicatula (James)
Dicranopora emacerata (Nicholson)
Fenestella granulosa Whitfield
Graptodictya perelegans (Ulrich)
Hallopora subnodosa (Ulrich)
Helopora elegans Ulrich
Heterotrypa subramosa prolifica (Ulrich)
Homotrypa austini Bassler
Homotrypa cylindrica Bassler
Homotrypa flabellaris Ulrich
Homotrypa flabellaris spinifera Bassler
Homotrypa nodulosa Bassler
Homotrypa ramulosa Bassler
Homotrypa richmondensis Bassler
Homotrypa wortheni (James)
Homotrypella hospitalis (Nicholson)
Homotrypella rustica Ulrich
Lioclemella fusiformis (Whitfield)
Mesotrypa patella (Ulrich)
Monticulipora cleavelandi James
Monticulipora epidermata Ulrich & Bassler
Monticulipora laevis Ulrich
Monticulipora parasitica Ulrich
Peronopora decipiens (Rominger)
Proboscina auloporoides (Nicholson)
Ptilodictya magnifica Miller
Ptilodictya plumaria James
Ptilodictya n. sp.
Rhinidictya lata Ulrich
Rhombotrypa quadrata (Rominger)
Stomatopora arachnoidea (Hall)

Brachiopoda
Crania laelia Hall
Crania scabiosa Hall
Dinorthis subquadrata (Hall)
Hebertella alveata Foerste
Hebertella alveata richmondensis Foerste
Hebertella occidentalis Hall
Hebertella occidentalis sinuata Hall
Leptaena richmondensis Foerste
Orbiculoidea williamsi sp. nov.
Platystrophia acutilirata (Conrad)
Platystrophia acutilirata prolongata Foe.
Platystrophia acutilirata senex Cumings
Plectambonites rugosus var. Foerste
Rafinesquina alternata (Emmons)

The Whitewater



General Comments.

These Oxford and Camden sections of the Whitewater agree quite closely with the typical Whitewater exposures along the Whitewater River at Richmond and along Elkhorn Creek and its tributaries. The composite section of the Richmond section shows with three exceptions exactly the same divisions, carrying the same faunules, and with essentially the same thicknesses as in the Oxford-Camden region. The three exceptions are that division 13, the basal *Tetradium* reef of the Saluda, has dropped out somewhere between Liberty and Elkhorn Creek, though isolated colonies still occur at that level; division 14 has become modified into harder, bluer and more calcareous limestones; and division 15, the *Homotrypa* bed, is more like division 16.

According to Charles L. Faber, when the old Cincinnati fossil collectors were at the height of their activity the cephalopod zone at the base of the Whitewater was extensively exposed by quarrying operations at Richmond where the Star Piano plant is now located, yielding numbers of complete and well preserved specimens of *Charactoceras*, *Diestoceras*, *Endoceras*, *Byssonychia*, etc. At present this horizon is not advantageously exposed anywhere about Richmond, usually being found in vertical exposures. The same is true of the lower Whitewater between the cephalopod zone and the limestone series representing the northward extension of the basal Saluda reef.[19] It is extensively exposed along the gorge, but the exposures are chiefly vertical.

The upper Whitewater is exposed very favorably at numerous points about Richmond, though the extreme top, the equivalent of division 18 of the Camden section, is shown at but two places and not very favorably at these. The zone of *Tentaculites oswegoensis* (*T. richmondensis* of Miller) is exposed in the bed of East Fork near Glen Miller Park, and on the tributary of Elkhorn Creek that heads toward Boston, the type of Miller's *Tentaculites richmondensis* coming from the former place. This *Tentaculites oswegoensis* zone is a very easily recognized one, and is exposed at a number of places between Oxford and Eaton.

In no respect but in that of a slightly greater thickness does the upper Whitewater of the Richmond region differ from that of the Oxford region.

Miscellaneous Sections.

As the Whitewater is traced eastward through Dayton, Ohio it loses much of its irregularly indurated nature, becomes somewhat more even-bedded, distinctly "sandy" from the development of dolomite crystals, and much less fossiliferous, both as regards specimens and species. A section showing this phase of the Whitewater is shown at the new Big Four Railroad cut at the Huffman Conservancy Dam, east of Dayton. Undoubtedly poor conditions of exposure are partly responsible for the much reduced fauna which has been assembled from this place, but the chief reason is that the conditions favorable for the usual prolific development of life in the Whitewater tended to fail in that direction. All of the more common Whitewater species have been found here, but in greatly reduced numbers.

There is no distinction between lower and upper Whitewater here such as is found further west where the base of the Saluda cuts into the Whitewater and gives a good division.

The *Rhynchotrema dentatum* zone is reduced to 18", and the top of this zone is but 7" below the basal shales of the Elkhorn, the 15' of heavier limestones as exposed in the Camden region being entirely absent here.

Tracing the Whitewater directly eastward from the Oxford region, but very few, small, and scattering exposures are found until east of the Little Miami River valley. At the levels where the member should be exposed, it has usually either been removed by erosion or covered by glacial drift.

Two miles west of Waynesville on the Springboro pike a section begins just above the road bridge, at the horizon of the upper Liberty. The base of the Whitewater is exposed, and part of the top, the interval being covered. The *Rhynchotrema dentatum* zone is 1' thick and 35' above the base of the Whitewater, associated with the characteristic fauna of *Ischyrodonta*, *Ortonella*, *Bucania*, *Salpingostoma*, etc.

The best exposure of the base of the Whitewater in this general region is the one found on Flat Fork Creek, three miles

north-east of Oregonia. Since this section is a continuation of the Liberty section previously given, in the following brief description of this section the numbering will be made conformable.

Flat Fork Creek Section

	Thickness
9 - Even-bedded limestones and shales to top of exposure	5'
8 - Mostly 1"-4" limestones and shales up to rock floor of creek beneath bridge	8'
7 - Heavy limestones at top and bottom, and rather soft, blocky, shaly limestones in the middle to top of barren, rough limestone exposed just above the level of the creek floor on the east side. This top limestone forms floor of creek for some distance and rises with the stream	5'6"
6 - Dense, hard, and barren, blue limestone. The "turkey track" layer at the base of the Whitewater	11'
5 - Liberty.	

Division 6 is entirely barren of fossils, and its characters as shown here are typical of the layer as found in Warren and Clinton Counties.

Division 7 is the cephalopod zone, the most common species here being *Charactoceras baeri*, *Endoceras proteiforme*, and various cyrtoceroid species which are undescribed, associated with *Whitella obliquata*. At present it is not very favorably exposed.

Division 8 is the most fossilliferous zone in the lower Whitewater. Near the middle is the *Streptelasma* layer referred to by Nickles as being approximately the top of the Liberty. This layer is a 1"-2" limestone full of large *Streptelasma rusticum* and with abundant *Rhynchotrema capax*, *Dinorthis subquadrata*, *Strophomena vetusta*, *Rafinesquina alternata*, *Batostoma variabile*, *Bythopora meeki* and *Rhombotrypa quadrata*. *Pachydictya fenestelliformis* is restricted to this stratum. Occasional specimens of *Ptilodictya flagellum* and *P. nodosa* are found. *Cupulocrinus polydactylus* is occasionally found just above this limestone and below it, *Xenocrinus baeri* seems to be essentially restricted to the bottom sides of shallow plano-convex lenses or miniature "horses", the occurrences evidently representing shallow tidal channels in which the animals grew and in which they were overwhelmed and buried by the rapid deposition of silt. This would indicate a habitat quite different from the usual deeper water habitat of modern crinoids. Beautiful slabs of this species have been dug out here and are to be seen in many of the larger museums. Occasional "pockets" of *Dendrocrinus* are also found in this division.

The next detailed Whitewater section to be described will be still farther east, along Cowan Creek and one of its tributaries. A half mile off the Cincinnati Pike on the Cowan creek road are the first Cowan Creek exposures, showing the top of the Waynesville and part of the Liberty.

A section up an eastern tributary at this point shows practically the whole of the Liberty, though poorly exposed, and the basal Whitewater, up as far as the layer containing *Streptelasma*, *Pachydictya*, etc. The first high exposure on Cowan's Creek above this tributary gully shows the cephalopod zone based about 4' feet above the creek, beneath the road. Scattering exposures carry the section up to a tributary gully above the road bridge, and the section follows up the gully toward the east. The section follows.

Cowans Creek Whitewater Composite Section

	Thickness
11 - Tough, resistant limestone. *Agelacrinites austini* sometimes found on top	3"-4"
10 - Shales and thin limestones full of *Bythopora delicatula*. *Drepanella richardsoni* runs through the division but is particularly abundant in the lower 2'	5'6"
9 - Thin even-bedded limestones and shales full of	

The Whitewater

Bythopora delicatula, to top of 3' falls just below wire fense at top of gully..... 5'8"

8 - Like division 7, to top of two 1" limestones. Layer of bryozoa just beneath top. Careful search failed to yield *Rhynchotrema dentatum*, though some were found at this level on the high wash bank of Cowan's Creek just above the mouth of this gully..... 15'5"

7 - Irregular limestones and grainy shales..... 20'5"

6 - Irregular limestones and grainy shales, to limestone floor of creek at mouth of first tributary gully from the east, about 0.25 mile above the old State Road bridge. The section follows up this gully..... 20'9"

5 - More shaly than division 4, to base of 5" barren, smooth shale..... 8'6"

4 - 5'7" To top limestones at upper end of exposure and base of more shaly portion.

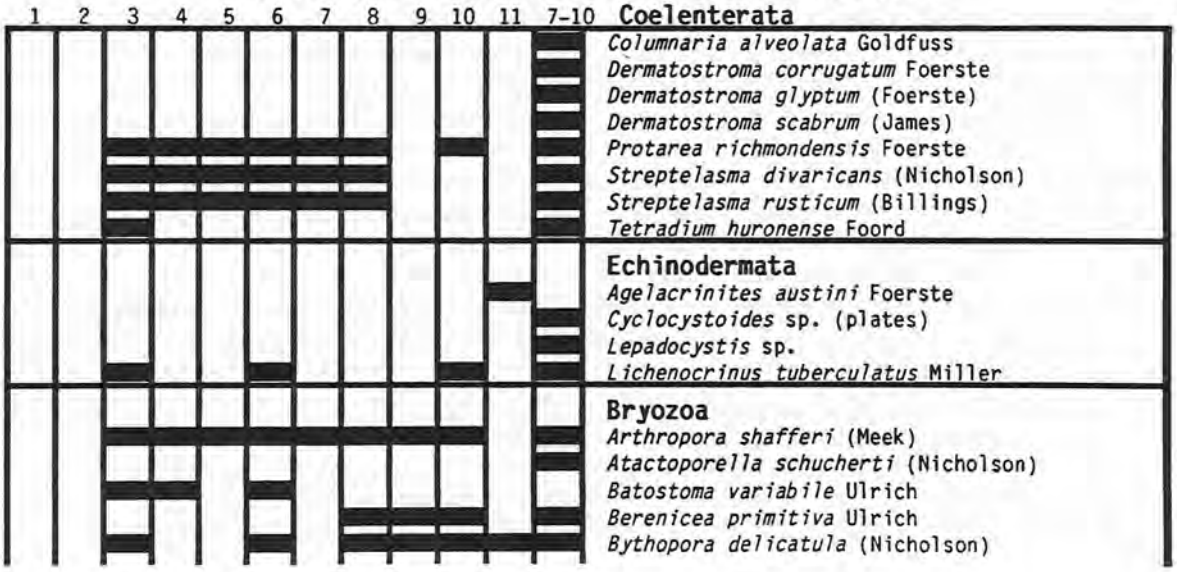
3 - Shales and thin limestones, mostly exposed in the same banks above division 2, mostly covered up the creek.

2 - 3' Cephalopod zone.

1 - 4' Shales and limestones, base of exposure to base of *Charactoceras baeri* zone. 6" "turkey track" layer at the top.

Following the curves of the valley, it is over two miles from the base of division 2 to the base of division 6. In this distance exposures are few and scattering, so the variable dip cannot be allowed for. Then, too, the Locke level is inaccurate for long sights. It is highly probable that divisions 3 and 6 are actually much less in thickness than the figures given, but no way was found of correcting these figures. Austin states[20] that the top of the "turkey track" layer or base of division 2 is 876' A.T., while the top of division 11 is 956' A.T., giving a thickness of 80' without any correction for dip. None of these divisions are very favorably exposed for study, but a high, more or less weathered bank, beneath the road and a short distance above the gully which shows divisions 7 - 11, shows fossils from divisions 7 - 10. While the bank cannot be sectioned on account of the quantity of loose debris covering its upper part, yet a fair fauna has been derived from the bank as a whole. On the faunal chart 7 - 10 is understood to mean the undivided faunules as found mingled in the talus of this wash bank.

Cowans Creek Composite Section Whitewater Fauna



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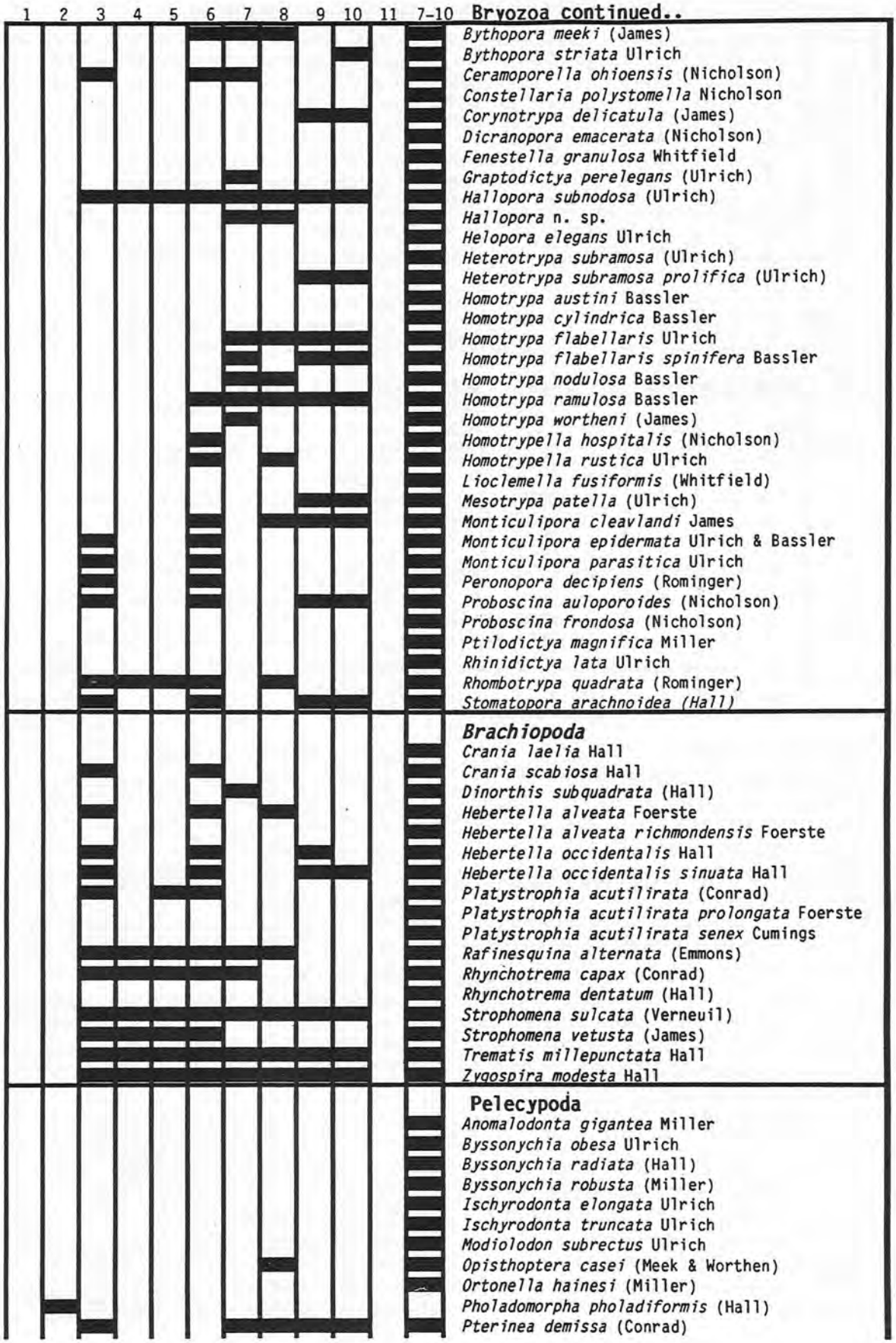
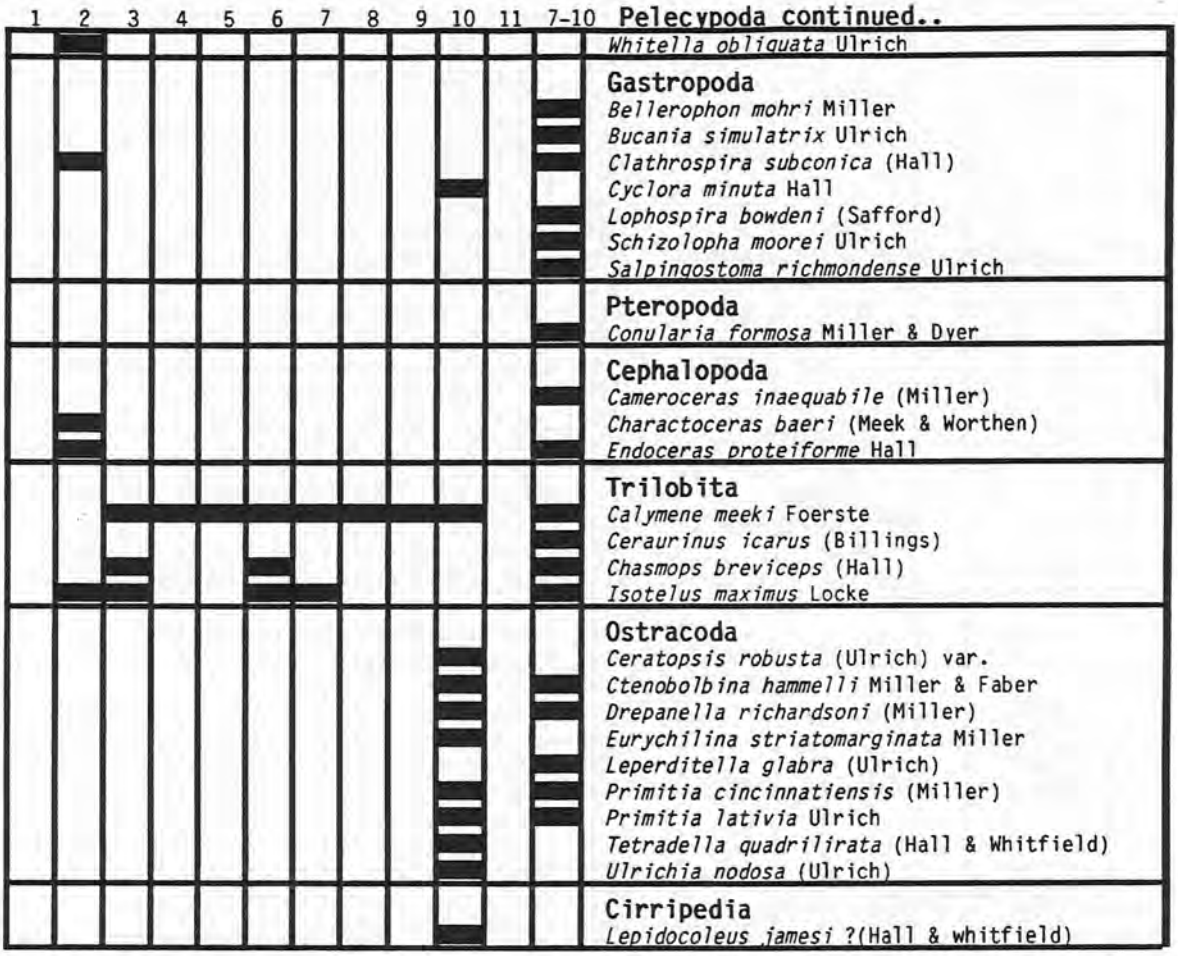


The Whitewater



General Comments.

Comparison of this section with the Oxford-Camden sections is not very satisfactory because of the poor conditions of exposure of the divisions, and because of the reduced fauna which the Whitewater shows here. The abundant specimens of *Ischyrodonta*, *Byssonychia*, *Ortonella*, *Bucania*, *Salpingostoma*, *Rhynchotrema dentatum*, *Monticulipora epidermata*, etc. etc., which give the Whitewater its typical faunal aspect, are represented here by but a few scattering specimens. On the other hand *Monticulipora cleavelandi*, which is quite rare west of the Great Miami River valley, is very abundant at the top of this section.

The strata are much less lumpy than in the more typical Whitewater region.

The tough, persistant limestone at the top, division 11 of this section, is considered by Dr. Austin to make the top of the Whitewater. This point will be discussed later.

Description of Dutch Creek

Supplementing the upper beds of this Cowan Creek section are some scattering exposures about 6 miles a little east of north of the end of the section, and about 4.5 miles a little west of north-west of Wilmington, on Dutch Creek and upon Hales Branch of Dutch Creek. Hales Branch heads west of the village of Oakland, and Dutch Creek crosses the Harveysburg road on the east side of Oakland.

On Dutch Creek the section begins at a horizon about 15.5' below the *Drepanella richardsoni* zone and extends but a few feet above the persistent hard limestone which carries *Ischyrodonta* and an occasional *Agelacrinites austini*, division 11 of the Cowan Creek section. On Hales Branch of Dutch Creek the exposures begin just beneath this hard limestone and extend about 30' above it. Since these two sections form a very good composite section they will be so treated, divisions 1-5 being shown on Dutch Creek and 5-9 on Hales Branch.

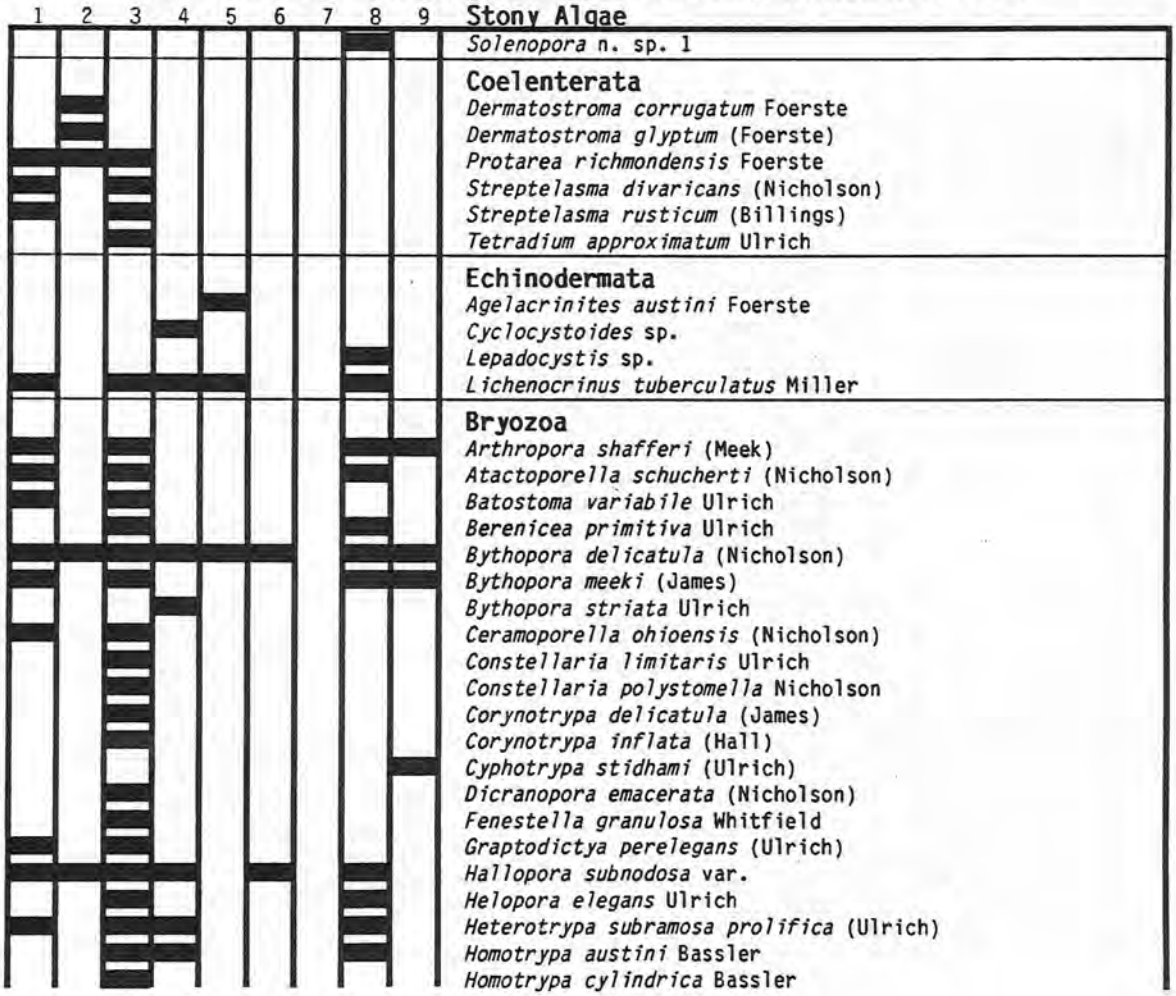
The Whitewater

Hales Branch/Dutch Creek Composite Section

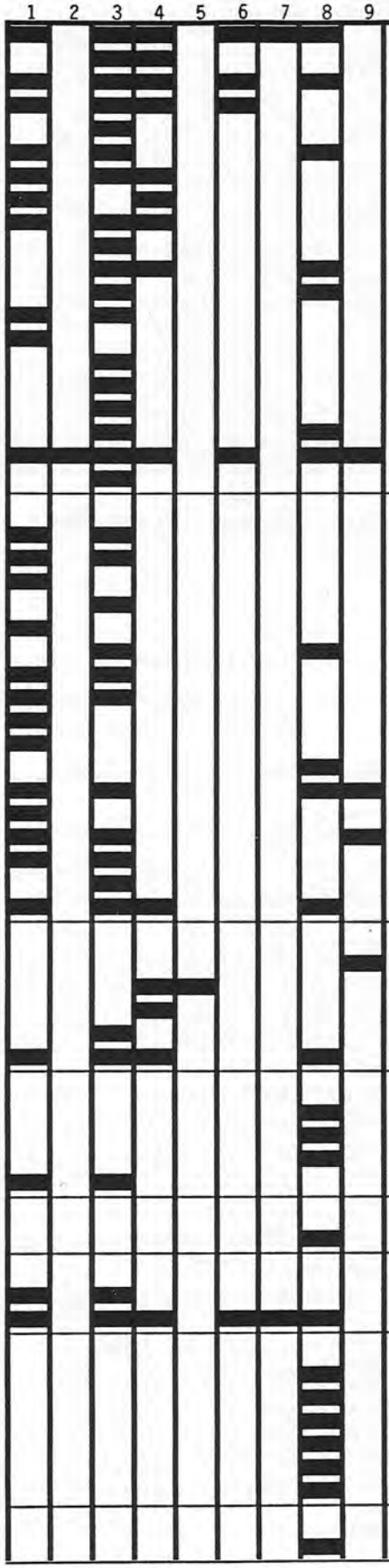
	Thickness
9 - Shales, top covered	15'
8 - Rather lumpy shales and thin limestones	5'6"
7 - Heavy, hard limestone	5"-9"
6 - Shales and thin limestones	2'9"
5 - Hard, tough, persistent limestone carrying a few *Ischyrodonta*, *Pterinea*, etc., and occasionally an *Agelacrinites*	5"-9"
4 - Mostly covered, rarely more than a few traces exposed. The *Drepanella* zone is very prolific when exposed, according to Austin	13'
3 - Rather even-bedded limestones and shales full of Bryozoa	5'6"
2 - Lumpy limestones and shales, more like typical Whitewater	4'
1 - Rather even-bedded limestones and shales with some uneven, shaly, lumpy limestones	6'

Excepting the lower divisions, the section is not very prolific of fossils. Shale washings would undoubtedly increase the fossil lists, but have been collected and examined only from division 8.

Dutch Creek/Hales Branch Composite Section Whitewater Fauna



The Whitewater



1	2	3	4	5	6	7	8	9	**Bryozoa continued...**
									Homotrypa flabellaris Ulrich
									Homotrypa flabellaris spinifera Bassler
									Homotrypa nodulosa Bassler
									Homotrypa ramulosa Bassler
									Homotrypa richmondensis Bassler
									Homotrypa wortheni (James)
									Homotrypella hospitalis (Nicholson)
									Homotrypella rustica Ulrich
									Mesotrypa patella (Ulrich)
									Mesotrypa n. sp.
									Monticulipora cleavelandi James
									Monticulipora epidermata Ulrich & Bassler
									Monticulipora parasitica Ulrich
									Peronopora decipiens (Rominger)
									Proboscina auloporoides (Nicholson)
									Proboscina frondosa (Nicholson)
									Ptilodictya magnifica Miller
									Rhinidictya lata Ulrich
									Rhombotrypa quadrata (Rominger)
									Stomatopora arachnoidea (Hall)
									Brachiopoda
									Crania laelia Hall
									Crania scabiosa Hall
									Dinorthis subquadrata (Hall)
									Hebertella alveata Foerste
									Hebertella alveata richmondensis Foerste
									Hebertella occidentalis Hall
									Hebertella occidentalis sinuata Hall
									Platystrophia acutilirata (Conrad)
									Platystrophia acutilirata prolongata Foerste
									Platystrophia acutilirata senex Cumings
									Platystrophia moritura Cumings
									Rafinesquina alternata (Emmons)
									Rhynchotrema capax (Conrad)
									Strophomena sulcata (Verneuil)
									Strophomena vetusta (James)
									Trematis millepunctata Hall
									Zygospira modesta Hall
									Pelecypoda
									Ctenodonta sp.
									Ischyrodonta sp.
									Modiolopsis sp.
									Opisthoptera casei (Meek & Worthen)
									Pterinea demissa (Conrad)
									Gastropoda
									Bucania simulatrix Ulrich
									Cyclora minuta Hall
									Microceras inornatum Hall
									Schizolopha moorei Ulrich
									Pteropoda
									Tentaculites oswegoensis Meek & Worthen
									Trilobita
									Calymene meeki Foerste
									Isotelus maximus Locke
									Ostracoda
									Bythocypris cylindrica (Hall)
									Ceratopsis robusta (Ulrich) var.
									Drepanella richardsoni (Miller)
									Eurychilina striatomarginata Miller
									Primitia cincinnatiensis var.
									Primitia lativia Ulrich
									Cirripedia
									Lepidocoleus jamesi ?(Hall & whitfield)

General Comments, "Belfast Bed".

Faunally, divisions 1-3 agree very well with division 8 of the Cowans Creek section. Division 4 is so poorly exposed here that comparison is impossible, except that in position it matches division 9 of the Cowans Creek section. Division 5 has the same characters as on Cowans Creek, where it is number 10. Division 6 and 7 are undoubtedly not as faunally reduced as the list would indicate, but the conditions of exposure are so poor that little could be learned of them. Division 8 shows some faunal points of considerable interest, chief of which is the occurrence of occasional specimens of *Tentaculites oswegoensis*. This is perfectly in order, for on the south side of Spring Hill, 3 miles N.W. of Clarksville and about 7 miles W. by S.W. of the Hales Branch locality, abundant fossils are sometimes turned up by the plow in a zone beginning 42' below the base of the Brassfield, the bed underlying the Brassfield, the Belfast, if present at all here, is so weathered and so poorly preserved as to be unrecognizable. Dr. Austin has kept this locality under observation for many years, and reports over 50 species of fossils from it. The writer was able to find, on a single visit made to this locality, about 25 species, mostly long-lived and wide-ranging forms, but including *Streptelasma divaricans* and *Streptelasma rusticum*, *Homotrypa nodulosa*, *Homotrypa ramulosa*, Homotrypa wortheni and variety *prominens Monticulipora cleavelandi*, *Platystrophia acutilirata*, *Platystrophia moritura*, *Leptaena richmondensis*, and *Tentaculites oswegoensis*. This combination of *Leptaena* and *Tentaculites*, more or less associated with the other species listed, is very characteristic of the top of the Whitewater farther west, and is known from no other horizon. And since the position of this fauna is just where one would expect to find *Tentaculites* zone fauna, the writer has no hesitation in correlating division 8 with the *Tentaculites* zone. The fauna of division 8 contains all of the Spring Hill species mentioned except the species of *Streptelasma*, and is considered to be the easternmost representation of the upper Whitewater farther west.

This interpretation is not agreed with by Dr. Austin, who is so thoroughly familiar with the faunules and the stratigraphy of this region that his opinion must be given consideration. Dr. Austin begins the Elkhorn with the hard, tough, *Ischyrodonta* limestone, division 5, largely because of the occurrence of such more or less characteristic Elkhorn species as *Platystrophia moritura*, *Agelacrinites austini* and *Homotrypa wortheni* var. prominens in or above that stratum. Regarding *Platystrophia moritura*, the occurrence of this species here loses much of its significance when one finds that it is but another example of a species which has been living in other parts of the Cincinnati province for a long time before reaching Ohio. Typically present in the Elkhorn of Ohio, and Indiana, *Platystrophia moritura* is common in the upper Whitewater about Versailles, Indiana, and is not rare in the Liberty as exposed between Fisherville and Bardstown in Kentucky. In the Versailles region it is associated with an abundance of *Homotrypa wortheni* var. *prominens*. As for *Agelacrinites austini*, specimens of this species have been found associated with *Dystactospongia madisonensis* at the base of the Saluda at numerous places in Indiana, though most of the specimens observed have been seen in the *Cyphotrypa stidhami* zone of the Elkhorn.

Considering that everywhere from Hamburg, Indiana, through Richmond, Indiana, and Eaton, Ohio to east of Dayton, Ohio the Whitewater is immediately followed by smooth, more or less barren blue clay shales constituting the basal Elkhorn, it seems clear to the writer that division 8 is the somewhat modified top of the Whitewater, and division 9 is the typical basal Elkhorn.

There is no evidence here of a physical break between the Whitewater and the Elkhorn. A series of somewhat heavier limestones becomes rapidly thinner and passes through a short transition into the smooth blue clay shales. The basal few feet of shales carry all of the limited fauna recorded from division 9 with the exception of *Cyphotrypa stidhami* and a species of *Ctenodonta*, which occur quite a bit higher in the section. The lithological change at this horizon is abrupt west of the Little

The Whitewater

Miami River valley, but from Clinton County southward it is impossible to determine the Whitewater-Elkhorn boundary. The specimens from the base of division 9 show no evidence of wave-action, are not found in the shales, and appear to be the last survivors of a fauna which was smothered out by the beginning deposition of the Elkhorn muds.

The Lynchburg Section.

In the 17-mile interval between Dutch Creek and Lynchburg there are no exposures of importance. At Lynchburg 30' of Whitewater are exposed on Turtle Creek between the road bridge south of town and the railroad bridge, but neither the base nor the top is shown. The section is poorly exposed both for sectioning and for faunal examination, but has a certain amount of importance in that it is practically all that bridges over the 44 miles between Dutch Creek and the Whitewater exposures about Harshaville, 3 miles S.E. of Seaman, Adams County. Along the east flank of the Cincinnati arch between Lynchburg and Harshaville the only Whitewater exposures are a few scattering ones on Buck Run, 6 miles north of Seaman, and in the valley of Brush Creek near the Serpent Mound.

The Lynchburg section follows.

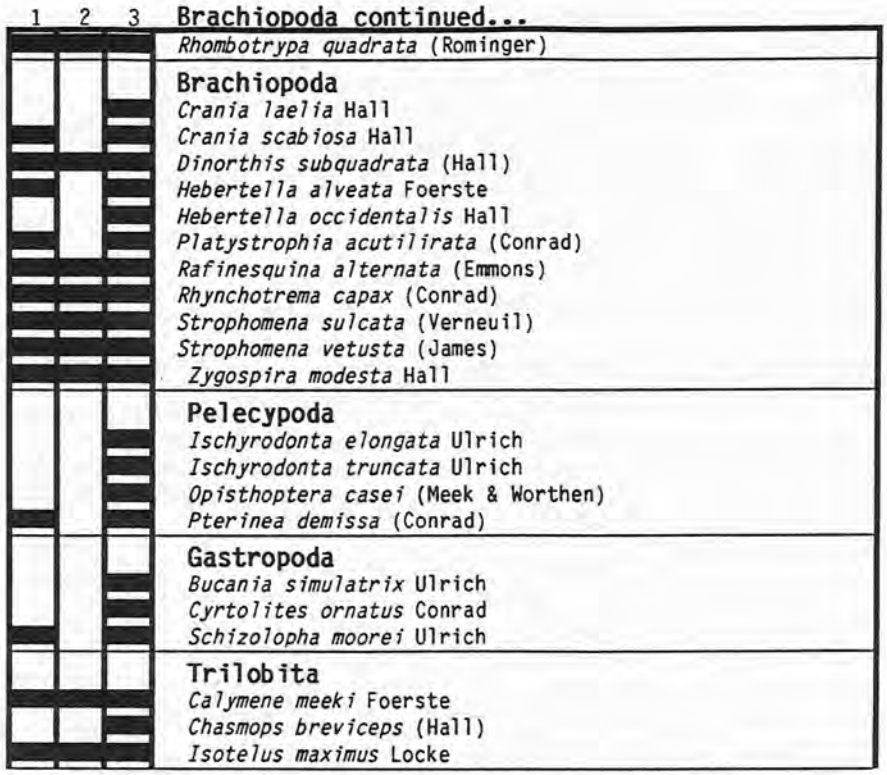
	Thickness
3 - A wash bank below the railroad bridge. Scattering exposures are found for some distance up the creek east of town but belong to this division.....	18'
2 - More or less even-bedded limestones and intercalated shales, exposed above division 1 in the same bank.....	8'
1 - Mostly grainy shales and shaly limestones, from water level to top of first blue, more or less even-grained limestone. Only upper 3' are well exposed.....	4'5"

Fossils are fairly abundant, especially Bryozoa, but not many species are present. This and the Clinton County sections serve to show the transition from the highly fossiliferous, typical Whitewater with its large faunal list to the much more restricted Whitewater fauna of Adams County.

Lynchburg Section Whitewater Fauna

1	2	3	
			Coelenterata
■	■	■	*Protarea richmondensis* Foerste
■	■	■	*Streptelasma divaricans* (Nicholson)
■	■	■	*Streptelasma rusticum* (Billings)
■		■	*Tetradium huronense* Foord
			Echinodermata
		■	*Lichenocrinus tuberculatus* Miller
			Bryozoa
■	■	■	*Arthropora shafferi* (Meek)
		■	*Batostoma variabile* Ulrich
	■	■	*Berenicea primitiva* Ulrich
■	■	■	*Bythopora delicatula* (Nicholson)
■	■	■	*Bythopora meeki* (James)
		■	*Fenestella granulosa* Whitfield
		■	*Graptodictya perelegans* (Ulrich)
■	■	■	*Hallopora subnodosa* (Ulrich)
		■	*Hallopora* n. sp.
		■	*Homotrypa flabellaris* Ulrich
■		■	*Homotrypa nodulosa* Bassler
■	■	■	*Homotrypa ramulosa* Bassler
		■	*Homotrypa wortheni* (James)
■	■	■	*Homotrypella hospitalis* (Nicholson)
	■	■	*Homotrypella rustica* Ulrich
■	■	■	*Mesotrypa patella* (Ulrich)
		■	*Monticulipora cleavelandi* James
		■	*Monticulipora parasitica* Ulrich
		■	*Peronopora decipiens* (Rominger)

The Whitewater



General Comments.

In division 3 *Strophomena sulcata* and *Strophomena vetusta* are abundant, but the species of *Streptelasma* and *Rhynchotrema capax* disappear toward the top. *Platystrophia acutilirata*, *Bucania simulatrix* and the species of *Ischyrodonta* are rather rare.

Lithologically, the shales are still more prominent, and the limestones still more shaly, than in the Cowans Creek and Dutch Creek localities in Clinton County. This tendency for the strata to become more shaly, and the fauna more reduced, toward the south and south-east is well shown at the next sections to be studied, those about Harshaville, Adams, County.

The Harshaville Section.

In the Harshaville region the basal part of the Whitewater is well shown in a continuation of the Liberty section on Cherry Fork already described. The same strata are shown as a continuation of the Liberty section on Grace Run, a tributary flowing into Cherry Fork from the west at Harshaville, and most of the strata on up to the Brassfield are seen in ascending a tributary of Grace Run which enters from the north about 2 miles south of Seaman. Divisions 6-8 of the following composite section are as exposed on Cherry Fork, and the higher divisions are those along Grace Run and on up the above mentioned tributary. Since this is but a continuation of the Harshaville Liberty section the numbering of the divisions will be made to correspond to those of the Liberty section.

	Thickness
19 - Brassfield.	
18 - Belfast.	
17 - Shale with few thin limestones.....	2'3"
16 - Purple shale bed, with a little inter-bedded greenish shale.....	5'7"
15 - Covered, to base of high overhanging exposure on left side of right fork of creek.....	19'6"

14 - Shales and thin limestones to top of last exposure showing nothing but Richmond strata. Partly covered..... 33'3"

13 - Shales and limestones to top first limestone ledge exposed above second floodgate. Partly covered..... 11'10

12 - Limestones and shales to top thin, barren, wave-marked limestone 11" above a 6" limestone forming a ledge across the creek..... 6'7"

11 - Limestones and shales to top 1"-2" limestone full of *Bythopora delicatula* at top second little falls above the mouth of the tributary, 2 miles south of Seaman..... 5'10"

10 - Shale bed at base, followed by limestones with a 6" conglomerate layer 9" below the top, to top of a 3" very rough limestone. This limestone is apparently barren, but when split open shows *Pachydictya fenestelliformis* inside. Between this rough limestone and the layer of conglomerate is a wave-marked limestone also showing *Pachydictya*. The rough top limestone is exposed above the top of a little waterfall above the ford 1.25 miles due west of Harshaville. These same strata also outcrop with essentially these same characters on Cherry Fork..... 3'9"

9 - Pebble zone, a limestone 0-1" thick carrying embedded in it peculiar intraformational pebbles up to 8" thick and 18" in diameter, covered with *Protarea*, Bryozoa, etc. Best exposed at the ford 1.25 miles west of Harshaville. This zone rises undulatingly with the creek bed, and outcrops again .75 miles farther west at the mouth of the tributary up which this section follows..... 0-8"

8 - Shales and thin limestones. A large lens overgrown with Bryozoa is near the base in the west bank. 2'9" above the base is a 2"-3" even-bedded limestone with many *Strophomena planumbona*. This limestone is the horizon for young *Agelacrinites rectiradiatus*. Top of division is base of a limestone carrying abundant intraformational pebbles..... 9'9"

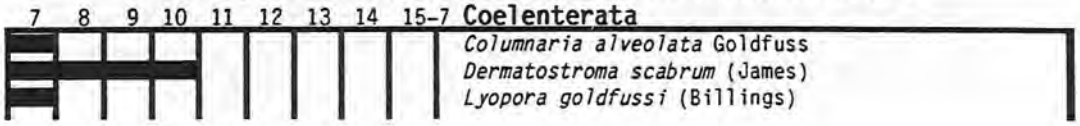
7 - Limestone series with interbedded shales. *Cupulocrinus* and *Lyopora* occur in interbedded shale 7" above base..... 2'8"

6 - Top of Liberty.

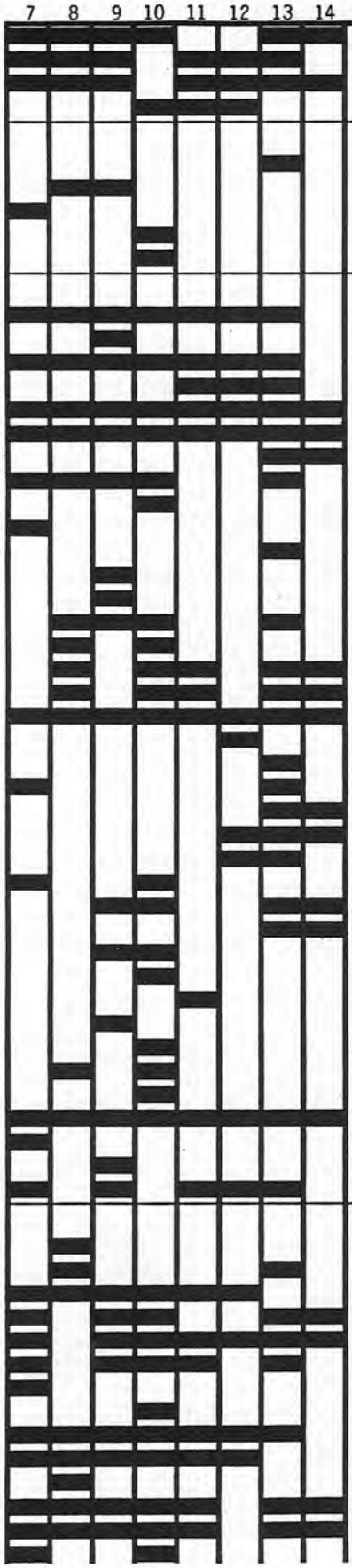
From the top of division 9 to the base of division 16 is 80'9" according to the above figures. The same thickness as measured from the ford where division 9 is best exposed up the road climbing the hill to the south is 69'6". This gives a discrepancy of 11'3", due in part to the impossibility of correcting for dip where the exposures are short and far between, and in part to the fact that where the sights with the Locke level are long they are correspondingly inaccurate. The figure of 60'6" is probably fairly accurate. Most of the error would be in the thickness of divisions 13-15.

Following is the faunal chart of this composite section.

Cherry Fork/Grace Run Composite Whitewater Fauna.



The Whitewater



Coelenterata continued...

Protarea richmondensis Foerste
Streptelasma divaricans (Nicholson)
Streptelasma rusticum (Billings)
Tetradium huronense Foord

Echinodermata

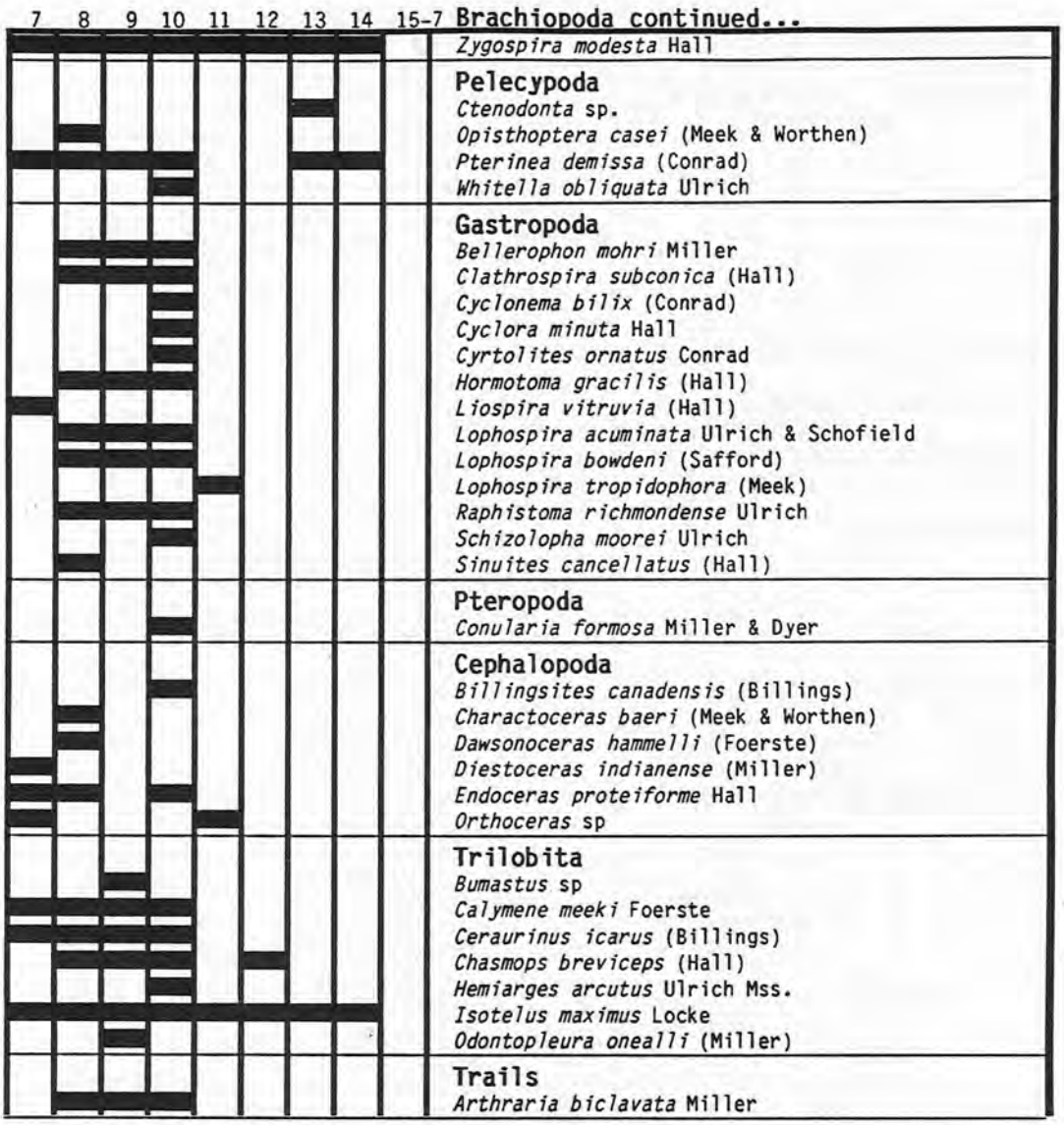
Agelacrinites austini Foerste
Agelacrinites rectiradiatus Shideler
Cupulocrinus polydactylus (Shumard)
Dendrocrinus sp.
Lichenocrinus tuberculatus Miller

Bryozoa

Arthropora shafferi (Meek)
Atactoporella schucherti (Nicholson)
Batostoma variabile Ulrich
Berenicea primitiva Ulrich
Bythopora delicatula (Nicholson)
Bythopora meeki (James)
Bythopora striata Ulrich
Ceramoporella ohioensis (Nicholson)
Constellaria limitaris Ulrich
Constellaria polystomella Nicholson
Corynotrypa delicatula (James)
Corynotrypa inflata (Hall)
Crepipora bellula sp. nov.
Dicranopora emacerata (Nicholson)
Eridotrypa simulatrix (Ulrich)
Fenestella granulosa Whitfield
Graptodictya perelegans (Ulrich)
Hallopora subnodosa (Ulrich)
Hallopora sp. nov.
Heterotrypa subramosa prolifica (Ulrich)
Homotrypa flabellaris Ulrich
Homotrypa nodulosa Bassler
Homotrypa ramulosa Bassler
Homotrypella hospitalis (Nicholson)
Homotrypella rustica Ulrich
Mesotrypa patella (Ulrich)
Monticulipora cleavelandi James
Monticulipora parasitica Ulrich
Pachydictya fenestelliformis (Nicholson)
Peronopora decipiens (Rominger)
Proboscina auloporoides (Nicholson)
Ptilodictya flagellum Nicholson
Ptilodictya nodosa James
Rhinidictya lata Ulrich
Rhombotrypa quadrata (Rominger)
Rhopalonaria venosa Ulrich
Stellipora williamsi sp. nov.
Stomatopora arachnoidea (Hall)

Brachiopoda

Crania laelia Hall
Crania scabiosa Hall
Dinorthis subquadrata (Hall)
Hebertella alveata Foerste
Hebertella occidentalis Hall
Hebertella occidentalis sinuata Hall
Platystrophia acutilirata (Conrad)
Plectambonites rugosus var. Foerste
Rafinesquina alternata (Emmons)
Rhynchotrema capax (Conrad)
Strophomena planumbona (Hall)
Strophomena sulcata (Verneuil)
Strophomena vetusta (James)
Trematis millepunctata Hall



General Comments. "Intraformational Pebbles"

Divisions 8-11 are also well exposed at and below the road bridge over Elk Fork 1.5 miles east of Winchester, and carry the same faunules. At this place the strongly developed wave-marks and the intraformational pebbles have been studied by various investigators, most recently by Foerste[21]. These abundant pebbles and the strongly wave-marked limestones are characteristic of this horizon wherever it is exposed in Adams County. These pebbles are of three types, one type, practically limited to division 9 of the Harshaville section (layer D of Foerste's paper) is a fine-grained mudstone, highly irregular in outline and sharply uneven on top, and shows little or no rounding of corners or edges due to wave-action, and ranges up to 12" by 18" across and 8" thick. When split open the pebbles are usually unfossiliferous, but occasional fragments of *Isotelus* or rare specimens of *Rhombotrypa quadrata*, *Bythopora meeki*, *Batostoma variabile* and *Dinorthis subquadrata* may be found. Encrusting growths of bases of *Batostoma variabile*, *Hallopora subnodosa*, *Homotrypella rustica* and colonies of *Atactoporella schucherti*, *Crepipora bellula*, *Ceramoporella ohioensis*, and *Stomatopora arachnoidea*, with *Protarea richmondensis*, *Dermatostroma scabrum* and *Streptelasma divaricans*, are more or less abundant. Commonly these encrusting growths are found on both sides of the pebble, showing that there was enough wave or current action to turn the stone over. The primitive *Agelacrinites rec-*

tiradiatus is, with the exception of occasional young specimens found on a single thin limestone in the division below, limited to the tops of the pebbles or to an occasional *Streptelasma* of this zone. At this horizon, at all of the lower Whitewater localities described in this work, are one or more limestones of variable thickness and having exactly the same types of upper surfaces that are seen in these more or less isolated and irregular pebbles. On Flat Fork, Warren County, a few specimens of *Batostoma* and *Ceramoporella* and a single example of *Agelacrinites rectiradiatus* were found encrusting the higher elevations of the lumpy top of such a limestone. It seems clear to the writer that these pebbles are but broken fragments of such a limestone, broken up probably by wave action and practically in situ while the stratum was in a partially indurated condition.

The second type of pebble is a thin, smooth stone, rounded to subangular in outline and fine-grained like the first type. Both exterior and interior are devoid of fossils. Foerste reports one of this type 14" by 7" and .5" thick, which is somewhat larger than any observed by the writer. This type is uncommon in division 9 but forms a very distinct 6" stratum near the top of division 10, this stratum being the same as layer G of Foerste's paper. The pebbles look quite like the shale fragments now dislodged from these same lower Whitewater beds and scattered along the stream beds by the spring freshets, the only difference being that the intraformational pebbles are indurated and are not mixed with foreign material.

It seems clear to the writer that this type of pebble was produced by either currents or waves peeling off fragments of partially indurated calcareous shales, and scattering them over the ocean floor.

The third type is a rather uncommon one, and is more crystalline, contains an abundance of fossil remains, usually fragments of *Isotelus*, with *Dinorthis*, *Hebertella*, *Streptelasma*, *Hallopora*, *Rhombotrypa*, *Batostoma*, *Bythopora*, *Homotrypella*, etc., etc., and is encrusted with the same Bryozoa etc., as are the pebbles of the first type, but especially with *Dermatostroma*. It is characterized by its large size, specimens having been found measuring 36" by 18" and 5" thick. Some examples show straight sides, but most of them show an acute angle where the side reaches the top, the side being cut back under the top as much as 9". These stones are all flat-topped, and are found isolated at various levels through division 10. The method of their formation is rather clearly indicated by the finding of occasional "lenses" such as the one mentioned as occurring near the base of division 8 on Cherry Fork, south of Harshaville. Here a limestone "lens" is embedded in the shales as exposed in the right bank of the creek, and is at least 5' in diameter and 9" thick, and both top and sides are abundantly encrusted with Bryozoa etc. The lens itself is clearly stratified, and seems to be a residual block that has survived the scouring action of currents, and the erosion of waves, that have removed the rest of the stratum in that locality. Such instances are not uncommon along shores today, and the writer has a vivid recollection of a partly indurated sandy clay on the harbor side of Stanley Park, Vancouver, B.C., where the stratum has been undercut in the same way as the Cherry Fork lens, and is sufficiently solid to form a place of attachment for abundant *Fucus*, barnacles, limpets etc.

Pebbles of one type or another are of casual occurrence from the base of the Whitewater, division 7, up to the top of division 10, and through this same general range as far west as the Ohio-Indiana state line. These, with the accompanying more or less strongly wave-marked limestones, and the "horses", lenses, and "hash limestones", indicate that after the post-Liberty emergence of the Cincinnati region was ended by the invasion of the Whitewater sea, shoal water conditions persisted until 12'-16' of limestones and shales had accumulated over the whole of the Whitewater region as exposed in Ohio.

Faunally, the chief point of interest is the assemblage of species that found a congenial home upon and among the pebbles of division 9. The return in the Richmond of the primitive straight-rayed type of *Agelacrinites* marks another recurrence of a Trenton type in the Richmond. The appearance of *Bumastus* is another, and the single specimen found here is the only known occurrence of this genus in the Richmond of the Cincinnati province. The

specimen is too fragmentary for a close comparison with *Bumastus beckeri* Slocom from the Maqouketa of Iowa.

Both *Strophomena planumbona* and *Plectambonites rugosus* are Liberty survivors which reappear in the lower Whitewater and give it a brief Liberty aspect. These species are of general occurrence at this horizon in Ohio and Indiana, but the *Plectambonites* is usually very rare. *Strophomena planumbona* has not been found above division 8, nor *Plectambonites* above 10.

Offsetting these species are the distinctive Whitewater species of *Ceraurinus icarus*, *Cupulocrinus polydactylus*, *Charactoceras baeri*, *Diestoceras indianense*, *Ptilodictya flagellum*, *Ptilodictya nodosa*, *Pachydictya fenestelliformis*, *Opisthoptera casei*, etc., etc. Examination of the fossil chart shows that the characteristic Whitewater species appear abruptly at the beginning of the section, and that the pebble zones are not in the Liberty, as interpreted by Foerste, but are in the typical basal Whitewater.

Although no fossils are reported from the top divisions, 16 and 17, this is primarily due to the fact that in this section the only outcrops are very unfavorably exposed, being almost vertical and covered with a wet and slimy growth of algae and moss. Elsewhere in Adams County are exposures which show a restricted fauna from this horizon.

?Whitewater/?Elkhorn.

If there be any distinct division between the Whitewater and the Elkhorn in this section, it is covered. It may be observed that the basal Whitewater is quite prolific in species of Bryozoa, though other groups are well represented.

Division 16 carries purplish red shales which are found within a few feet of the Belfast, or of the Brassfield where the Belfast is absent, wherever this horizon is exposed in Adams County. Sometimes only the solidly colored upper part of the zone is present, but commonly there are 4-5' of alternating greenish and purplish shales beneath. Sometimes a few rare specimens of *Bythopora delicatula*, *Bythopora meeki*, *Hebertella occidentalis* and *Strophomena sulcata* are seen and in one place *Drepanella richardsoni* is common, but usually these shales are entirely barren of fossils.

Whether or not this shale zone is to be correlated with the similar purplish red shale zone in the Elkhorn of Warren and Clinton, Counties is not certain. Both are found at the same position beneath the Brassfield, and they are identical lithologically. But at several places in Adams County these shales are followed by a few feet of bluish shales and thin limestones carrying a reduced fauna which is much like that of divisions 9-10 of the Cowan Creek section (p. 68), at the top of the Whitewater. Two miles below Lawshe a small tributary comes into Brush Creek from the east, directly across the valley from the Tater Ridge School. In the thin zone between the red shales and the Belfast the following fauna was obtained.

Echinodermata
- *Agelacrinites austini*
- *Lichenocrinus tuberculatus*

Bryozoa
- *Batostoma variable*
- *Berenicea primitiva*
- *Bythopora meeki*
- *Bythbpora delicatula*
- *Homotrypa flabellaris*
- *Homotrypella hospitalis*
- *Mesotrypa patella*
- *Monticulipora cleavelandi*
- *Proboscina auloporoides*
- *Rhinidictya* sp.

Brachiopoda
- *Hebertella occidentalis*
- *Platystrophia acutilirata*
- *Platystrophia moritura*
- *Rafinesquina alternata*
- *Strophomena sulcata*

Mollusca
- *Byssonychia richmondensis*
- *Ischyrodonta* sp.
- *Microceras inornatum*
- *Orthoceras* sp.
- *Pterinea demissa*

Crustacea
- *Isotelus* sp.
- *Drepanella richardsoni*

Two interpretations are possible. Either this fauna is to be correlated with divisions 9-10 of the Cowans Creek section, in which case this red shale is not the same as that in Clinton and Warren Counties, or the two shale beds are identical, and the fauna

merely another one of the recurrent faunas of the Richmond. The Lynchburg region throws no light on the question. Because of the progressive thinning down of the Elkhorn through Montgomery, Warren and Clinton Counties, it seems probable that it may have thinned out and disappeared in the Adams County region hence the first interpretation is taken.

Sections Southward.

A good Whitewater section is found on Treber Run, beginning at the Gulf School, about a mile above the mouth of the creek. A reduced basal Whitewater fauna occurs, of the same type as that at Harshaville, but south of this it fails rapidly, though still distinct on Soldiers Run, east of West Union.

Southward in Kentucky the predominant shales become increasingly sandy, quickly become devoid of fossils, and in Fleming County, and southward cannot be distinguished from the Liberty beneath. The Whitewater is extensively developed in Canada, extending from Drummond Island, Michigan, eastward across Ontario, the Queenston phase reaching 1000' in thickness 40 miles east of Three Rivers, almost midway between Montreal and Quebec.[22]

To summarize the Whitewater, it everywhere is distinctly separated from the Liberty by a disconformity. The distinctive Whitewater fauna appears immediately above this disconformity, though associated for a short time with a few Liberty survivors. The fauna is distinctly northern in origin. The normal marine sediments of the Whitewater in the shallow water then prevailing in southern Indiana, developed coral reefs. Similar coral reefs are developed on Drummond and Manitoulin Islands, and all these reefs are associated with strata which have the characteristics of shoal water or littoral deposits, and the Saluda of Indiana and Kentucky is but such a phase of the deeper water upper Whitewater. The Whitewater passes into the Elkhorn without evidence of more than a slight break in sedimentation.

NOTES

*1 The Amer. Geol., Vol. 32, 1903, pp. 208-9.
*2 The Amer. Geol., Vol. 32, 1903, p. 209.
*3 Ind. Dept. Geol. & Nat. Res., 32nd Ann. Rept., 1907, p. 678.
*4 Ind. Dept. Geol. & Nat. Res., 21st Ann. Rept., 1896, p. 214.
*5 The Amer. Geol., Vol. 30, 1902, p. 369.
*6 Ind. Dept. Geol. & Nat. Res., 21st Ann. Rept., 1896.
*7 Ind. Dept. Geol. & Nat. Res., 24th Ann. Rept., 1899, p. 63.
*8 Ind. Dept. Geol. & Nat. Res., 32nd Ann. Rept., 1907, p. 678.
*9 Ind. Dept. Conserv., Pub. 21, 1922, pp. 436-7.
*10 Ohio Natualist, Vol. 14, 1914, p. 235.
*11 Personal communication.
*12 Margin note, "Have these been compared with S.A. Miller's *Angellum* which is a *Cyrtodonta*?
*13 "Surface? A geologic boundary is two dimensional." Initialed B ?Butts, Charles.
*14 Margin note initialed B, "Are there Arnheim and Waynesville deposits just like the banded Saluda of Jefferson County, Kentucky & Madison, Indiana?" ?Butts, Charles.
*15 Margin notes initialed B, "Can an incursion be a divisional line?" ?Butts, Charles.
*16 Margin note initialed B, "How do you define Saluda? Does it include the 20 ft. or so of mud underneath coral reefs beneath the shaly limestone at Madison, or do you regard this as below the real Saluda and both this and the real Saluda as ?over_____ the Whitewater at Madison. Such an interpretation would seem to fit in with your discussion here." ?Butts, Charles.

*17 Margin note, "18' or 1'8"" (?) Initialed CB. ?Butts, Charles.
*18 Shideler's margin note "Check! Copied incorrectly."
*19 E.R. Cumings, Ind. Dept. Geol. & Nat. Res., Vol. 32, 1907, pp. 663, 678-9.
*20 Personal communication.
*21 Jour. Geol., Vol. XXV, No. 3, 1917, pp. 289-306.
*22 Foerste, A.F. Can. Dept. Mines, Geol. Surv., Mem. 83, 1916, p. 174.

The Richmond Group Index

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