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THE ARNHEIM FORMATION WITHIN THE AREAS TRaversED BY THE CINCINNATI GEANTICLINE.

By AUG. F. FOERSTE.

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1. Subdivisions of the Arnheim.

Along the eastern line of outcrop of the Ordovician formations in Kentucky, and in the immediately adjacent parts of Ohio, the lower part of the Arnheim member of the Richmond is comparatively unfossiliferous, while the upper part is abundantly supplied with fossils. The transition is sufficiently abrupt to be traced readily in the field. In fact, the line of separation between the lower, comparatively unfossiliferous division and the upper richly fossiliferous part of the Arnheim may be traced more readily, with greater exactness, and for a greater distance than any other horizon in the Richmond along its eastern line of outcrop. For this reason, the line of separation between the upper and lower Arnheim is more definitely known than any other horizon in the Richmond of eastern Kentucky, and it has been found convenient

to give special designations to these divisions; the upper Arnheim being called the *Oregonia* division, and the lower Arnheim, the *Sunset* division.

The ease with which the two divisions of the Arnheim may be traced is due largely to the fact that the *Oregonia* division includes a characteristic fauna which may be identified readily even by a beginner in the study of fossils. This fauna includes *Dinorthis carleyi*, *Rhynchotrema dentata* var., *Leptaena richmondensis* var., and *Platystrophia ponderosa*.

In Ohio and Indiana *Dinorthis carleyi* recurs in a slightly different form at the base of the Blanchester division of the Waynesville member; *Rhynchotrema dentata* is found in the Blanchester division of the Waynesville member and near the upper part of the Whitewater member; and *Leptaena richmondensis* ranges from the Clarksville division of the Waynesville to the top of the Whitewater. But none of these fossils is found associated with *Platystrophia ponderosa* anywhere except in the lower part of the *Oregonia* division of the Arnheim. It is this association of fossils which gives them such great value as horizon markers. Moreover, if attention be confined to Kentucky, then *Dinorthis carleyi* and *Rhynchotrema dentata* here occur only in the *Oregonia* division, and within this limited territory they are strictly characteristic of the upper Arnheim.

TABLE OF SUBDIVISIONS OF CINCINNATIAN STRATA.

Richmond	Laughery	{ Elkhorn Whitewater Saluda
		{ Liberty Waynesville Blanchester Clarksville Fort Ancient
		{ Arnheim Oregonia Sunset
Maysville	McMillan	{ Mount Auburn Corryville Bellevue
	Fairview	{ Fairmount Mount Hope
Eden	Eden	{ McMicken Southgate Economy Fulton
Catheys	Catheys	{ Nicholas Greendale

2. Eastern Kentucky, from Maysville to Stanford.

Platystrophia ponderosa ranges from the middle Fairmount to the base of the Richmond. Alone, it does not designate any special horizon within this large vertical range, unless advantage be taken of some of the slight variations in form which may be recognized at certain horizons. However, associated with any of the other fossils mentioned above, it at once designates the Oregonia division of the Arnheim.

At weathered exposures, the upper or Oregonia division usually is represented by a limestone rubble. This term is used to designate a mass of small, irregular limestone fragments. The limestones from which the fragments are derived are thin, their upper and lower surfaces frequently are irregular, they are more or less penetrated by argillaceous material, and they break readily, especially along the surfaces of the included fossils. Some layers consist chiefly of entire shells and large fragments of fossils embedded in a matrix of clay which is somewhat more indurated than the clays immediately above and below. This induration is due to a greater lime content, probably owing to the imbedded fossils which may have given up part of their lime to the infiltrating waters. On weathering, these layers are reduced to a mass of fossils, partly free, but largely attached to one another more or less irregularly at their surfaces of contact. These masses of free fossils, of fossils partly cemented together by lime or indurated clay, and of irregular fragments of limestone are very characteristic of the upper or Oregonia division of the Arnheim.

The lower or Sunset division of the Arnheim presents a very different lithological appearance, but this appearance varies along the line of exposure.

At the deep railroad cut three miles southeast of Maysville, in Kentucky, the Sunset division, 16 feet thick, consists chiefly of comparatively unfossiliferous argillaceous limestone layers interbedded with clay. The limestone layers usually are several inches thick; they are of rather even texture, and their upper and lower surfaces are not conspicuously irregular. They, therefore, do not wear into a rubble, as in the case of the upper division of the Arnheim.

Northward, in Ohio, the quantity of clay interbedded with the limestones of the lower division of the Arnheim increases, fossils become fairly numerous, some of the limestone layers are distinctly less argillaceous, and the strata forming the upper and lower divisions of the Arnheim are less readily distinguishable, except by means of their fossil content, the species of *Platystrophia*, *Leptaena*, *Rhynchotrema*, and *Dinorthis*, mentioned above, occurring at the base or in the lower part of the upper or Oregonia division of the Arnheim.

South of Maysville, however, the lithologic differences between the upper and lower Arnheim become even more striking.

About a third of a mile southwest of Sunset, and two miles southwest of Hillsboro, in Fleming county, Kentucky, the Sunset division, 13 feet thick, consists of a rather uniform section of dense, argillaceous, dark blue limestone, nearly unfossiliferous, but containing a few specimens of *Platystrophia ponderosa* about three feet below the top. The overlying Oregonia division contains considerable clay, interbedded with fossiliferous limestone which has weathered into a limestone rubble.

East of Wyoming, four miles south of Sunset, the lower Arnheim, 15 feet thick, presents the same lithological appearance as at Sunset. Occasional specimens of *Platystrophia ponderosa* occur at different elevations. A variety of *Leptaena richmondensis* and one of *Rhynchotrema dentata* are found at the base of the Oregonia division.

The dark blue argillaceous limestone phase of the lower or Sunset division of the Arnheim bed may be traced as far south as Howards Mill, five miles east of Mount Sterling, Kentucky. East of the mill, it is 18 feet thick and contains occasional specimens of *Platystrophia ponderosa* near the base. The overlying Oregonia division consists of rubble limestone with numerous bryozoans.

South of Howards Mill, the lower division of the Arnheim becomes more shaly and weathers into a more sandy rock. *Platystrophia ponderosa* disappears, southward, from the lower division but becomes more abundant in the upper division. Half a mile southwest of Howards Mill, the lower division, 14 feet thick, consists of rather unfossiliferous, brown, shaly, sandy rock, weathering to a sandy clay. In the overlying Oregonia division, *Rhynchotrema dentata* is rather rare and *Heterospongia subramosa* occurs. *Platystrophia ponderosa* is abundant.

At the mouth of the Red river, at Merritts Ferry, *Platystrophia ponderosa* is abundant in the lower 8 feet of the Oregonia division. *Leptaena richmondensis* is found at the base, and *Rhynchotrema dentata* occurs one foot above the base of this division. The top of the lower division is formed by a very fine grained, bluish limestone, containing small gasteropods, chiefly *Lophospira*. Traces of this limestone are found as far northward as Indian Fields, eight miles northeast of Merritts Ferry.

The same limestone, blue, fine grained, and containing gasteropods, occurs one mile east of College Hill, four miles south of Merritts Ferry. Here the upper layer of limestone is one foot thick, the lower layer is a foot and a half thick, and the underlying shaly part of the lower Arnheim has a thickness of 11 feet. In the Oregonia division, *Platystrophia ponderosa* is confined to a section about two feet thick, two feet above the base of the division.

At Cobb Ferry, 6 miles south of the mouth of the Red river, only the upper third of the shaly part of the lower Arnheim is exposed. The fine grained, blue limestones, with gasteropods, at the top of this division forms a section about 4 feet thick. In descending order this section consists of one foot of limestone, two feet of sandy shale with several thin limestone layers, and one foot of limestone, underlaid by the upper third of the characteristic shaly section. The Oregonia division here appears practically unfossiliferous.

East of the reservoir, two and a half miles east of Richmond, Kentucky, the shale bed forming the major portion of the lower or Sunset division of the Arnheim, is 11 feet thick. It is overlaid by very fine grained blue limestone, one foot thick; thin layers, poorly exposed, having a total thickness of two feet; and hard dense limestone, two feet thick, probably forming the top of the lower Arnheim division. The basal part of the Oregonia division consists of very dark shaly rock, one foot thick, This is overlaid by hard blue limestone, 4 feet thick, containing fossils; spalling clay rock, two feet thick; and light colored clay, bluish or greenish in tint, assumed to form the base of the Waynesville or the top of the Arnheim section. According to this interpretation, the thickness of the Oregonia division of the Arnheim here is about 7 feet.

The light colored clay, which occurs at the top of the Arnheim section east of Richmond, is seen also east of College Hill, where the thickness of the Oregonia division is estimated at 11 feet. At Merritts Ferry, there is a layer of light blue clay sixteen and a half feet above the base of the Oregonia division. At Ophelia, four miles north of Richmond, the light colored clay is 11 feet above the base of the Oregonia division. These data suggest a local thinning of the Oregonia division southward as far as Richmond, accompanied by a diminution of its fossils content.

North of Ophelia, only the upper part of the lower Arnheim division is well exposed. The lower part of the exposure, 5 feet thick, consists of rather shaly limestone. The immediately overlying part of the section, 4 feet thick, consisting of fine grained limestone more or less interbedded with clay shale, is regarded as forming the top of the lower Arnheim. Two of the component limestone layers contain small gasteropods. The lower part of the Oregonia division, six and a half feet thick, consists of rubble limestone, containing *Platystrophia ponderosa*, *Leptaena richmondensis*, and *Rhynchotrema dentata*. This more fossiliferous part of the section is overlaid by 4 feet of argillaceous strata containing *Stromatocerium* in the lower half.

Stromatocerium occurs in the upper half of the Oregonia division also at Merritts Ferry, at the mouth of the Red river. Here it is found 9 feet above the base of this division, above the richly fossiliferous horizon, and 7 feet below the top of the Arnheim.

Stromatocerium occurs also four and a half miles south of Paint Lick, or 15 miles southwest of Richmond. Here it occurs about 8 feet above the base of the Oregonia division. The richly fossiliferous part, containing *Platystrophia ponderosa* and *Leptaena richmondensis*, forms the lower five and a half feet of this division. The top of the lower Arnheim consists of fossiliferous dove colored limestone, 5 feet thick, representing the fine grained limestone layers containing gasteropods, as seen at Cobb Ferry, College Hill, and at the mouth of Red river. Below the dove colored limestone, the characteristic shale bed of the lower Arnheim, 13 feet thick, is found.

The unfossiliferous shaly layers, characteristic of the lower or Sunset division of the Arnheim, may be traced with confidence as far west as Stanford. At three localities along the southwestern border of Garrard county, the thickness of the shaly layers varies from 16 to 17 feet, and that of the overlying dove colored limestones, at the top of the lower Arnheim, from four to five and a half feet. These localities are: half a mile east of the northern end of Preachersville; three miles southeast of Lancaster, a few hundred yards west of the pike, along Gilbert creek; and two and a half miles southwest of Lancaster, west of the pike to Stanford. Farther westward, apparently, the shaly part of the lower Arnheim thins rapidly. Two miles northeast of Stanford, and also two and three-quarter miles north of Stanford, along the road to Lancaster, the thickness of the shaly section is reduced to 7 feet, the overlying dove-colored limestone, at the top of the lower Arnheim, measuring three and five feet respectively.

The territory between Stanford and the mouth of Red river may be regarded as representing a distinct phase of the Arnheim sedimentation. Within this territory the lower Arnheim is characterized by an unfossiliferous shaly rock overlaid by a thinner section of dove colored limestones. The basal part of the upper Arnheim division contains *Leptaena richmondensis* and *Rhynchotrema dentata*, the latter at a slightly higher elevation whenever a difference in elevation is noted. The overlying part of the upper Arnheim section usually is richly fossiliferous, and contains among other fossils rather numerous specimens of *Platystrophia ponderosa*. At the top of the Arnheim section there is a layer of light colored clay, one or two feet thick, frequently containing numerous specimens of bryozoans. This clay layer has been assumed to form the base of the Waynesville bed, but it may be necessary to revise this classification when the fauna is better known. It is probable that most of these features may be detected as far north as Howards Mill, in the eastern part of Montgomery county.

The territory from Montgomery county to Mason county, already described, includes another phase of Arnheim sedimentation. Here the lower Arnheim consists of a rather uniform

argillaceous limestone section containing few fossils, although occasional specimens of *Platystrophia ponderosa* are found. The shaly layers and the dove colored limestone are absent. *Platystrophia ponderosa* is not abundant in the upper Arnheim at any horizon, but specimens occur in moderate quantities at the base of this upper division. The exact horizon of the various fossils has not been worked out in all of this territory, but at Maysville, and northward, the *Platystrophia ponderosa* horizon is below, not above, the horizons containing *Leptaena richmondensis* and *Rhynchotrema dentata*.

3. Central Kentucky, from Stanford to Lebanon.

The most western locality in Lincoln county at which *Leptaena richmondensis* at present is known from the Arnheim is found by going from the center of Stanford three-quarters of a mile southward and then the same distance southwestward. The nearest point at which *Rhynchotrema dentata* is known, is four miles northeast of Stanford, three-quarters of a mile directly south of Gilbert Creek station. West of these localities there is a gap of 14 miles within which no specimens of *Leptaena* or *Rhynchotrema* are known in the Arnheim. Within this gap it has been found difficult to assign definite limits between the upper and lower divisions of the Arnheim, although a few data are known which may prove of assistance.

At the locality a mile and a quarter southwest of Stanford, already mentioned, it is possible to identify the light colored clay with bryozoans, at the top of the Arnheim; the richly fossiliferous zone containing *Platystrophia ponderosa* and forming the lower part of the upper or Oregonia division of the Arnheim; and the *Leptaena richmondensis* horizon at the base of this division. At the top of the lower or Sunset division of the Arnheim, dove colored limestones occur, and these contain a globular bryozoan, which has been called *Prasopora* in the field.

This globular bryozoan occurs three and a half miles southwest of Stanford, a mile south of the Turnersville pike, east of the former site of a creamery at the home of Katie Ador. Here the globular bryozoan is fairly common in massive argillaceous rock, 4 feet thick. The layers with *Hebertella*, and a species of *Platystrophia* near *Pl. clarksvillensis*, are regarded as equivalent to the light colored clay layer at the top of the Arnheim. It was not possible to assign a definite limit to the base of the Arnheim.

The same globular bryozoan occurs also on the hill northwest of McKinney; in the railroad cut south of Moreland; and north of Knob Lick branch, a mile south of Shelby City station. The significance of this globular bryozoan horizon can be best understood after an examination of some of the sections still farther west, at which *Leptaena* and *Rhynchotrema* again occur at the Arnheim horizon.

One of the most instructive sections in this connection is that exposed along the lower part of Walloway creek, opposite the home of J. W. Isaacs, in Marion county. The locality may be reached by going one mile west of Rileys station and then following a road southward almost two miles. The section is described in descending order.

Argillaceous nodules and globular bryozoan	1 ft. 10 in.
Interval with various fossils.	3 ft. 6 in.
Richly fossiliferous horizon with <i>Platystrophia ponderosa</i>	6 ft. 6 in.
<i>Leptaena richmondensis</i> at various levels, but rare except at base.	5 ft. 6 in.
Argillaceous limestone, fossils few	3 ft. 6 in.
Large branching bryozoans resembling <i>Batostoma</i>	1 ft.
Same large bryozoans and the globular bryozoans resembling <i>Prasopora</i>	6 in.
Argillaceous limestone with the same large branching bryozoans	1 ft.
Argillaceous rock, fossils few.	3 ft.
Dove colored limestone with <i>Platystrophia ponderosa</i>	5 ft.
Opposite home of J. F. Crews, remainder of section down stream not visited.	

In this section, the *Leptaena* horizon is regarded as the base of the upper or Oregonian division of the Arnheim. Globular bryozoans occur at two horizons; at the top of the Arnheim section, associated with argillaceous nodules; and a short distance below the *Leptaena* horizon in strata which may belong to the lower division of the Arnheim but whose exact stratigraphical equivalent can be determined only after further study. It is possible, for instance, that the lower Arnheim practically thins out west of Stanford. The two horizons for the *Prasopora* usually may be distinguished readily. At the upper horizon, argillaceous nodules frequently are present, and both the globular bryozoans and the nodules occur in a whitish or light colored clay which is regarded as the stratigraphical equivalent of the light colored clay at the base of the Waynesville section northeast of Stanford as far as the mouth of the Red river. This horizon is always above the highest layers containing *Platystrophia ponderosa*. The lower horizon with the globular bryozoan occurs at the top of a section consisting of dove colored limestones and usually is overlaid by a small section of strata containing *Platystrophia ponderosa*. Near the base of this upper *Platystrophia ponderosa* horizon, *Leptaena richmondensis* and *Rhynchotrema dentata* occur at numerous localities, but where the latter species are found, the globular bryozoan is not needed as a horizon marker.

The globular bryozoan has a fair distribution at both the upper and the lower horizon. At the upper horizon it occurs from the vicinity of Lebanon as far east as Scrubgrass creek southwest of Mitchellsburg in Boyle county, and a mile east of Harveyton, in Casey county. Southward it is known as far as Rush Branch, in the southeastern corner of Marion county. At the lower horizon, it is known at numerous localities southwest of

Rileys, in Marion county, and thence southward to Rush Branch and eastward to Gravel Switch in Marion county, and Ellisburg, in Casey county. At several localities, among these the one about a mile east of Harveyton, in Casey county, the globular bryozoan occurs apparently immediately above the horizon containing *Leptaena richmondensis* and *Rhynchotrema dentata*.

At most of the localities in Marion, Boyle, and Casey counties, at which *Leptaena richmondensis* and *Rhynchotrema dentata* occur, the latter are found about 16 to 18 feet below the top of the upper horizon at which the globular bryozoans, associated with the argillaceous nodules occur. Below the *Leptaena* horizon, within a moderate distance, dove colored limestones are found. Near Lebanon, these dove colored limestones occur sufficiently far below the *Leptaena* horizon to suggest their equivalence to strata elsewhere assigned to the upper Corryville. In the area between Hankla, in Boyle county, and the locality southwest of Stanford, within which *Leptaena richmondensis* and *Rhynchotrema dentata* are unknown, these dove colored limetstones appear to lie nearer the lower *Prasopora* or globular bryozoan horizon, suggesting a thinning of the lower Arnheim and the absence of the Mount Auburn along this axial region of the Cincinnati geanticline.

4. Western Kentucky, from Nelson to Trimble Counties.

Between Lebanon and Cox Creek, seven miles north of Bardstown, a total distance of 25 miles, the Arnheim horizon has not been studied. North of Cox Creek, on the pike to Mount Washington and Louisville, *Leptaena* is associated with *Platystrophia ponderosa*. Seven miles farther northward, in the southwestern corner of Spencer county, between High Grove and Smithville *Leptaena richmondensis* and *Rhynchotrema dentata* occur in the Arnheim member. The exposures here are so evidently related lithologically to those near Mount Washington, in Bullitt county, about five miles farther, toward the northwest, that they will be discussed in the same relation.

Southwest of Mount Washington, along the pike to Smithville and Bardstown, the following section is exposed:

Argillaceous limestone with <i>Platystrophia ponderosa</i> and <i>Constellaria polystomella</i>	2 ft. 8 in.
Hard fossiliferous limestone forming a small fall near the home of F. C. Porter, where a fence crosses the creek.....	2 ft. 6 in.
Richly fossiliferous argillaceous rock with <i>Platystrophia ponderosa</i> a foot and a half from the top and with <i>Leptaena richmondensis</i> near the base.....	5 ft. 4 in.
Argillaceous rock and thin limestone, richly fossiliferous, with <i>Leptaena richmondensis</i> at various intervals. <i>Platystrophia cypha-conradi</i> occurs rather abundantly. <i>Rhynchotrema dentata</i> is present at the base, on the eastern side of the creek, where a wagon road crosses the creek near the level, 485 feet above sea.....	14 ft.

- Interval with *Leptaena richmondensis* rather common in the upper part, the lowest specimens occurring near the home of J. D. Stansbury.....10 ft.
- Strongly cross bedded, rather coarse grained limestone layers, forming crescentic sweeps of strongly inclined limsetone laminae, striking in a general way North 40° West. The concave sides of these crescentic curves face the southwest. The length of the curves averages about 20 feet. The total thickness of this crossbedded section is not known; it can not be less than 6 feet and may equal.....12 ft.
- The base of the strongly cross-bedded section is directly east of the most northern farm house seen on the western side of the creek.

The most striking features of this section, southwest of Mount Washington, are: The presence of *Leptaena richmondensis* throughout a vertical range of 24 feet, with *Rhynchotrema dentata* near the middle of this range. The presence of *Platystrophia ponderosa* for a distance of 10 feet above the *Leptaena* horizon. This strongly cross bedded limestone is regarded as equivalent to the lower Arnheim elsewhere. It suggests the presence of shallow waters with strong currents and in this respect is in rather strong contrast with the exposures so far described. Possibly the thickness of the strata containing *Leptaena*, and the thickness of the underlying cross bedded limestone section have been greatly exaggerated, in attempting to estimate their thickness along the creek.

About two and a half miles southeast of Mount Washington, *Leptaena richmondensis* has a vertical range of 14 feet. *Platystrophia cypha-contradi* is common. *Dinorthis carleyi* occurs at the base. *Platystrophia ponderosa* occupies a section about 4 feet thick, at a distance 10 feet above the *Leptaena* horizon. Cross bedded limestones occur at the base of the Arnheim section, but some of the layers near the top also are coarse grained.

The greatest thickness of coarsed grained, cross bedded limestone at the base of the Arnheim section is seen about a mile northwest of High Grove, in the southwestern corner of Spencer county. Here it is 12 feet thick, and is immediately overlaid by strata containing *Leptaena richmondensis* and *Rhynchotrema dentata*. The vertical range of *Leptaena* has not been established here.

About a mile southeast of Smithville, along the pike to Bardstown, coarse grained limestone, 5 feet thick, occurs below layers containing *Leptaena richmondensis* and *Dinorthis carleyi*. Loose specimens of *Rhynchotrema dentata* also are found. The exact succession has not been established beyond doubt.

About a mile west of Smithville, on the north side of Salt river, the coarse grained limestone in the Arnheim section is about three and a half feet thick. *Platystrophia ponderosa* occurs at a higher level.

Near the home of Asa Lutes, southwest of the Grinwell ford, *Leptaena* is present within two feet above a cross bedded limestone containing *Platystrophia ponderosa*.

In this area including the eastern part of Bullitt county, the southeastern part of Jefferson county, and the adjacent parts of Spencer county, the Arnheim is more variable from exposure to exposure than in any other known area of equal size. This probably is due to shallow water conditions and current action.

About a mile west of Fisherville, *Dinorthis carleyi* is overlaid by strata containing *Leptaena richmondensis* and *Rhynchotrema dentata*, and the latter by layers containing *Platystrophia ponderosa*.

This is the most northern locality at which *Platystrophia ponderosa* is known to occur above the *Leptaena* horizon, on the western side of the Cincinnati geanticline. North of Fisherville, *Platystrophia ponderosa* is known only from below the *Leptaena* horizon. A similar succession is noted on tracing the Arnheim strata on the eastern side of the Cincinnati geanticline northward. As far as the mouth of the Red river and Howards Mill, *Platystrophia ponderosa* is found above the *Leptaena* horizon as well as in the underlying Maysville beds, but toward the Ohio river and northward, this species occurs only below the *Leptaena* horizon.

About a mile northeast of Pendleton, in Henry county, *Dinorthis carleyi* occurs immediately above a section, two feet thick, in which *Leptaena richmondensis* is common, but the latter species occurs also 6 feet farther up.

At Scott's Hill, in the eastern part of Trimble county, four miles east of Bedford, *Dinorthis carleyi* and *Leptaena richmondensis* occur in the Arnheim, and they occur also at Milton, on the Ohio river, with *Dinorthis carleyi* about two feet above the *Leptaena richmondensis* horizon.

5. Indiana.

Along the railroad in the northwestern part of Madison, Indiana, *Dinorthis carleyi* is rather common in a section about a foot and a half thick. *Leptaena richmondensis* occurs about four feet lower, and the horizon for *Platystrophia ponderosa* is seven and a half feet farther down.

Platystrophia ponderosa is not known in the Arnheim of Indiana anywhere north of Madison. *Leptaena richmondensis* is associated with *Dinorthis carleyi* about a mile southeast of Sparta, or eight miles west of Lawrenceburg; five miles east of Brookville, on Big Cedar creek; and a mile north of Brownsville or five miles northwest of Liberty. It is a comparatively rare fossil in Franklin and Union counties, however, and it has not been found at any locality between Franklin county and the Ohio river except at Madison. Even *Dinorthis carleyi* is comparatively rare in the area south of

Franklin county, although this is the only one of the fossils characteristic of the basal part of the upper or Oregonia division of the Arnheim which has a fairly general geographic distribution in the area designated. In most of this territory, the Arnheim consists of argillaceous limestone, and indurated clay layers interbedded with much larger quantities of soft clay. The lower Arnheim does not differ lithologically from the upper part.

The chief characteristic of the Arnheim in Franklin and Union counties, in Indiana, is the presence of a variety of *Dalmanella jugosa* in rather large numbers. Northwest of the home of William Bauman, two miles southwest of Brookville, *Dalmanella* has a considerable vertical range above the *Dinorthis carleyi* horizon. At New Trenton, Indiana, *Dalmanella* has a considerable vertical range below the *Dinorthis carleyi* layer; in fact, it occurs even as low as the Mount Auburn. North of Brookville, as far as the northern boundary of Franklin county, *Dalmanella* ranges from several feet above the *Dinorthis carleyi* horizon to at least 10 feet below that level.

6. Ohio.

Dalmanella has a considerable vertical range in the Arnheim also in the western half of Hamilton and Butler counties, in Ohio. Farther eastward, as far as Adams county, on the Ohio river, *Dalmanella* is restricted, in the Arnheim, to a vertical range of only a few inches, at or immediately above the *Platystrophia ponderosa* horizon, and distinctly beneath the *Leptaena richmondensis* and *Dinorthis carleyi* horizons. Wherever, at these more eastern localities, *Dalmanella* has a considerable vertical range, it is known to characterize the Waynesville member. The result is that, farther eastward, *Dalmanella* may be used to identify readily the Waynesville member, especially the lower part, where other conspicuous characteristic fossils are not common. While in the western part of Butler and Hamilton counties, and in Franklin county, this species may prove misleading if only a superficial study be given to a line of outcrops.

A most peculiar section, differing in some respects from any other known, occurs about a mile north of Collinsville, or eight miles northwest of Hamilton, Ohio. The top of the Arnheim is not exposed.

Nodular argillaceous limestone near the top of the Arnheim...	2 ft.
Interval with <i>Byssonychia</i> and <i>Rafnesquina</i> common.....	11 ft. 6 in.
Clay with <i>Dalmanella</i> and with a single loose specimen of <i>Dinorthis carleyi</i> which may have come from this horizon..	3 ft. 6 in.
Clay and limestone. Topmost layer wave-marked.....	7 ft. 4 in.
<i>Dalmanella</i> abundant in clay and thin limestone.....	6 ft. 8 in.
Clay interbedded with limestone.....	6 ft. 9 in.
Argillaceous rubble limestone.....	2 ft. 9 in.
Highest <i>Leptaena richmondensis</i> horizon.	
Interval with <i>Platystrophia ponderosa</i> at various levels.....	1 ft. 9 in.
<i>Leptaena richmondensis</i> .	
Interval.....	1 ft. 8 in.
<i>Platystrophia ponderosa</i> just above creek level.	

Lithologically, the rock from the creek level as far up as the argillaceous rubble limestone above the highest *Leptaena* horizon resembles the rock forming the Mount Auburn member in most of Ohio and adjacent Kentucky. Moreover, there is a considerable interval between this part of the section and the *Dinorthis carleyi* horizon. However, *Leptaena richmondensis* is unknown in the Mount Auburn member from any of the numerous exposures where this horizon has been definitely identified. Hence, the Collinsville section may be merely an Arnheim exposure in which the interval between the *Platystrophia ponderosa* horizon and the *Dinorthis carleyi* horizon is represented by an unusual thickness of strata.

As a rule, *Leptaena richmondensis* occurs in the Arnheim of Ohio only a short distance below the *Dinorthis carleyi* horizon. The interval rarely exceeds five feet, and frequently is reduced to only a few inches.

At the Blacksmith hollow, a short distance north of the railroad station, at Oregonia, Ohio, six miles northeast of Lebanon, the following section is seen:

Massive nodular argillaceous limestone.....	5 ft. 6 in.
One specimen of <i>Strophomena concordensis</i> .	
Rubble clay rock with some argillaceous limestone.....	15 ft.
<i>Dinorthis carleyi</i> common.....	6 in.
Rubble clay rock with <i>Dinorthis</i> at various intervals.....	5 ft.
Rubble clay rock with <i>Rafinesquina</i>	1 ft.
<i>Dinorthis carleyi</i> common and one specimen of <i>Leptaena richmondensis</i> in thin limestone.	
Interval.....	9 in.
<i>Dinorthis carleyi</i> , one specimen.	
<i>Leptaena richmondensis</i> common.....	1 ft. 6 in.
Rubble clay.....	1 ft. 6 in.
<i>Platystrophia ponderosa</i> rare.	
Rubble clay rock, with <i>Cyclonema humerosum</i> , <i>Rafinesquina loxorhysis</i> , and <i>Zygospira modesta</i>	12 ft.
Interval not exposed.....	17 ft.
Estimated level of base of Arnheim. No exposures here.	

A similar succession of strata is found near the home of G. W. Robertson, at the mouth of Lick run, opposite the mouth of Caesar creek, less than three miles north of Oregonia:

Nodular limestone, forming small falls.	
Interval.....	15 ft. 6 in.
<i>Dinorthis carleyi</i> at various intervals.....	6 ft.
<i>Leptaena richmondensis</i> common.....	6 in.
Interval.....	3 ft. 6 in.
Strongly wave marked limestone layer, trend of ridges about north and south.	
Interval.....	3 ft.
<i>Platystrophia ponderosa</i> rather common.....	4 in.

A similar succession of strata is seen three miles northeast of Goshen, at the middle part of the northern edge of Clermont

county. Here *Dinorthis carleyi*, *Leptaena richmondensis*, *Dalmanella jugosa*, and *Platystrophia ponderosa* are found in descending order.

The typical exposure of the Arnheim bed is located on Straight creek, about a mile south of Arnheim, and five miles northeast of Georgetown, in Brown county:

<i>Strophomena concordensis</i> near top of blue, nodular clay rock.....	6 ft.
Limestone interbedded with much clay.....	12 ft.
Strongly wave-marked limestone.	
Limestone interbedded with clay.....	7 ft.
<i>Dinorthis carleyi</i> rare.	
Thin limestones and clay, with <i>Leptaena richmondensis</i> and <i>Rhynchotrema dentata</i>	6 in.
Limestone and clay with <i>Leptaena richmondensis</i>	9 in.
Clay with layers of nodules.....	2 ft. 4 in.
Thin limestone with <i>Leptaena richmondensis</i> abundant.....	2 in.
Limestone and clay.....	5 ft.
<i>Platystrophia ponderosa</i> abundant in limestone.....	8 in.
<i>Dalmanella jugosa</i> var., abundant, largest specimens 22 millimeters wide, associated with <i>Platystrophia ponderosa</i> , rather few.....	9 in.
Poorly exposed.....	7 ft.
Coarse grained, cross bedded limestone, with wave-marked layer five inches above the base.....	5 ft. 6 in.
Limestone and clay interbedded.....	7 ft. 6 in.
<i>Rafinesquina</i> very abundant.....	4 ft. 6 in.
Limestone with bryozoans and other fossils.....	1 ft. 6 in.
Mount Auburn top, consisting of clayey limestone with <i>Platystrophia ponderosa</i> rather abundant.....	3 ft. 9 in.
Wave-marked limestone layer.	

At Eddies run, one mile east of the line between Brown and Adams counties, and about six miles west of West Union, the following section is seen:

<i>Strophomena concordensis</i> common in nodular clay rock.....	5 ft.
Interval.....	18 ft. 6 in.
<i>Leptaena richmondensis</i> rare.....	4 in.
Interval.....	5 ft.
<i>Leptaena richmondensis</i> abundant.....	1 ft.
Interval.....	10 ft.
<i>Platystrophia ponderosa</i> and <i>Dalmanella jugosa</i> var. associated in the same layers.....	1 ft.

Half a mile east of Manchester, the Beasley fork pike to West Union crosses Island creek, and a mile northward the Mount Auburn bed is exposed. A quarter of a mile farther northward, northwest of the home of A. H. Foster, *Leptaena richmondensis* is exposed five feet above layers containing *Dalmanella jugosa* var. and *Platystrophia ponderosa*. *Strophomena concordensis* occurs farther up stream.

About three miles south of Maysville, in Kentucky, the deep cut at the highest point reached by the railroad exposes the following section:

<i>Strophomena concordensis</i> , associated with <i>Dalmanella jugosa</i> in bluish limestone.....	2 ft.
Argillaceous limestone.....	16 ft.
<i>Dinorthis carleyi</i> occurs somewhere in this argillaceous limestone section. Loose specimens have been found at various intervals between five and eight feet above the base of this argillaceous limestone, but, although the specimens are fairly abundant in the rock quarried out while making the cut, no specimens have been seen in place.	
<i>Leptaena richmondensis</i> abundant.....	1 ft.
<i>Rhynchotrema dentata</i> belongs somewhere near this horizon since it occurs loose on the slopes below.	
Argillaceous limestone.....	3 ft. 6 in.
Softer clay rock, weathering back.....	1 ft. 6 in.
Limestone.....	10 in.
<i>Platystrophia ponderosa</i>	2 ft. 4 in.
<i>Dalmanella jugosa</i> abundant, associated with <i>Platystrophia ponderosa</i>	6 in.
Argillaceous limestone interbedded with considerable clay, forming the Sunset division of the Arnheim.....	18 ft.
Mount Auburn member.	

The presence of *Platystrophia ponderosa* and *Dalmanella jugosa* var. at the base of the upper or Oregonia division of the Arnheim may be detected throughout the Ohio area of exposure, although these fossils are common as a rule only in the more eastern exposures and are entirely absent at many of the western localities.

At Pisgah, ten miles southeast of Hamilton, the following section is seen:

<i>Dinorthis carleyi</i> fairly common.....	4 ft.
<i>Dinorthis carleyi</i> rare, associated with <i>Leptaena richmondensis</i>	2 ft.
Interval.....	2 ft. 6 in.
<i>Platystrophia ponderosa</i> rare.....	2 ft.

At Reileys, seven miles west of Hamilton, a thin horizon containing *Dalmanella* is overlaid by *Leptaena richmondensis*, and the latter by *Dinorthis carleyi*.

Along the railroad northwest of Bridgetown, seven and a half miles northwest of the center of Cincinnati, a single specimen of *Platystrophia ponderosa* was found just beneath *Leptaena richmondensis* and *Dinorthis carleyi*.

7. Nodular Top of Arnheim in Ohio.

The so-called nodular argillaceous limestone at the top of the Arnheim section in many parts of Ohio, is in reality not nodular at all, in the ordinary acceptance of this term. The limestone is irregular bedded and breaks up into lumps, so that the term lumpy limestone is more descriptive. It forms a very characteristic part of the Arnheim sections first studied, namely those near Lebanon and Oregonia, in Warren county, Ohio. Similar exposures occur at the southern edge of Montgomery county, opposite the Franklin Chautauqua. At Oregonia the thickness of this lumpy limestone is five and a half feet. North of Lebanon, it is four and

a quarter. At the Franklin Chautauqua, it is three feet. About four miles west of Middletown, or two and a half miles south of the southeastern corner of Preble county, the thickness of the massive argillaceous limestone at the top of the Arnheim section is two feet three inches. These data suggest a thinning of the lumpy limestone section westward, and indicate why it is so difficult to identify the so-called nodular limestone at the top of the Arnheim section still farther westward.

At the locality on the Dry fork of Elk run, four miles west of Middletown, the following section is seen:

Massive argillaceous, more or less lumpy, limestone.....	2 ft. 3 in.
Interval with <i>Anomalodonta gigantea</i> , <i>Rafinesquina loxorhytis</i> , and <i>Cyclonema humerosum</i> at various intervals.....	11 ft. 6 in.
<i>Dinorthis carleyi</i>	4 ft. 6 in.

The interval between *Dinorthis carleyi* horizon and the lumpy limestone may have been considerably greater than 12 feet since it was measured along the creek which here has a very low gradient.

Two and a quarter miles northwest of Hamilton, and also a mile southwest of McGonigle, or seven miles a little north of west from the center of Hamilton, the base of the Waynesville bed consists of very coarse grained, cross bedded limestone, five feet thick at the latter locality. In this limestone, *Dalmanella jugosa* is abundant. Southward from these localities, in the western parts of Butler and Hamilton counties, it is difficult to draw an exact line between the Waynesville and Arnheim beds, although the approximate position of this line is indicated by the first appearance of limestones with *Dalmanella*, which on weathering tend to take a reddish hue. The *Dalmanella* bearing beds at the Arnheim horizon appear not to be inclined to take this tint, and are more likely to change to yellowish or brownish colors.

Strophomena concordensis appears limited to the lumpy limestone horizon at the top of the Arnheim bed, but it is not known farther west than the southeastern part of Butler county, or farther north than Lebanon and Oregonia, in Warren county. Southeastward from these localities, *Strophomena concordensis* is found at practically every exposure of the top of the Arnheim as far as Maysville and Concord, in Kentucky. As a rule, the lumpy limestone section is about five feet thick, and *Strophomena concordensis* often ranges throughout the entire section. South of Arnheim, in Brown county, the lumpy limestone is about six feet thick, and the *Strophomena* occurs chiefly near the top. The lumpy argillaceous character of the limestone continues through Adams county nearly as far as the Ohio river. Three miles south of the Ohio river, at Maysville, *Strophomena concordensis* occurs in a limestone, weathering reddish and containing numerous specimens of *Dalmanella jugosa*, difficult to distinguish lithologically from the overlying Waynesville section.

Along the creek directly east of Concord, Lewis county, Kentucky, *Strophomena concordensis* is confined to an argillaceous rock, similar to the lumpy limestone, and a foot in thickness. This exposure is unique among all those known in Ohio, Indiana, Kentucky, and Tennessee, in containing *Streptelasma canadensis* and *Opisthoptera casei* five and a half feet below the *Strophomena concordensis* horizon, and *Streptelasma canadensis* and *Columnaria alveolata* five feet above this *Strophomena* layer.

The only other locality at which *Columnaria alveolata* is known from the Arnheim is at Clifton, on the Tennessee river, in western Tennessee, where it is associated with *Dinorthis carleyi*, *Rhynchotrema dentata*, *Leptaena richmondensis*, and a variety of *Dalmanella jugosa*.

8. Arnheim includes first advent of Richmond fauna.

The presence of *Strophomena concordensis*, *Streptelasma canadensis*, and *Columnaria alveolata* at the top of the Arnheim bed, at Concord, Kentucky, suggests the advent of the Richmond fauna. In fact, the nodular or lumpy limestone, at the top of the Arnheim section as originally defined, could with propriety be removed to the Waynesville member of the Richmond. However, *Leptaena richmondensis*, *Rhynchotrema dentata*, and *Dinorthis carleyi*, near the base of the upper or Oregonia division of the Arnheim, also suggest the advent of a Richmond fauna, and although limited to only a part of the Oregonia division, the latter also may be added to the Richmond section. The Sunset division is included in the Richmond only for the reason that southward, in Kentucky, it represents a period of diastrophic movement, the nearest thing to a sandstone sedimentation found in this part of the Cincinnati section, and is regarded as inaugurating a new period of sedimentation rather than closing a former period. It is quite in keeping with this view, that northward, where no similar diastrophic movements are recorded, there should be no evidence of a faunal break sufficient to demand the separation of the lower or Sunset division of the Arnheim from the Mount Auburn member.

Before discussing this subject further, some of the more southern exposure of the Arnheim, in southern Kentucky, and in Tennessee, should be noted.

9. Adair County with nearest outcrops in Marion and Casey Counties, Kentucky.

The most southern localities, in the widespread Ordovician area including central and northern Kentucky, southwestern Ohio and southeastern Indiana, at which the characteristic fauna of the Arnheim has been found, occur along the South Fork of Rolling Fork. In the southeastern corner of Marion county,

about three-quarters of a mile southwest of Rush Branch postoffice, *Leptaena richmondensis* and *Rhynchotrema dentata* occur at the base of several feet of argillaceous limestone containing *Platystrophia ponderosa*. On the Steele Knob road from Chilton post-office to Liberty, about a mile south of South Fork of Rolling Fork, near the northwestern edge of Casey county, *Leptaena richmondensis* occurs three feet below strata containing *Platystrophia ponderosa*.

Near the northeastern edge of Adair county, about a quarter of a mile south of the road from Dunnville to Neatsville, along Damron creek, twenty miles south of the localities on the South Fork of Rolling Fork, *Leptaena richmondensis* and *Platystrophia cypha-conradi* occur in the following section:

Greenish clay shale.....	7 in.
Irregular hard clay nodules.....	1 in.
Greenish clay shale.....	5 in.
Argillaceous limestone rubble interbedded with irregular indurated fossiliferous clay masses and considerable softer clay, containing <i>Leptaena richmondensis</i> , <i>Platystrophia cypha-conradi</i> , <i>Anomalodonta gigantea</i> , <i>Byssonychia radiata</i> , <i>Hebertella occidentalis</i> and other fossils.....	3 ft. 2 in.
Spalling clay rock.....	1 ft. 2 in.
Shaly material weathering into small fragments.....	5 in.
Argillaceous limestone.....	8 in.
Argillaceous rock, splitting into irregular thin layers and breaking up into small fragments owing to vertical cracks.....	6 ft.
Interval, covered.....	4 ft. 6 in.
Damron Creek.	

Platystrophia ponderosa is exposed at a lower horizon, farther up the creek, in hard, fine grained, bluish limestone, apparently corresponding to the dove colored limestones below the Arnheim horizon in Lincoln, Garrard, and Madison counties, northward.

10. Western Tennessee.

Nearly a hundred miles southwest of Damron creek, nearly four miles north of Gallatin along the railroad toward South Tunnel, *Leptaena richmondensis* associated with *Platystrophia ponderosa* occurs at the Arnheim horizon in a section about 12 feet thick. In the lower half of this section consisting of argillaceous limestone, both species are common. In the upper part, consisting of more coarse grained limestone, only occasional specimens of *Leptaena* occur. At the very top of the section, small specimens of *Dalmanella* are found. *Platystrophia ponderosa* continues common for ten feet below the lowest strata at which *Leptaena* occurs.

Rhynchotrema dentata is common in the Arnheim eight miles northeast of Goodletsville, about ten miles west of Gallatin, in Tennessee. It occurs in the Arnheim, associated with *Dalmanella jugosa* var. and an occasional specimen of *Platystrophia ponderosa*,

also at Newsom, about 15 miles southwest of Nashville. At Clifton, on the Tennessee river, about 85 miles southwest of Nashville, *Rhynchotrema dentata* occurs associated with *Dinorthis carleyi*, *Leptaena richmondensis*, *Dalmanella jugosa* var., and *Columnaria alveolata*, at the Arnheim horizon.

The connection of these Arnheim localities in Tennessee with those in Kentucky is hidden at present by the covering of later rocks. This connection probably extended from the vicinity of Gallatin, in Tennessee, northward toward Bullitt county, in Kentucky. It is significant that the most southern exposures in Kentucky containing *Dinorthis carleyi* are in the northern part of Nelson county, on the western side of the Cincinnati geanticline, and in Mason county, on the eastern side. In the large series of exposures of the Arnheim, connecting these localities across central Kentucky, *Dinorthis carleyi* is unknown. Moreover, even *Leptaena richmondensis* and *Rhynchotrema dentata* disappear from the Arnheim along the axial part of the Cincinnati geanticline and along its eastern side long before reaching the Cumberland river in southern Kentucky.

11. Southern Kentucky along the Cumberland River.

Richmond strata, containing *Streptelasma*, *Stromatocerium*, and *Columnaria*, probably *Columnaria vacua*, are exposed along the Cumberland river, in the northern part of Wayne county, opposite the mouth of Forbush creek, and about a mile farther west, below the mouth of Little Cub creek. This horizon probably corresponds approximately to the base of the Liberty member of the Richmond, as exposed in central Kentucky. Farther down the river, the thin bedded strata, forming the Waynesville member, are exposed. Along the southern border of Russell county, at the northern end of the first bend made by the Cumberland river on reaching the county, a globular *Prasopora* and *Heterospongia subramosa* are present immediately above strata containing *Platystrophia ponderosa*. Stratigraphically, this *Prasopora* here occurs at the Arnheim horizon, but no diagnostic fossils were found. The same horizon is exposed again at Harmon creek shoals, about four miles farther down the river.

No specimens of *Prasopora* have been seen at the exposures below Creasy creek, below Indian creek, below Willis creek, or at any of the other exposures farther down the Cumberland river, in Kentucky, where strata equivalent to the Arnheim might be expected to occur.

12. Globular bryozoans in Casey and Lincoln Counties, Kentucky.

At Kidd's store, in Casey county, about eight miles northeast of Liberty, on the road to Hustonville, a globular bryozoan identified in the field as *Prasopora*, occurs at the Arnheim horizon,

above strata in which *Platystrophia ponderosa* is rare. It is important to remember that the globular bryozoan frequently referred to *Prasopora* in this discussion has not been subjected to microscopic investigation, so that its real affinities remain to be determined.

Northwest of Ellisburg, *Prasopora* occurs eleven feet below a light blue clay layer containing clay nodules. In the lower part of the intervening section, interpreted as upper Arnheim, *Platystrophia ponderosa* occurs. *Prasopora* is abundant on the hill supporting the stand-pipe northwest of McKinney, in Lincoln county; also along the railroad, a short distance south of Moreland. About a mile south of Shelby City, where the pike crosses Knob-Lick branch, *Prasopora* occurs below strata containing *Platystrophia ponderosa*. The locality at the former site of the creamery, three and a half miles southwest of Stanford has been mentioned. All of these localities belong to the territory in which *Leptaena richmondensis* and *Rhynchotrema dentata* are absent. Even *Prasopora* is not present at all of the exposures regarded as belonging to the Arnheim horizon, at least approximately. In its absence, the identification of the Arnheim becomes difficult, in the territory under discussion.

Possibly the difficulty of identifying the Arnheim in some parts of Casey and Lincoln counties may be due to a thinning out of this member of the Richmond southeastward. This might account also for the disappearance of the *Leptaena* and *Rhynchotrema* fauna at all the more southern exposures in Kentucky, with the single exception of the exposure along Damron creek, in the northeastern corner of Adair county.

13. Diastrophic movements during deposition of the Arnheim.

The Arnheim period of deposition apparently began with a slight diastrophic elevation on the southeastern side of the Arnheim sea. This gave rise to the thin bedded, unfossiliferous, argillaceous strata forming a characteristic part of the Lower or Sunset division of the Arnheim, in Kentucky, from Lincoln county northward beyond the mouth of the Red river. It produced apparently the paucity of life in the argillaceous limestones forming the Lower Arnheim farther northward, from the vicinity of Howards Mill to the Ohio river at Maysville. Still farther northward, there was a sudden extinction of the great *Platystrophia ponderosa* colonies which characterized the Mount Auburn in many parts of Ohio. In Indiana, there is no evidence of any considerable change either in the character of the sedimentation or of the enclosed fauna on passing from the Mount Auburn to the Lower Arnheim.

Possibly the lower Arnheim thins out southward also on the western side of the Cincinnati geanticline, at least locally. The

coarse grained, more or less cross bedded limestones at the base of the Arnheim section, in the southern part of Jefferson county, in Kentucky, and thence southward to the northern part of Nelson county, suggest the presence of strong, irregular currents, but do not necessarily indicate an elevation of the sea bottom. These coarse grained limestones may represent in part the lower division of the Arnheim, east of the Cincinnati geanticline.

The sudden influx of *Leptaena richmondensis*, *Rhynchotrema dentata*, and *Dinorthis carleyi* during the deposition of the lower part of the upper or Oregonia division of the Arnheim, suggests the lowering of some barrier which for long geologic periods had kept any representatives of this group of species from Cincinnati areas. The most astonishing feature of this faunal immigration is its great geographical range compared with its extremely short duration. What were the favorable conditions which in a brief time permitted this fauna to reach points as remote as southern Tennessee and southwestern Ohio? What were the unfavorable conditions which with equal suddenness caused the disappearance of this fauna? Where was the basin from which this fauna entered the Cincinnati areas?

14. Origin of Arnheim faunas.

These questions are easier asked than answered. For instance, the general geographical distribution of *Dinorthis carleyi* in southwestern Ohio, southeastern Indiana, and western Kentucky, as far south as Nelson county, suggest its origin from some northern source, until it is remembered that this species occurs also at Clifton, in southwestern Tennessee. The northern origin of *Dinorthis carleyi* is favored also by the greater abundance of this species and by its greater vertical range in southwestern Ohio compared with its occurrence in southeastern Indiana, western Kentucky, or southwestern Tennessee. Moreover, the species attains a larger size and the valves are thicker as a rule in Ohio. In most of Kentucky, and at almost all localities in western Tennessee, from which the Arnheim is known, *Dinorthis carleyi* is absent. These facts suggest that the conditions were much more favorable for the growth of this species northwards, rather than southwards. As a matter of fact, however, the Arnheim is absent also along Lake Huron and Lake Ontario, and no trace of it has been recorded from Wisconsin or Minnesota on the northwest, nor from Pennsylvania or New York on the northeast. *Dinorthis carleyi* is so closely related to *Dinorthis retrorsa* from the Bala group of Wales that it certainly must be regarded as a derivative, but by what path did it enter Cincinnati areas? Billings figured a specimen of *Dinorthis retrorsa* from the Trenton in the vicinity of Ottawa, in Canada, but this species is not mentioned by Dr. Ami, in any of his more recent studies from this locality.

The species of *Dalmanella*, which occurs so abundantly in the Arnheim of southwestern Ohio, is found also in the adjacent parts of Indiana. Southward, it is absent until the exposures at Newsom and Clifton, in western Tennessee are reached. There may have been a connection between southwestern Ohio and Tennessee by a path farther west than any now exposed. The origin of the *Dalmanella* found in the Arnheim of southwestern Ohio and the adjacent part of Indiana, however, may have been indigenous. In Franklin and Dearborn counties, in Indiana, *Dalmanella* occurs at various levels in the Arnheim, being quite abundant in the lower half. It occurs in the same area also at various levels in what is identified as the Mount Auburn. Near Brookville, it is very abundant in the Corryville, and it occurs in moderate numbers also in the more northern exposures of the Corryville in Ohio. Not all of the specimens of *Dalmanella* found in the Fairmount belong to *Dalmanella fairmountensis*. That species has a rather restricted geographical range. A derivative of *Dalmanella multisecta* is rather widely distributed at the *Strophomena planoconvexa* horizon, and it is from the Eden *Dalmanella multisecta* that the Arnheim species may have evolved. The vertical distribution of *Dalmanella* is limited to the lower part of the upper or Oregonia division of the Arnheim southeast of Butler and Hamilton counties, in Ohio, suggesting an entry into this area from the northwest, from Indiana.

Leptaena richmondensis is one of the most widely distributed species found in the Arnheim. It occurs almost over the entire area investigated, both north and south, wherever the Arnheim is known. It is a typical eastern Richmond species, and was certainly not derived from *Leptaena unicosta*, the western Richmond form. It is the latter species which has varied most from the primitive form. *Leptaena richmondensis* is least abundant in southeastern Indiana, and is entirely absent in southern Kentucky, along the Cumberland river. It is most abundant in southwestern Ohio and in central Kentucky. Probably the latter areas were once connected by Arnheim deposits which since have been eroded away, since there is a small area in western Lincoln and eastern Casey and Boyle counties, in Kentucky, from which *Leptaena* is absent. *Rhynchotrema dentata* is absent from the same area, in central Kentucky, and may have used the same hypothetical passage a moderate distance northward.

Rhynchotrema dentata is much more abundant southwards, in Kentucky, than northwards, and in Ohio and Indiana it is confined to the most southern exposures. Certainly, it would be difficult to imagine a northern origin for this species, as far as its entry into the Arnheim is concerned. Moreover, it occurs also at Goodlettsville, Newsom, and Clifton, in western Tennessee. As in the case of *Dinorthis carleyi*, and *Leptaena richmondensis*, it had

its precursors already in the Trenton. The Trenton of New York, and New Jersey, for instance, contains a species of *Rhynchotrema* which is sufficiently like the Arnheim form to have served at least as an ancestral form. But this does not furnish a hint as to the direction from which the Arnheim fauna invaded the Cincinnati areas.

Platystrophia ponderosa is another species which appears to have entered the Cincinnati areas from the south. The species may have been of indigenous origin. It certainly is known in Kentucky as early as the Fairmount, if not the upper Eden, and was very abundant during the Corryville, and locally also during the Mount Auburn. In the Mount Auburn it is found in great numbers from the eastern half of Hamilton and Butler counties, in Ohio, southeastward to Maysville, in northern Kentucky, and thence southward toward Lincoln county. It is very rare at the Mount Auburn horizon in most parts of Indiana and in the adjacent parts of western Kentucky. During the lower or Sunset division of the Arnheim it occurs apparently only in the dark blue, argillaceous limestone between the southern part of Fleming county and the eastern part of Montgomery county. It occurs here in such small numbers that it is difficult to believe that it could have spread during the upper Arnheim over by far the larger part of the Cincinnati areas from such a restricted source. During the earlier part of the upper Arnheim, before the advent of *Leptaena richmondensis*, *Rhynchotrema dentata*, and *Dinorthis carleyi*, it spread over southwestern Ohio, and along the eastern side of the Cincinnati geanticline as far south as Maysville, Kentucky.

Along the more southern exposures on the eastern side of the Cincinnati geanticline, from the eastern part of Montgomery county, in Kentucky, southward to Lincoln, and westward to Marion county, *Platystrophia ponderosa* occurs distinctly above the *Leptaena-Rhynchotrema* horizon. Between the more northern areas, in which *Platystrophia ponderosa* occurs beneath the *Leptaena richmondensis* horizon, and the more southern areas in which *Platystrophia ponderosa* occurs chiefly above the *Leptaena* horizon, there is an intermediate area, on both sides of the geanticline, in which *Platystrophia ponderosa* and *Leptaena richmondensis* occur together, in the same restricted zone, near the base of the upper or Oregonia division of the Arnheim. The anomalous association of these fossils at Collinsville, in the northern part of Butler county, has been mentioned already.

The occurrence of *Stromatocerium* in the Arnheim is limited to a relatively small area in central Kentucky, where, usually, it is quite rare excepting at a few localities. A single locality is known, in the southern part of Fleming county, where *Stroma-*

tocerium is present in the Mount Auburn bed. In southern Kentucky, along the Cumberland river, it occurred already during the upper Fairmount, often in great numbers. During the deposition of the Waynesville and later deposits of the Richmond, the species has a much wider geographical distribution.

In the table of Cincinnati strata, the term Laughery is used to include the Waynesville and Liberty members of the Richmond, the Saluda being regarded as deposited during one of the more important diastrophic movements during this period. The typical exposures occur along the Laughery creek, in Ripley county, from the vicinity of Versailles to Osgood, Indiana.

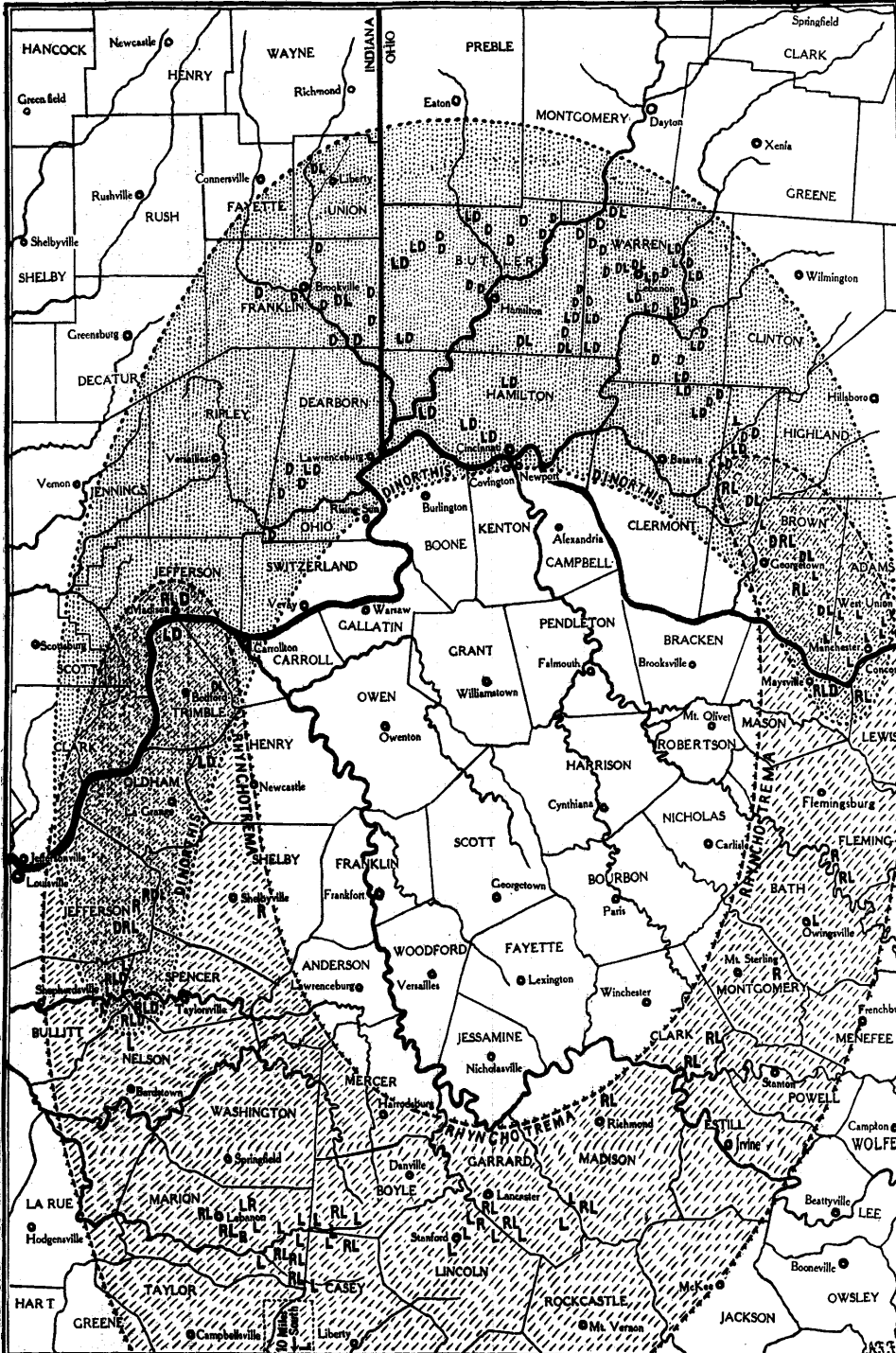
On the accompanying charts, the letters designate the localities at which the writer found the species in question. The letters have the following signification:

- D—*Dinorthis carleyi*.
- R—*Rhynchotrema dentata*—arnheimensis.
- L—*Leptaena richmondensis*—precursor.
- P—*Platystrophia ponderosa*.
- A—*Dalmanella jugosa*, var.
- S—*Stromatocerium huronense*.

Platystrophia and *Leptaena* occur also 10 miles south of the southern margin of the area covered by these charts, in Adair county, Kentucky, as indicated by the direction of the small arrow on the charts. (See plates XX, XXI.)

PLATE XXII.

- Fig. 1. *Dalmanella jugosa*. A, B, pedicel valves; C, D, brachial valves. E, F, G, interiors of brachial valves; H, interior of pedicel valve. Arnheim bed, south of Arnheim, Ohio.
- Fig. 2. *Heterospongia subramosa-knotti*. Lateral view showing osculum surrounded by radiating channels. Arnheim bed, northwest of home of Col. J. B. Wathen, about a mile west of Lebanon, Ky.
- Fig. 3. *Platystrophia cypha-conradi*. A, pedicel valve; B, C, anterior views. Arnheim bed, half a mile south of Smithville, in Bullitt County, Kentucky. These figures, in the order named, represent other views of the specimens illustrated by figures 14 A, 7 B, and 7 A, on Plate IV, in Volume XVI, of the Bulletin, Scientific Laboratories, Denison University, 1910.
- Fig. 4. *Platystrophia* with outline of *Pl. clarksvillensis*, but the prominent median fold on the brachial valve has the two median plications much more conspicuously elevated than the lateral ones on the fold, as in *Pl. cypha*, to which it is closely related. Arnheim bed, south of Arnheim, Ohio.
- Fig. 5. *Platystrophia cypha*. Anterior view of specimen represented by Figure 5, on Plate III, Bulletin, Denison University, 1910. Arnheim bed, three miles south of Maysville, Kentucky, in deep railroad cut.
- Fig. 6. *Platystrophia wallowayi*. A, brachial valve; B, C, posterior views; D, anterior view; E, lateral view with the beaks directed downward. Arnheim bed, on Walloway Creek, two miles south of Rileys, in Marion County, Kentucky. Horizon, 15 feet above the lowest strata containing *Leptaena richmondensis*. A globose form with rather strong growth striae in the majority of specimens.
- Fig. 7. *Leptaena richmondensis-precursor*. Brachial valve. Arnheim bed, one mile south of Pisgah, in the southeastern corner of Butler County, Ohio.
- Fig. 8. *Dinorthis carleyi*. A, brachial valve; B, C, pedicel valves; D, interior of pedicel valve. Arnheim bed, Oregonia, Ohio. In *Dinorthis retrorsa*, of Wales, the median part of the brachial valve is figured as more angular in its elevation, with somewhat flattened lateral slopes.
- Fig. 9. *Rhynchotrema dentata-arnheimensis*. A, pedicel valve, from Arnheim, Ohio, from same specimen as Fig. 12, Plate IV, Volume XIV, Bulletin, Denison Univ., 1909. B, lateral view, of specimen from Mount Washington, Bullitt County, Kentucky. Arnheim bed.
- Fig. 10. *Strophemona concordensis*. A, interior of brachial valve, three miles south of Maysville, Kentucky; B, interior of pedicel valve, more abruptly thickened along the anterior and lateral margin than in the great majority of specimens. Arnheim bed, on Eddies Run, in Adams County, one mile east of Clermont County, along the pike from West Union to Decatur, Ohio.
- Fig. 11. *Platystrophia ponderosa*. Pedicel valve, rather strongly water worn, with holes bored by some other animal. Arnheim bed, south of Arnheim, Ohio.



DISTRIBUTION OF *DINORTHIS CARLEYI*, *RHYNCHOTREMA DENTATA* VAR. AND *LEPTAENA RICHMONDENSIS* VAR. IN THE ARNHEIM.



TRIBUTION OF PLATYSTROPHIA PONDEROSA, DALMANELLA JUGOSA, AND STROMATOCERIUM HURONENSE IN THE ARNHEIM. STROMATOCERIUM AT BASE OF MOUNT AUBURN.=Δ.

