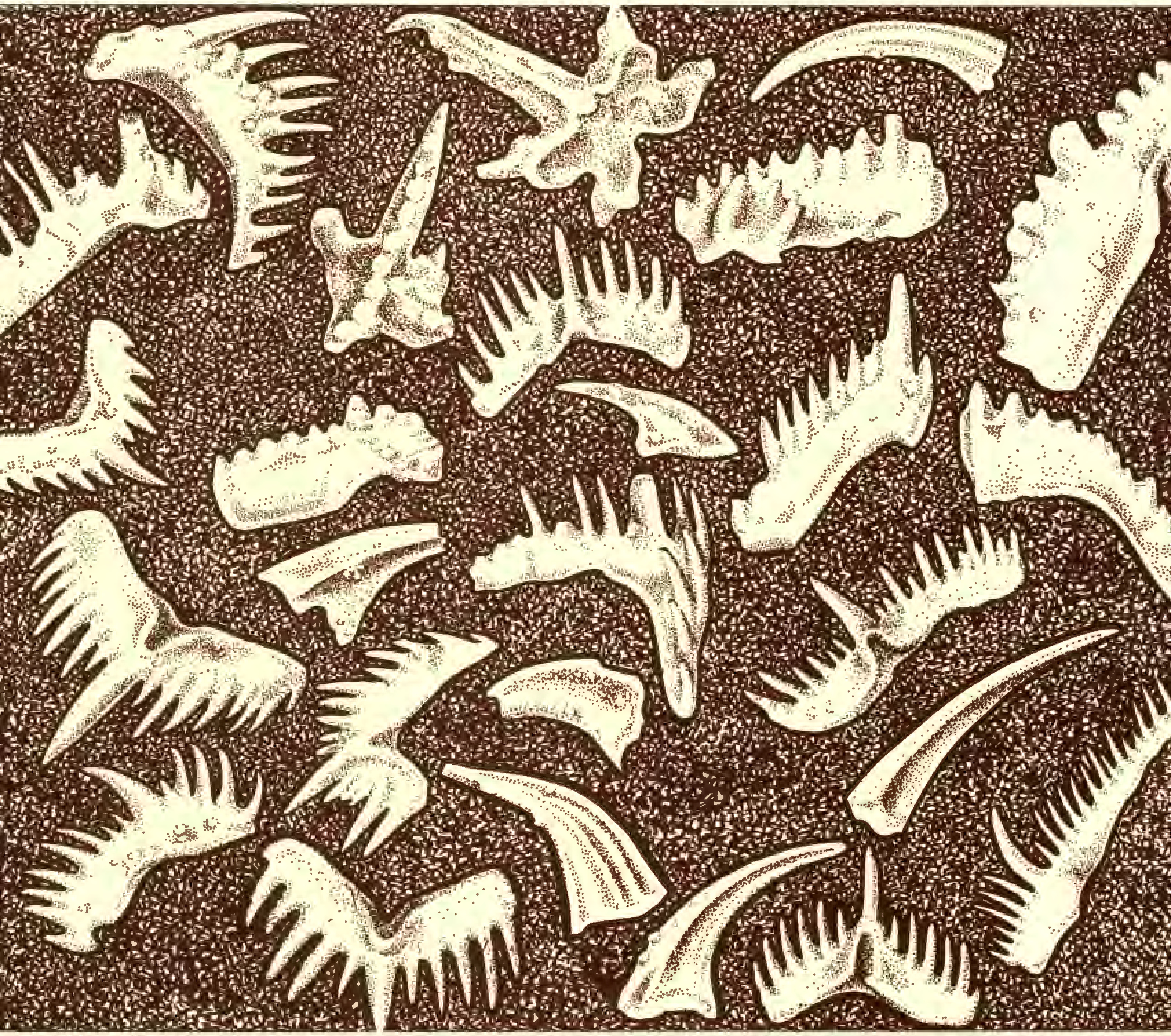
CONODONTS FROM THE LOUISVILLE LIMESTONE AND THE WABASH FORMATION (SILURIAN) IN CLARK COUNTY, INDIANA, AND JEFFERSON COUNTY, KENTUCKY

Special Report 16



State of Indiana
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By CARL B. REXROAD, ANNE V. NOLAND, *and* CHARLES A. POLLOCK

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Abstract

Ten multielement species of conodonts representing the *Kockelella variabilis* Zone are described from samples from 10 locations in the Louisville Limestone and in the lower part of the Wabash Formation in the type area of the former. The conodonts have moderately long stratigraphic ranges, but their association is compatible with a late Wenlockian-early Ludlovian age assignment for the two stratigraphic units. Genera recorded include *Kockelella, Ozarkodina, Dapsilodus, Decoriconus, Panderodus,* and *Walliserodus.* A new subspecies of *Ozarkodina confluens* is recognized but not named.

Introduction

PURPOSE AND SCOPE

The study of conodonts from the Louisville Limestone and the Wabash Formation in the type area of the Louisville is part of a broad biostratigraphic study of Silurian conodonts in Indiana. Although the main emphasis of the study now is interpretation of subsurface relationships in northern Indiana, study of outcropping strata provides a basic standard of comparison that is not limited by spacing of cores or restricted to the small amounts of rock available from cores. For example, studies of the Brassfield Limestone and the Salamonie Dolomite (Rexroad, 1967; Nicoll and Rexroad, 1969) on outcrop on the margin of the Cincinnati Arch and of the Wilhelmi, Elwood, Kankakee, and Joliet Formations (Liebe and Rexroad, 1977) on the Kankakee Arch have been important tools in interpreting relationships of equivalent strata in the subsurface. Description of the conodont fauna is the basic reason for the present study.

When Foerste named the Louisville Limestone in 1897, he referred to exposures just east of Louisville, Jefferson County, Ky., but did not designate a specific type section. We collected longer and better exposed sections within the city and from the excellent series of exposures along U.S. Highway 42 east of Louisville (fig. 1). Figure 2 shows how the Louisville and the Wabash relate to the remainder of the Silurian of southern Indiana. The Silurian section along Indiana Highway 62 on the east bluff of Fourteenmile Creek exposes the most complete outcropping Silurian section known in southeastern Indiana and has become a classic reference section. Samples were also taken from the Louisville there and from three quarries in Clark County, Ind. Also, material from three cores in Clark County was studied.

The Wabash Formation was traced in the subsurface as far south as New Albany by Patton (1955), although at that time the lower part of what is now called the Wabash Formation was referred to as the Mississinewa Shale. Subsequently, the unit was recognized in the Speed Quarry of the Louisville Cement Co., the Sellersburg Stone Co. quarry, and the T. J. Atkins & Co. quarry near Jeffersonville. (After completion of the present study the Liter's Quarry of Indiana, Clark Military Grant 50, was deepened into the Wabash Formation.) Only the upper part of the interval is exposed in the first two of three quarries studied, but a core at the Speed Quarry also includes the total thickness. Because the Wabash is lithologically transitional with the underlying Louisville, because the limited Wabash exposures in southern Indiana do not merit a separate study, and because conodonts in the Louisville are sparse, we include both the Louisville and the Wabash in a single study. General lithologies and sample intervals of the sections collected are shown in figure 1.

STRATIGRAPHIC SUMMARY

Although the Louisville on outcrop appears rather uniform, its lithology is variable. In Clark County it varies from limestone to dolomite, although in the type area across the Ohio River much of the formation is a slightly dolomitic limestone along with a few beds of dolomite. To the north in Indiana dolomite predominates. Many beds are argillaceous, and chert is common in the upper part. Some beds, including many formerly used as building stone, are nearly white, but commonly the Louisville varies from light to medium brown and from gray to bluish gray. Some beds are mottled. The formation ranges texturally from fine grained or micritic to coarse bioclastic or sparry. The lower 20 feet commonly is coarser and includes more fossils and fossil-fragmental debris. The formation generally is thick bedded, but bedding also varies.

Fossils are common in some sections, but they tend to be concentrated in a few beds, particularly in the lower part of the formation. Butts (1915) compiled a list of megafossils that had been recorded from the formation at that time, and it included corals (113 species), brachiopods (61 species), sponges, crinoids, bryozoans, gastropods, cephalopods, and trilobites.

In its type area the Louisville Limestone is commonly between 40 and 55 feet thick, but primarily because of pre-Middle Devonian erosion, it is highly variable in thickness, ranging from 0 to more than 60 feet, and according to Butts (1915) to about 100 feet in southern Jefferson County, Ky. Exposures are common as far north as Shelby County, Ind., but are sporadic north of there because of glacial drift. In the subsurface of northern Indiana the Louisville can be traced as far north as the Fort Wayne Bank, where it merges with the lower part of that feature. The Louisville is exposed southward from the type area into Nelson County, Ky., where progressively more of the Silurian was removed during pre-Middle Devonian erosion before it was overlapped by Devonian rocks. The Louisville reappears at the surface in southeastern Allen County, Ky. (Nelson, 1962), on the Kentucky-Tennessee boundary. The Louisville overlies the Waldron Shale with a gradational contact and in turn is overlain either with complete transition by the Wabash or unconformably by Devonian rocks. In the type area it is mostly late Wenlockian in age, but its upper part is early Ludlovian according to Berry and Boucot (1970).

The Wabash Formation was named by Pinsak and Shaver (1964) for strata in northern Indiana that lie south of the Fort Wayne Bank and are above the Louisville Limestone and below the Salina Formation or below Devonian rocks where the Salina is absent. They included within the formation beds previously referred to the Mississinewa Shale below and to the Liston Creek Limestone above and reduced these two units to member rank. Reefal and reef-related strata previously collectively placed in the Huntington Dolomite were referred by them to the Huntington Lithofacies. Although strata in southern Indiana above the Louisville Limestone are recognized as lateral equivalents of the lower part of the Wabash Formation, that is, of the Mississinewa Shale Member, the lithology changes in the intervening area, so that the unit does not display characteristic Mississinewa lithology. Accordingly, member designation is not applied in southern Indiana (French, 1967).

As noted, the Wabash is exposed in southern Indiana only in four quarries in Clark County. Its lithology here and in much of northern Indiana is completely gradational with that of the underlying Louisville, and an interval of as much as 20 feet forms a transition zone between the two. Generally in Clark County the Wabash consists of a sequence of thick-bedded argillaceous buff-weathering gray dolosiltite alternating with argillaceous fossiliferous gray dolomitic limestone that includes chert, micritic intervals, and bioclastic lenses and stringers, all of which may be bioturbated. The former lithology is similar to that of the Mississinewa Shale Member in northern Indiana, but the latter lithology reflects characteristics similar to those of the Louisville. This sequence consisting of alternating lithologies of the transition interval is here placed in the Wabash Formation. Thus the base of the Wabash is above the continuous carbonate sequence of the Louisville and at the base of the lowest interval of dolosiltite or silty carbonate. These lower Wabash rocks in southern Indiana are early Ludlovian in age.

ACKNOWLEDGMENTS

We greatly appreciate the courtesy of officials of the Louisville Cement Co., Sellersburg Stone Co., and T. J. Atkins & Co. in allowing access to their quarries. We also acknowledge the critical reading of the manuscript by Dr. Walter C. Sweet, of The Ohio State University. The study was initiated as part of a National Science Foundation grant (GP-5629) by Pollock, who at that time was a Research Affiliate, Department of Geology, Indiana University. Publication is authorized by Amoco Canada Petroleum Co., Ltd.

Although opinions on taxonomic problems have varied, comments by Richard J. Aldridge, University of Nottingham, James E. Barrick and Gilbert Klapper, University of Iowa, R. L. Ethington, University of Missouri-Columbia, Hans P. Schönlaub, Geologische Bundesanstalt, Vienna, and Otto Walliser, George August-Universität, Göttingen, have strengthened the manuscript. Material from the University of Iowa collections was loaned by Klapper.

OVERSIZED DOCUMENT

Now located at end of publication.

The Conodont Fauna

Ten multielement species were recognized in the collections, four composed only of cone elements, and six of ramiform or ramiform and platform elements. But conodonts are rare in both the Louisville Limestone and the Wabash Formation. In fact, slightly less than 25 percent of the 190 sample intervals yielded any conodonts (fig. 1), and in slightly more than 75 percent of the conodont-bearing samples the only conodonts found were cones, mostly representing *Panderodus*. Only four samples produced more than 10 conodonts per kilogram of sample, and in only three were specimens both abundant and diversified.

Panderodus unicostatus and *Walliserodus curvatus* are the common species with cone-only apparatuses. *Dapsilodus obliquicostatus* and *Decoriconus fragilis* are represented only by one specimen and by two specimens (table 1). In only three of the other species were all elements recognized. These are in descending order of abundance *Kockelella variabilis, Ozarkodina excavata,* and *O. confluens* new subspecies. Four and possibly five elements of *K. absidata* are recognized in the collections, but *?K. fundamentata* and *O.* aff. *O. sagitta* are poorly represented.

The ranges of all conodonts are compatible with a late Wenlockian-early Ludlovian age assignment for the Louisville and lower Wabash rocks, but at the specific level none of the conodonts is so restricted in stratigraphic range. Neither the European zonation of Walliser (1964) nor that in the central Appalachians (Helfrich, 1975) can be applied to our units. Certainly the fauna fits within the *Kockelella variabilis* Zone defined as a local zone in southern Oklahoma (Barrick and Klapper, 1976), but that zone is defined as extending from the earliest occurrence of *K. variabilis* (latest Wenlockian) up to the base of the *Polygnathoides siluricus* Zone, which starts in the middle Ludlovian. *Kockelella variabilis* continues upward through much of the latter zone. Thus, no further limits are provided for the age of the lower Wabash rocks in southern Indiana.

Register of Localities

1. Carter Coordinates line between 2- and 9-U-46, Jefferson County, Ky., Louisville East Quadrangle. Bluff of Beargrass Creek in Cherokee Park, 0.3 km downstream from bridge at Big Rock Pavilion. Field designation is Big Rock.
2. Carter Coordinates 2-U-46, Jefferson County, Ky., Louisville East Quadrangle. Cut on south side of Lexington Road at Cross Hill Road in residential area of Louisville. Field designation is Lexington Road.
3. Carter Coordinates 23-V-46, Jefferson County, Ky., Jeffersonville Quadrangle. North end of abandoned quarry on Bickel Street in residential area of Louisville. Field designation is Bickel quarry.
4. Carter Coordinates 8- and 13-V-47, Jefferson County, Ky., Anchorage and Jeffersonville Quadrangles. Three road cuts on U.S. Highway 42, 1.1, 2.1, and 2.5 miles (1.8, 3.4, and 4.0 km) northeast of junction of U.S. Highway 42 and Kentucky Highway 22. Field designations are Highway 42, stop 1, stop 3, and stop 2.
5. W¼ lot 10, Clark's Grant, Clark County, Ind., Jeffersonville Quadrangle. T. J. Atkins & Co. quarry. Field designation is Atkins Quarry Jeffersonville (surface).
6. S¼W¼ lot 90, Clark's Grant, Clark County, Ind., Charlestown Quadrangle. Abandoned part of Sellersburg Stone Co., Inc., quarry. Field designation is Sellersburg Quarry.
7. Lot 132, Clark's Grant, Clark County, Ind., Charlestown Quadrangle. Indiana Geological Survey drill hole 145, Louisville Cement Co. Speed Quarry.
8. W¼ lot 79, Clark's Grant, Clark County, Ind., Owen Quadrangle. Indiana Geological Survey drill hole 146, Martin-Marietta.
9. S¼S¼ lot 121, Clark's Grant, Clark County, Ind., Owen Quadrangle. Road cut on north side of Indiana Highway 62. Field designation is Fourteen Mile Creek.
10. S¼ lot 246, Clark's Grant, Clark County, Ind., Otisco Quadrangle. Indiana Geological Survey drill hole 147, Ralph Dieterlen.

Systematic Paleontology

All specimens are reposited in the Indiana University-Indiana Geological Survey collections. Numbers in parentheses following each repository number refer to the locality and sample number for that specimen. Only skeletal synonymies are given. They include multielement references to complete or nearly complete apparatuses. Type specimens of disjunct element species may represent elements shared with other species and may not belong in the multielement species given. As a matter of convenience in elucidating the element composition of the given multielement species, however, all initial designations of elements originally speciated in disjunct element taxonomy are listed. The locational notations for apparatuses containing ramiform conodonts follow those of Sweet and Schönlaub (1975).

Genus DAPSILODUS Cooper, 1976

Type species: Distacodus obliquicostatus Branson & Mehl, 1933.

Dapsilodus obliquicostatus (Branson & Mehl, 1933)

Plate 1, figure 9

Multielement:

Dapsilodus obliquicostatus (Branson & Mehl), COOPER, 1976, p. 212, pl. 2, figs. 10-13, 18-20.

Acontiodus obliquicostatus (Branson & Mehl), SERPAGLI, 1970, p. 82, pl. 23, figs. 1-10; pl. 24, figs. 1-6.

Disjunct element:

Acodus inornatus ETHINGTON, 1959, p. 268, pl. 39, fig. 11.

Distacodus obliquicostatus BRANSON & MEHL, 1933a, p. 41, pl. 3, fig. 2.

Distacodus posterocostatus REXROAD & CRAIG, 1971, p. 689, pl. 82, figs. 1-4.

Remarks: Only a single specimen, which is referable to disjunct element *Distacodus obliquicostatus,* was recovered.

Material studied: One specimen.

Repository: 15339 (7-39).

Genus DECORICONUS Cooper, 1975

Type species: Paltodus costulatus Rexroad, 1967.

Decoriconus? fragilis (Branson & Mehl, 1933)

Plate 1, figure 10

Multielement:

Decoriconus fragilis (Branson & Mehl), COOPER, 1976, p. 212, pl. 2, figs. 5, 8, 14-17.

Disjunct element:

Paltodus fragilis BRANSON & MEHL, 1933a, p. 43, pl. 3, fig. 3.

Drepanodus aduncus NICOLL & REXROAD, 1969, p. 35, pl. 7, figs. 11-15.

Remarks: This species is represented by only two specimens of disjunct element *Drepanodus aduncus* Nicoll & Rexroad. Generic characteristics of early Silurian cones have not become established yet. We question the generic assignment on the grounds that according to Cooper (1975) the type species includes only two elements, which are closely similar in general form to each other; but Cooper (1976) described *D. fragilis* as consisting of three elements, disjunct element *Drepanodus aduncus* Nicoll & Rexroad being an addition to elements like those of the type species. It seems likely that *D.? fragilis* is an evolutionary descendant of *D. costulatus* with one separable intermediary, but the differences in element composition suggest assignments to different genera.

Material studied: Two specimens.

Repository: 15340 (6-4).

Genus KOCKELELLA Walliser, 1957

Type species: Kockelella variabilis Walliser, 1957.

Kockelella absidata Barrick & Klapper, 1976

Plate 1, figures 28-32

Multielement:

Kockelella absidata BARRICK & KLAPPER, 1976, p. 73, pl. 2, figs. 15, 16.

Disjunct element:

Pa s.l. *Spathognathodus fundamentatus* WALLISER, 1957, p. 47, pl. 1, figs. 11-15.

Pb aff. *Ozarkodina ziegleri* WALLISER, 1957, p. 41, pl. 1, figs. 26-30.

M *Neoprioniodus multiformis* WALLISER, 1964, p. 50, pl. 29, figs. 14, 16-25.

Sc cf. *Ligonodina salopia* RHODES, 1953, p. 307, pl. 23, figs. 245, 257, 260.

Sb *Lonchodina greilingi* WALLISER, 1957, p. 38, pl. 3, figs. 20-26.

Sa *Trichonodella inconstans* WALLISER, 1957, p. 50, pl. 3, figs. 10-17.

Diagnosis: The species is a *Kockelella* represented in discrete element taxonomy by a Pa element initially included in a broad concept of *Ozarkodina fundamentata* (Walliser), a Pb element not positively identified but perhaps one represented by specimens having affinities with *Ozarkodina ziegleri* Walliser, an M element included in *Neoprioniodus multiformis* Walliser, an Sc element referred by Walliser to *Ligonodina* cf. *L. salopia* Rhodes, an Sb element included in *Lonchodina greilingi* Walliser, and an Sa element included in *Trichonodella inconstans* Walliser and indistinguishable from the Sa element of *Kockelella variabilis.*

Remarks: (1) Pa element. Barrick and Klapper (1976) pointed out that Walliser in 1964 included much more diverse specimens in disjunct element species *Ozarkodina fundamentata* than he had in 1957 and that others accepted this broader concept. They placed one of these in their new species *Kockelella absidata,* whose relationships with other species of *Kockelella* are unclear.

That the two elements were included initially in a single disjunct element species suggests that these two are closely related to each other and also to *Kockelella variabilis* from which disjunct adult specimens of *O. fundamentata* s.s. cannot be distinguished according to Walliser (1957). In addition to noting similarities between *O. fundamentata* and *K. variabilis,* Walliser (1957) suggested a connection between *O. fundamentata* and *Spathognathodus* [*Prioniodella*] *inclinatus* (Rhodes). We doubt this connection, however, and at that time it would not have applied to the *K. absidata* Pa element. Later Walliser (1964) said that *O. fundamentata* is derived from *Ozarkodina ortus* Walliser. His figure 3 suggests that this derivation applies only to the part of *O. fundamentata* now placed as a Pa element in *K. absidata.* This origin suggests that the element is a Pb rather than a Pa element. This further obscures the relationship of *K. absidata* to other species of *Kockelella,* and our material does not clarify this problem.

(2) Pb element. Unfortunately, Barrick and Klapper (1976) did not figure the Pb element of this species, but their description suggests that the difference between it and named subspecies of *Ozarkodina ziegleri* s.f. is that its anterior process has fewer denticles. There is overlap in this character, however. The anterior process of the specimens that we potentially associate with *K. absidata* is broken, and the twist of the blade produces some eversion of the basal cavity on the inner side, a feature which also differs from the Barrick and Klapper description.

(3) M element. Barrick and Klapper (1976) said that the M, Sc, Sb, and Sa elements appear to be identical with those of *Kockelella variabilis.* We agree that these elements in both species would each have been referred to a single disjunct element species, particularly as rather broadly construed by Walliser, but we believe that there are minor differences in the M, Sc, and Sb elements between *K. absidata* and *K. variabilis.*

The denticles on the anterior part of the main cusp of the *K. absidata* M element are mostly suppressed, so that all but their tips are inserted within the cusp, but they almost form an anterior process in the other species. Also, the basal cavity of the *K. absidata* M element generally has a broader flare.

(4) S elements. Both the Sc and Sb elements of *K. absidata* have slightly flattened, more closely spaced denticles on the processes than do the corresponding elements of *K. variabilis.* Many fewer Sa than Sc or Sb elements were recovered, and we could not make any separation of the Sa element.

Material studied: 38 specimens.

Repository: 15358-15362 (all 6-4).

Kockelella variabilis Walliser, 1957

Plate 1, figures 33-40

Multielement:

Kockelella variabilis Walliser, WALLISER, 1972, p. 77; KLAPPER & MURPHY, 1975 (part), p. 53, 54, pl. 9, figs. 5-11; pl. 10, figs. 1-7, 12-16 only; BARRICK & KLAPPER, 1976, p. 77-78, pl. 3, figs. 12-17.

Disjunct element:

Pa *Kockelella variabilis* WALLISER, 1957, p. 35, pl. 1, figs. 3-10.

Pb *Ozarkodina ziegleri ziegleri* WALLISER, 1957, p. 41, pl. 1, figs. 26-30.

M *Neoprioniodus multiformis* WALLISER, 1964, p. 50, pl. 29, figs. 14, 16-25.

Sc aff. *Ligonodina silurica* BRANSON & MEHL, 1933a, p. 48, pl. 3, figs. 18, 20.

Sb *Lonchodina greilingi* WALLISER, 1957, p. 50, pl. 3, figs. 20-26.

Sa *Trichonodella inconstans* WALLISER, 1957, p. 50, pl. 3, figs. 10-17.

Diagnosis: The species is a *Kockelella* comprised of elements which in terms of disjunct element taxonomy are listed above. The M element has more pronounced anterior denticulation than that of *K. absidata,* and the Sc and Sb elements have slightly less compressed and more separated denticles than those of *K. absidata.*

Remarks: An association of elements composing *Kockelella variabilis* was recognized by Walliser (1964) and informally designated as apparatus G. Then in 1972 he formally designated this apparatus as *K. variabilis,* and his interpretation subsequently has been modified only slightly. Walliser (1957, 1964) included either *Ligonodina silurica* Branson & Mehl or *L. salopia* Rhodes or both in the species as an Sc element, but we agree with Klapper and Murphy (1975) and Barrick and Klapper (1976) in assigning to *K. variabilis* only part of the material Walliser placed in *L. silurica* and in excluding type material of *L. silurica* and *L. salopia.* Klapper and Murphy (1975) incorrectly included the Pa element of *K. variabilis,* apparently following the idea of Klapper and Philips (1971), but this was corrected by Barrick and Klapper (1976). Barrick and Klapper (1976) indicated that the M, Sc, Sb, and Sa elements of *K. variabilis* and *K. absidata* are identical, but we believe that there are slight differences in the first three as discussed under *K. absidata* and mentioned in the diagnosis.

Material studied: 100 specimens.

Repository: 15363-15370 (all 6-4).

?*Kockelella fundamentata* (Walliser, 1957)

Plate 1, figures 23, 24

Disjunct element:

Spathognathodus fundamentatus WALLISER, 1957, p. 47, pl. 1, figs. 11-15.

Remarks: Included among the Pa elements of *Kockelella variabilis* are several that we suspect are referable to the disjunct element species *Spathognathodus fundamentatus* Walliser, a species subsequently expanded in concept by Walliser (1964) and placed in *Ozarkodina.* Walliser (1957) said that adult specimens of *S. fundamentatus* could not be distinguished from juvenile forms of *K. variabilis.* The similarities were also noted by Liebe (1962), who considered the two synonymous, and by Ethington and Furnish (1962). That specimens of *Kockelella variabilis* and *S. fundamentatus* cannot always be distinguished and that Pa elements of *K. absidata* and *S. fundamentatus* were included in the same form species clearly connect *fundamentatus* phylogenetically to these two species. Therefore, we place the disjunct element species *S. fundamentatus* in *Kockelella* (multielement) as a Pa element. *K. fundamentata,* then, would have the same kinds of elements as typified by *K. variabilis,* but none of them have been recognized with certainty. Two ozarkodinaform (Pb) and one ligonodiniform (Sc) specimens found with the Pa elements have characteristics suggestive of association, and perhaps the remaining elements cannot at this stage of knowledge be distinguished from elements of other species of *Kockelella.* A few Pa elements differ slightly from most of those discussed herein, and these are referred to only as comparing with (cf.) the rest of the specimens.

The possible Pb element belonging in *K. fundamentata* is ozarkodinaform. It is almost unarched and displays almost no bowing, although it is slightly twisted as seems to be characteristic of *O. ziegleri* s.f. The blade is thick but not high and bears about five or six laterally compressed denticles anterior to the small main cusp and about five denticles posterior to it. The denticles are free in the upper third and no suppressed denticles were observed. The possible Sc element is ligonodiniform and is closely similar to the Sc element of *K. variabilis,* differing in being smaller and in bearing more compressed and more closely spaced denticles.

Because juvenile specimens of the Pa element of *K. variabilis* are practically indistinguishable from adult specimens of the Pa element of *K. fundamentata,* the latter may be ancestral to the former. The trend of evolution of the Pa element in the *Kockelella* lineage giving rise to *K. variabilis* as postulated by Barrick and Klapper (1976), however, is for a decrease in the size of the basal cavity, so that the posteriormost part loses its identity as part of the cavity, which then is in a more central position. We suspect that this trend along with the loss of surface ornamentation led to the separation of *K. fundamentata* from *K. variabilis.*

The above-postulated lineage is not completely convincing, first because of the close similarity of the Pa elements of *K. absidata* and *K. fundamentata* and the occurrence of the former in rocks much older than those from which *K. variabilis* has been recorded. The age ranges recorded for *S. fundamentatus* s.f. in the literature are not reliable now because of the inclusion of more than one species. Initially, Walliser considered *K. variabilis* and *S. fundamentatus* to overlap only in the younger part of the range of *K. variabilis,* and this seems more likely than a coincidence of their ranges.

Although it does not seem to be a strong possibility, one must also consider the possibility that the ontogeny of *K. variabilis* reflects its phylogeny as a derivative of *K. fundamentata.* There are earlier Pa elements, such as *Spathognathodus hassi* Pollock, Rexroad & Nicoll, from which the Pa element of *K. fundamentata* in turn readily could have evolved. The Pa element of *K. absidata* either could have come from the same ancestral form or could have evolved from *K. fundamentata.* If *K. variabilis* evolved from *K. fundamentata,* this lineage of *Kockelella* would be separated from the *ranuliformis* lineage suggested by Barrick and Klapper. Either P element of *Ozarkodina protoexcavata* Cooper, 1975, (*Ozarkodina* n. sp. A or n. sp. B of Pollock, Rexroad & Nicoll, 1970) is similar enough to our suggested Pb element to be an ancestral form, and both are associated with *S. hassi* s.f. Much more data will be required to firmly establish the *Kockelella* lineage.

Material studied: 16 specimens.

Repository: 15353, 15354 (both 6-4), and cf. *?Kockelella fundamentata* 15355 (6-3).

Genus OZARKODINA Branson & Mehl, 1933

Type species: Ozarkodina typica Branson & Mehl, 1933.

Ozarkodina confluens (Branson & Mehl, 1933), new subspecies

Plate 1, figures 11-16

Disjunct element:

Pa *Spathodus primus* BRANSON & MEHL, 1933a, p. 46, pl. 3, figs. 25-30.

Pb aff. *Ozarkodina typica* BRANSON & MEHL, 1933a, p. 51, pl. 3, figs. 43-45.

M *Prioniodus bicurvatus* BRANSON & MEHL, 1933a, p. 44, pl. 3, figs. 9-12.

Sc *Hindeodella confluens* BRANSON & MEHL, 1933a, p. 45, pl. 3, figs. 21-23.

Sb *Plectospathodus flexuosus* BRANSON & MEHL, 1933a, p. 47, pl. 3, figs. 31, 32.

Sa *Trichognathus symmetrica* BRANSON & MEHL, 1933a, p. 50, pl. 3, figs. 33, 34.

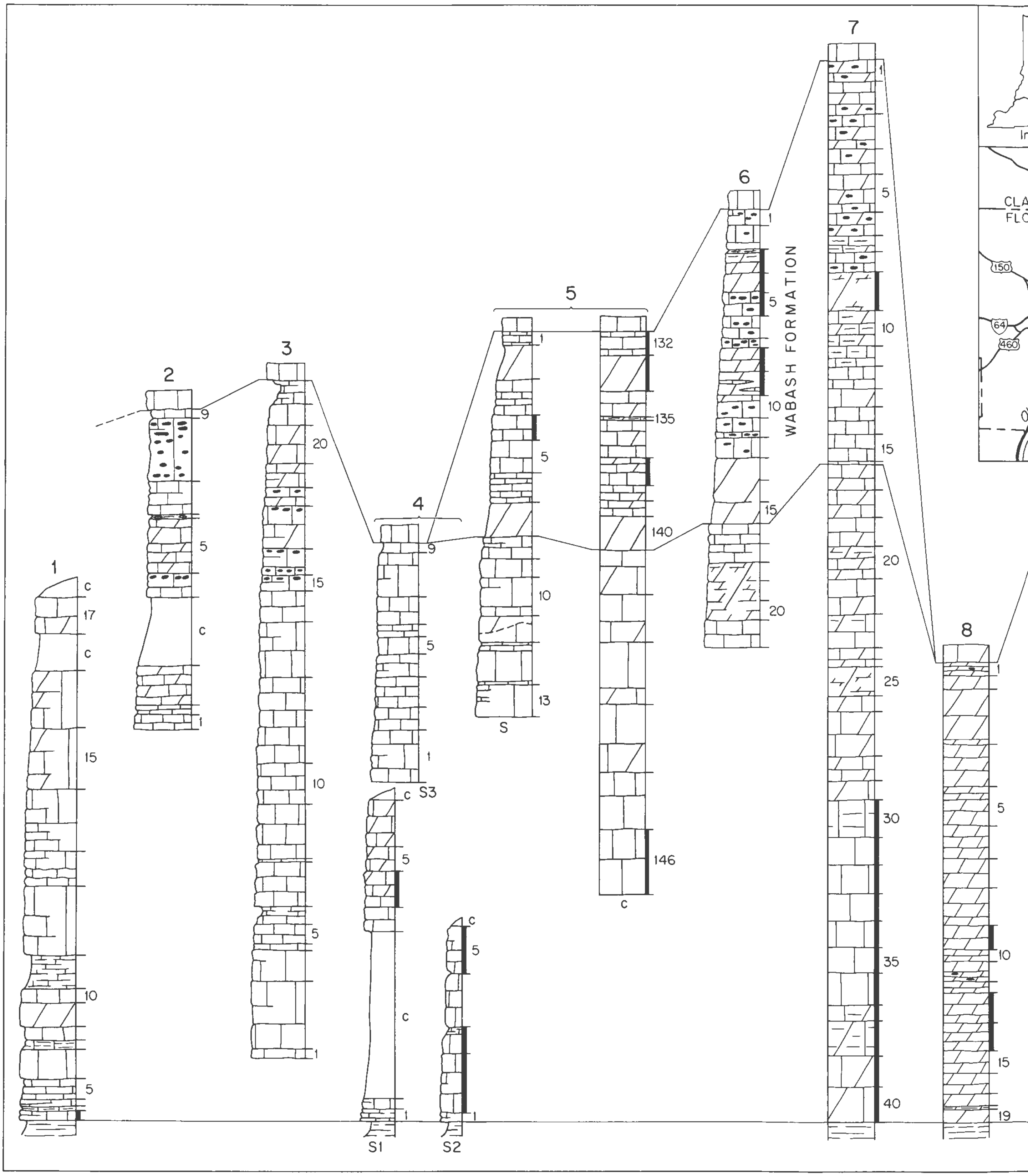
Diagnosis: This is an *Ozarkodina* that except for the Pb element conforms to Jeppsson's (1969) definition of *Ozarkodina confluens,* which includes as an apparatus the disjunct elements listed above for the Pa, M, Sc, Sb, and Sa elements plus *Ozarkodina typica* s.s. rather than the related form described below.

Description: The Pa, M, Sc, Sb, and Sa elements are identical with those of *Ozarkodina confluens confluens.* The Pb element is arched and bowed, is slightly twisted in some specimens, and in adults bears six to eight anterior and four to six posterior denticles, which are strongly compressed, sharp edged, and fused through about two-thirds to three-fourths of their length. The main cusp is about twice the width of the other denticles, is much longer, and also is sharp edged. The basal cavity is generally in the middle third of the specimens, is deepest beneath the main cusp, and tapers both anteriorly and posteriorly, the anterior part generally being somewhat the longer. Denticles are almost totally white matter, which is lacking below them. There are no suppressed denticles in the specimens observed.

Remarks: Agreement has been general that Jeppsson (1969) correctly associated the elements of *Ozarkodina confluens.* As noted, the Pb element in our collection differs from that of *O. confluens confluens.* Generally, we believe that associations with different Pa elements should be placed in separate species but that differences in any one of the other elements warrants no more than subspecific differentiation. Accordingly, we treat our taxon as a subspecies but leave it in open nomenclature.

Material studied: 46 specimens.

Repository: 15341-15346 (all 6-4).


1
2
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WABASH FORMATION
132
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140
146
CLA
FLO

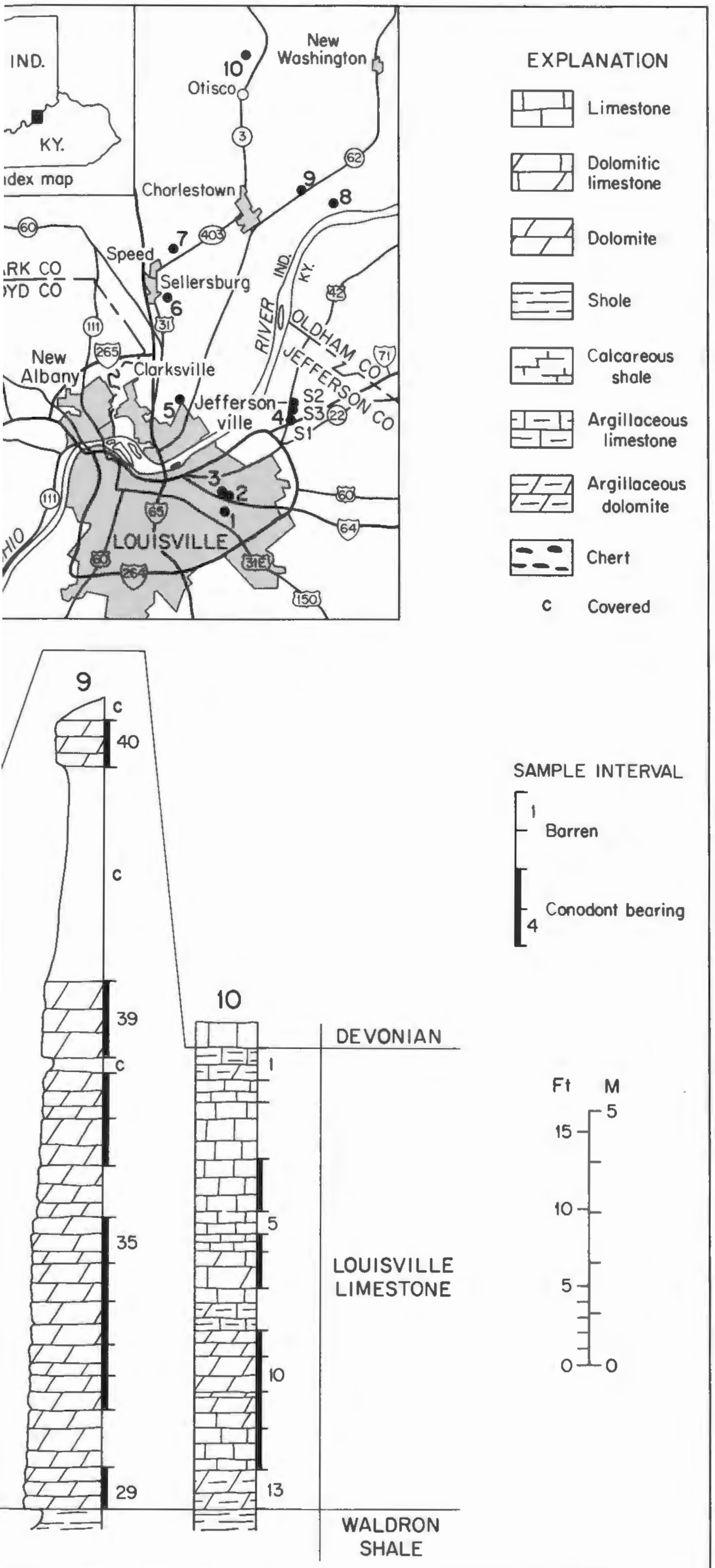

Figure 1. Location map and measured sections showing stratigraphic units, generalized lithologies, and sample intervals. Precise locations are given in the text under "Register of Localities."

Ozarkodina excavata excavata
(Branson & Mehl, 1933)

Plate 1, figures 17-22

Multielement:

Hindeodella excavata (Branson & Mehl), JEPPSSON, 1969 (part), p. 18.

Hindeodella excanata [stet] (Branson & Mehl, 1933), JEPPSSON, 1972 (part), p. 61.

Hindeodella excavata excavata (Branson & Mehl, 1933), JEPPSSON, 1974 (part), p. 25.

Ozarkodina excavata excavata (Branson & Mehl), KLAPPER & MURPHY, 1975 (part), p. 34-36; BARRICK & KLAPPER, 1976 (part), p. 77, 78.

Synonymies in each of the above list *Ozarkodina simplex* and (or) *Prioniodus excavatus* from the Bainbridge, but none of the plates include illustration of disjunct *O. simplex* s.s.

Discrete element:

Pa *Ozarkodina simplex* BRANSON & MEHL, 1933a, p. 52, pl. 3, figs. 46, 47.

Pb *Ozarkodina media* WALLISER, 1957, p. 40, pl. 1, figs. 21-25.

M *Prioniodus excavatus* BRANSON & MEHL, 1933a, p. 45, pl. 3, figs. 7, 8.

Sc *Hindeodella equidentata* RHODES, 1953, p. 303, pl. 23, figs. 248, 252-254.

Sb *Plectospathodus extensus* RHODES, 1953, p. 323, pl. 23, figs. 236-240.

Sa *Trichognathus excavatus* BRANSON & MEHL, 1933a, p. 51, pl. 3, figs. 35, 36.

Diagnosis: This is an *Ozarkodina* composed of elements which would be represented in discrete element taxonomy by the species listed above.

Remarks: In 1964 Walliser recognized in open nomenclature an apparatus that differs from the present one only by the substitution of *Spathognathodus* [*Prioniodella*] *inclinatus inclinatus*

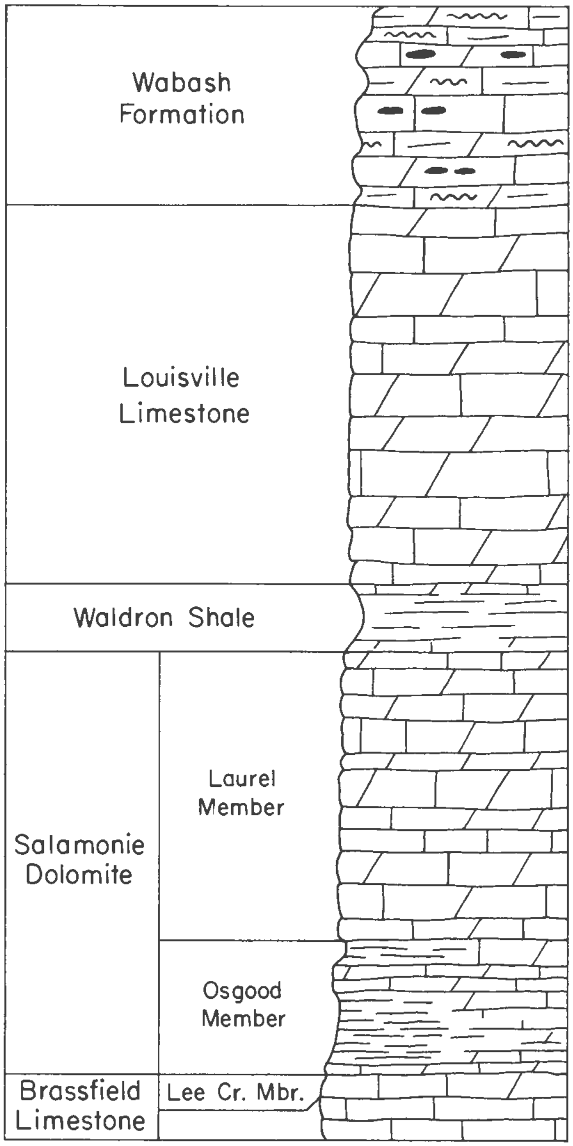

Figure 2. Generalized columnar section of Silurian strata of southeastern Indiana.

(Rhodes) for *Ozarkodina simplex* as the Pa element. Subsequently Walliser (1972) formally designated the apparatus *Ozarkodina inclinata* (Rhodes) and listed elements corresponding to the 1964 list, that is, differing from the elements listed in the above diagnosis of *O. excavata* only by the replacement of *O. simplex* by *Spathognathodus inclinatus.* Jeppsson (1969), however, was first to apply a formal name, *Hindeodella excavata* (Branson & Mehl, 1933), to a group of elements that would include all of the above. We believe that the inclusion of both *O. simplex* and *P. inclinata* in one apparatus is incorrect, that two species are present having different Pa elements associated with the remaining elements that have not been differentiated in terms of disjunct element taxonomy.

The name *H. excavata* must be assigned to the apparatus that includes the *O. simplex* Pa element, because the type species, that is, the name bearer of *excavata* from the Bainbridge Formation, belongs in this species. Branson and Mehl (1933a) reported the Pa, M, and Sa elements in association at Lithium, Mo. Rexroad and Craig (1971) additionally reported the Pa and Sb elements in association with the others at that locality, and as pointed out by Klapper (oral communication, 1972) the Sc element also was present in their collection. *Prioniodella inclinata* was not recorded from the Bainbridge, and thus the Bainbridge type of *Prioniodus excavatus* is associated with the *simplex*-bearing apparatus rather than the one with *inclinatus.* Jeppsson's (1969) figure 3, then, is correctly assigned to *Ozarkodina inclinata* (Rhodes). The synonymy of *O. inclinata* includes several forms named at the same time as *Prioniodella inclinata,* but Walliser's (1972) choice, [*Prioniodella*] *inclinata,* as the first reviser becomes the valid name. If he had considered *O. simplex* and *P. inclinata* as two names for the same Pa element, the correct choice of names would have been *O. simplex* rather than *O. inclinata.*

Material studied: 112 specimens.

Repository: 15347-15352 (all 6-4).

Ozarkodina sp. aff. *O. sagitta* (Walliser, 1964)

Plate 1, figures 26, 27

Disjunct element:

aff. *Spathognathodus sagitta* WALLISER, 1964, p. 82-84, pl. 18, figs. 8-24.

Diagnosis: This is a species of *Ozarkodina* with a Pa element similar to that of disjunct element *Spathognathodus sagitta* but with a narrower basal cavity. Other elements are presumed to be similar to, or the same as, those of the subspecies of *Ozarkodina sagitta,* but they are not represented in the present collection.

Description: (1) Pa element. The limited number of specimens and their fragmental nature preclude a complete description of this element. Only the posterior portion is preserved. The low robust blade is turned down posteriorly from a point above the posterior part of the basal cavity, which is lanceolate as viewed from below and which extends almost but not quite to the posterior tip. The lips are flared less than in the Pa elements of *O. sagitta,* although they are flared nearly as much as in *O. sagitta rhenana.* The blade denticles of some specimens are completely fused above the basal cavity.

(2) Other elements. We were unable to associate any other elements with the Pa element.

Remarks: Without associated elements the evolutionary relationship of the Pa element recovered in this study cannot be determined. Although it differs from the corresponding element of described subspecies of *O. sagitta,* its morphology is similar enough to suggest a relationship. In terms of time it would fit within the range of that species, early Wenlockian into early Ludlovian (Aldridge, 1975) and possibly into late Ludlovian time (Barrick and Klapper, 1976). The Pa element is also closely similar to the Pa element of the Early Devonian species *Ozarkodina eurekaensis* Klapper & Murphy, but it tends to be turned down more posteriorly.

Material studied: Six specimens.

Repository: 15356, 15357 (both 6-4).

Genus PANDERODUS Ethington, 1959

Type species: Paltodus uniconstatus Branson & Mehl, 1933.

Panderodus unicostatus (Branson & Mehl, 1933)

Plate 1, figures 6-8

Multielement:

Panderodus unicostatus (Branson & Mehl), COOPER, 1976, p. 213, pl. 1, figs. 1-7, 22.

Panderodus serratus Rexroad, COOPER, 1975, p. 993, pl. 1, figs. 3-5, 7-9, 13, 14, 23.

Disjunct element:

Paltodus unicostatus BRANSON & MEHL, 1933a, p. 42, pl. 3, fig. 3.

Paltodus gracilis BRANSON & MEHL, 1933b, p. 108, pl. 8, figs. 20, 21.

Paltodus simplex BRANSON & MEHL, 1933a, p. 42, pl. 3, fig. 4.

Diagnosis: This is a species of *Panderodus* that includes a simplexiform element and two intergradational costate elements recognized in disjunct element taxonomy as the species listed above. *P. gracilis* is shared with at least one other species, however, and we believe that its type is not included in *P. unicostatus.*

Remarks: Our concept of the species is similar to that of Cooper (1976). However, he excluded pre-St. Clair representatives of elements that in disjunct element taxonomy would be referred to *Panderodus unicostatus, P. simplex,* and *P. gracilis.* We believe that *P. unicostatus* was derived from an Ordovician species of *Panderodus* that included *Panderodus gracilis* and early forms of *P. unicostatus* as the costate elements and *Paltodus compressus* Branson & Mehl, 1933, as the simplexiform element. The evolution was completed by the beginning of Silurian time, and *Panderodus unicostatus,* present in the Wilhelmi Formation of Illinois, was an extremely long-lived and common Silurian form.

We believe that multielement *Panderodus serratus* Rexroad of Cooper (1975) was a minor reiterative variant of *Panderodus unicostatus* that represented only a small fraction of the Brassfield panderodids, the great majority of the specimens being assignable to *P. unicostatus* undifferentiated. Because we have found two serrate specimens in the present samples identical to those of the much older Brassfield Limestone, we doubt that this variation deserves even subspecification.

Because *Panderodus simplex* is now included in *P. unicostatus,* the correct name for the *Panderodus simplex* Assemblage Zone becomes the *Panderodus unicostatus* Assemblage Zone.

Material studied: 409 specimens.

Repository: 15336 (6-3), 15337 (6-4), 15338 (6-3).

Genus WALLISERODUS Serpagli, 1969

Type species: Paltodus debolti Rexroad, 1967 [a junior synonym of *Walliserodus curvatus* (Branson & Branson). See Klapper and Murphy (1975, p. 21, 30) for a discussion of the taxonomic-nomenclatorial implications.]

Walliserodus curvatus (Branson & Branson, 1947)

Plate 1, figures 1-5

Multielement:

Walliserodus curvatus (Branson & Branson), COOPER, 1975, p. 995, pl. 1, figs. 10, 11, 16-21.

Discrete element:

Acodus curvatus BRANSON & BRANSON, 1947, p. 554, pl. 81, fig. 20.

Acodus unicostatus BRANSON & BRANSON, 1947, p. 554, pl. 82, figs. 9, 10, 41, 43.

Paltodus debolti REXROAD, 1967, p. 41, pl. 4, figs. 22-25.

Paltodus dyscritus REXROAD, 1967, p. 42, pl. 4, figs. 30-34.

Paltodus multicostatus BRANSON & MEHL, 1933a, p. 43, pl. 3, fig. 5.

Remarks: Two elements recognized in disjunct element taxonomy as *Acodus curvatus* and *Paltodus multicostatus* are very poorly represented in the collection for reasons that are uncleai to us. In terms of disjunct elements *P. multicostatus* is the senior name of the elements composing the species. Probably, however, the type material from the Bainbridge Formation belongs in a different species that includes *Acodus biocostatus* Branson & Mehl. Further, elements represented by disjunct element *Paltodus debolti* Rexroad have not been reported for the Bainbridge, which suggests a further distinction between *W. curvatus* and the Bainbridge species.

Serpagli (1967) defined the species *Walliserodus debolti* (Rexroad) as including disjunct elements *Paltodus debolti* Rexroad, *Paltodus dyscritus* Rexroad, and *Paltodus migratus* Rexroad. On this basis his synonymy could be cited as a partial reconstruction of *Walliserodus curvatus.* Rexroad has examined Serpagli's figured specimens, however, and has found that none is conspecific in the disjunct sense with any of the three listed for the species, although several of the specimens are closely similar. Also, Serpagli's figured specimen of *Acodus curvatus* is not conspecific with that disjunct species, but it is similar. Specimens figured by Serpagli as *Acodus trigonius* (Schopf) do not belong in that species but are similar to *Acodus unicostatus.* (In disjunct element taxonomy a distinction between *P. debolti* and *Distacodus? trigonius* Schopf is uncertain.) We suggest that the forerunner of *Walliserodus curvatus* was present in Serpagli's material, that a single very plastic group represented by his material developed into the *P. debolti, P. dyscritus,* and *P. multicostatus* elements, and that specimens labeled as *A. curvatus* and *A. trigonius* were predecessors of the *A. curvatus* and *A. unicostatus* elements of *Walliserodus curvatus.*

Material studied: 49 specimens.

Repository: 15331 (6-3), 15332 (6-4), 15333 (6-4), 15334 (6-4), 15335 (6-3).

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Appendix

Samples from cores at localities 7, 8, and 10 were shared with the Geochemistry Section of the Indiana Geological Survey and so were not numbered consecutively. To simplify the present report, consecutive numbers were assigned (see fig. 1), but all conodont slides of unfigured specimens reposited for this study bear the original designations. It is necessary, then, to provide a conversion table showing the corresponding sets of numbers for users of these slides.

Locality 7		Locality 8		Locality 10	
New	Original	New	Original	New	Original
1	220	1	17, 18, 19	1	702, 704
2	222-1	2	22	2	706
3	222-2	3	24	3	708
4	224	4	26	4	710, 711, 712
5	226-1	5	28	5	714
6	226-2	6	30, 32	6	716
7	228	7	34	7	718-1
8	230, 231	8	36	8	718-2
9	235	9	38	9	720, 722-1
10	237	10	40	10	722-2
11	239-1	11	41, 43	11	724, 726, 728
12	239-2	12	45	12	730
13	241	13	47	13	732
14	243-1	14	49		
15	243-2	15	51-1		
16	244	16	51-2		
17	246, 247	17	53		
18	249, 250-1	18	55		
19	250-2	19	57		
20	254, 256, 258				
21	259-1				
22	259-2				
23	261				
24	263				
25	264				
26	266				
27	268				
28	270-1				
29	270-2				
30	272-1				
31	272-2				
32	272-3				
33	272-4				
34	274-1				
35	274-2				
36	274-3				
37	276				
38	278, 280				
39	282-1				
40	282-2				

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Plate 1

PLATE 1

All figures are × 40

1-5 *Walliserodus curvatus* (Branson & Branson) (p. 12)
Lateral views of discrete element *Acodus unicostatus* 15331 (6-3), *Paltodus debolti* 15332 (6-4), *A. curvatus* 15333 (6-4), *P. multicostatus* 15334 (6-4), and *P. dyscritus* 15335 (6-3).

6-8 *Panderodus unicostatus* (Branson & Mehl) (p. 11)
Lateral views of discrete element *Panderodus gracilis* 15336 (6-3), *P. simplex* 15337 (6-4), and *P. unicostatus* 15338 (6-3).

9 *Dapsilodus obliquicostatus* (Branson & Mehl) (p. 4)
Lateral view of discrete element *Distacodus obliquicostatus* 15339 (7-39).

10 *Decoriconus? fragilis* (Branson & Mehl) (p. 4)
Lateral view of discrete element *Drepanodus aduncus* 15340 (6-4).

11-16 *Ozarkodina confluens* (Branson & Mehl) (p. 7)
Inner lateral view of Sc element 15341, posterior view of Sa element 15342, inner lateral view of M element 15343, outer lateral view of Pb element 15344, outer lateral view of Pa element 15345, and inner lateral view of Sb element 15346 (all 6-4).

17-22 *Ozarkodina excavata excavata* (Branson & Mehl) (p. 9)
Lower view of Sa element 15347, inner lateral views of M element 15348, Sc element 15349, Sb element 15350, Pb element 15351, and outer lateral view of Pa element 15352 (all 6-4).

23, 24 *?Kockelella fundamentata* (Walliser) (p. 6)
Outer and inner lateral views of Pa element 15353 and Pb element 15354 (both 6-4).

25 cf. *?Kockelella fundamentata* (Walliser) (p. 7)
Outer lateral view of 15355 (6-3).

26, 27 *Ozarkodina* sp. aff. *O. sagitta* (Walliser) (p. 10)
Lateral views of Pa elements 15356 and 15357 (both 6-4).

28-32 *Kockelella absidata* Barrick & Klapper (p. 4)
Inner lateral views of Pb element 15358, Sc element 15359, M element 15360, outer lateral view of Pa element 15361, and posterior view of Sb element 15362 (all 6-4).

33-40 *Kockelella variabilis* Walliser (p. 5)
Inner lateral views of Pb element 15363, M element 15364, Sb element 15365, Sc element 15366, lower view of Pa element 15367, upper view of Pa element 15368, lateral view of Pa element 15369, and posterior view of Sa element 15370 (all 6-4).

LOUISVILLE AND WABASH CONODONTS

OVERSIZED DOCUMENT

The following pages are oversized and need to be printed in correct format.

Table 1. Distribution of conodonts in the Louisville Limestone and the Wabash Formation

Species	Locality	1	$^{4}S_{1}$	$^{4}S_{2}$			^{5}S	^{5}C				6				7												8			9										10							
	Sample	2	4	2	3	5	4	146	137	133	132	9	8	4	3	40	39	38	37	36	35	34	33	32	31	30	9	14	13	9	29	31	32	33	34	35	37	38	39	40	12	11	10	9	7	6	4	3
Kockelella																																																
K. absidata																																																
Pa														7																																		
Pb														2																																		
M														2																																		
Sc														7	1																																	
Sb														10																																		
K. variabilis																																																
Pa										1				33													2																					
Pb										2				4																																		
M										2				5																																		
Sc										2		1		10	2																																	
Sb										2				13																																		
Sa														5																																		
?K. fundamentata																																																
Pa														8	1																																	
Pb?										1				2	1																																	
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Ozarkodina																																																
O. confluens n. subsp.																																																
Pa														5																																		
Pb														7	1																																	
M														1																																		
Sc														10													1																					
Sb														8	2												1																					
Sa														1																																		
O. excavata excavata																																																
Pa										5				13	3												1																					
Pb										3				15	1																																	
M										11			1	11	1																																	
Sc										6				7	1												2																					
Sb										3				4	1																																	
Sa										3				5													1																					
O. sp. aff. *O. sagitta*																																																
Pa														4													1																					
Unassigned																																																
Pb																											1																		1			
M																																													1			
Sc												1		1	1																				1													
Sb																													1			1																
Dapsilodus																																																
D. obliquicostatus																																																
obliquicostatus element																	1																															
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D.? fragilis																																																
aduncus element										1				1																																		
Panderodus											1	2							1	1	2				7		3	1				3	2	1	1	1	1	1	1	2	1							
P. unicostatus																																																
gracilis element		1								13	1	3	1	11	4	1		3	2	5	1	2	1	1	6		9	2			5	4	1	3		4					1	2	2	1	3		3	
unicostatus element		1	1	1	1	1	2			20	1	1	2	4	10			2	1	2	2	1		1	2		3			1	3							1			5	7	2	3	1	1	2	1
simplex element							1	1	1	23		1	3	14	10						1			1	2						1		1		1	1	1				1	2	2				2	
Walliserodus														2																	1								1									
W. curvatus																																																
curvatus element										1				1																																		
unicostatus element										3		1	1	6	1																		1					1	1									
debolti element														6	1																																	
dyscritus element										1				5	2											1																						
multicostatus element														1																																		