

Calymenid and Other Ordovician Trilobites from Kentucky and Ohio

GEOLOGICAL SURVEY PROFESSIONAL PAPER 583-B

*Prepared in cooperation with the
Kentucky Geological Survey*



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By REUBEN JAMES ROSS, JR.

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY

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*Species of the trilobites Isotelus, Bathyurus?,
Proetidella, Gravicalymene, Flexicalymene,
and Acidaspis are described from Middle and
Upper Ordovician strata of Kentucky*



UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY

CALYMENID AND OTHER ORDOVICIAN TRILOBITES FROM KENTUCKY AND OHIO

By REUBEN JAMES ROSS, Jr.

ABSTRACT

Specimens of the trilobite genera *Isotelus*, *Bathyrurus*, *Proctidella*, *Flexicalymene*, *Gravicalymene*, and *Acidaspis* were obtained from Middle and Upper Ordovician rocks of Kentucky. For uncertain reasons *F. senaria* was not collected from strata of Trenton age in Kentucky. Examination of topotype material from the Trenton Limestone of Trenton Falls, N.Y., proves that many specimens labeled *F. senaria* actually belong to *Gravicalymene*. A new species of *Gravicalymene* and one of *Flexicalymene* are described in this report, and a neotype of *F. senaria* (Conrad) is designated.

INTRODUCTION

Despite the small number of trilobites collected to date from the Ordovician rocks of Kentucky, important questions concerning stratigraphic ranges and taxonomy have been raised in the course of this study. The limited samples include specimens of *Isotelus*, *Bathyrurus*, *Proctidella*, *Flexicalymene*, *Gravicalymene*, and *Acidaspis*, and were obtained mainly from Middle Ordovician formations.

Because collecting was undertaken in conjunction with detailed stratigraphic study by other members of the U.S. Geological Survey and by members of the Kentucky Geological Survey, large numbers of fossils have been obtained from Ordovician rocks with good lithostratigraphic control. Main effort was directed toward obtaining brachiopods, bryozoans, and conodonts in the belief that they would have the greatest practical zonal value in interpreting regional stratigraphy. Accordingly, other groups of fossils are less well represented in the collections.

Many unresolved problems have arisen as a result of this study. For instance, *Gravicalymene* is the only calymenid genus obtained from the Lexington Limestone, a formation of probable Trenton age. In the collections from the Lexington, I had expected to find *Flexicalymene senaria* (Conrad), a venerated guide to strata of Trenton age. Failure to find it in Kentucky collections led to a check of collections purported to contain *F. senaria* from the type Trenton Limestone of New

York that are deposited in the U.S. National Museum, the New York State Museum, and the American Museum of Natural History.

I discovered that most of those collections, plus other collections from Michigan, include one or two species of *Gravicalymene*, as well as specimens that probably are *F. senaria*. Several of these specimens are illustrated on plate 2, figure 23; plate 3, figures 18, 19, 22, 23, and plate 4, figures 1-13.

Some of the questions arising from the calymenid phase of this study to date are:

1. Is the seeming absence of *Flexicalymene* from the Lexington Limestone real?
2. What is the detailed stratigraphic distribution of species of *Flexicalymene* and of *Gravicalymene* within the type section of the Trenton Limestone of New York and within the Ordovician rocks of Michigan?
3. Is there any geographic control over distribution of *Flexicalymene* that is different from that over distribution of *Gravicalymene*?

Answers to these questions and to others about other kinds of Ordovician trilobites must be sought in the future. This report will call attention to a few of the taxonomic and stratigraphic problems that need resolution.

ACKNOWLEDGMENTS

John Pojeta made available excellently preserved specimens of *Flexicalymene meeki* (Foerste) from the rocks of Maysville age in the vicinity of Cincinnati, and G. W. Weir collected equally fine examples of *F. retrorsa* (Foerste) from the type section of Foerste's so-called Arnheim Formation. I have been assisted in other collecting by E. R. Cressman, D. F. B. Black, Ellis Yochelson, R. B. Neuman, Olgarts Karklins, and F. A. Schilling. Dr. D. W. Fisher and C. F. Kilfoyle provided specimens of *Flexicalymene* from the New York State Museum. F. J. Collier lent specimens of the same genus from the U.S. National Museum. Dr. E. C. Stumm

arranged the loan of types of three calymenid species from Michigan. Specimens of *Flexicalymene*, one of which is here designated as neotype of *Flexicalymene senaria*, were lent by Dr. Roger Batten from the American Museum of Natural History. An unsuccessful search for Conrad's type specimen of *F. senaria* was made by Dr. Horace Richards in the collections of the Philadelphia Academy of Sciences. Specimens were mounted and photographed by L. A. Wilson.

LOCALITIES

The described trilobites were collected from six stratigraphic sections in central Kentucky, from one section in northern Kentucky, and at two localities in Ohio. Relative positions of these sections and localities are

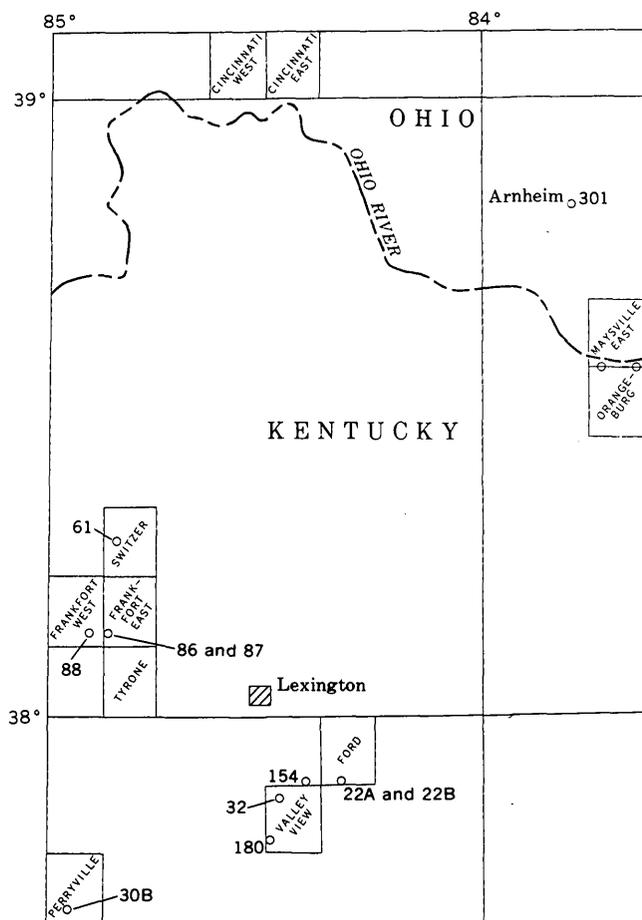


FIGURE 1.—Location of measured stratigraphic sections (numbered) in Kentucky and Ohio from which trilobites were obtained for this report. Named quadrangles are U.S. Geological Survey 7½-minute quadrangles.

shown in figure 1. Terminology of Ordovician lithologic stratigraphic units in this area has been revised recently by Weir and Greene (1965) and by Black, Cressman, and MacQuown (1965), and the reader will find familiarization with these two papers helpful in understanding the stratigraphic position of the described fossils.

A stratigraphic study and compilation using all the paleontologic information obtained so far is in preparation by E. R. Cressman and will include, among others, the sections involved here. These sections are:

Section 22B (Clays Ferry Supplementary). (See Weir and Greene, 1965, tables 1, 2.) Measured along old Clays Ferry Road, beginning about 750 ft west of bridge piers for Interstate Highway 75 to hairpin turn and uphill to barn at altitude 965 ft. Kentucky coord., south zone: E. 2,407,000 ft. N. 566, 600 ft, Ford quad., Kentucky.

Section 180 (Antioch Church). Along road from Antioch Church to Trinity Church, northwest of Kentucky River. Kentucky coord., south zone: E. 2,361,200 ft, N. 532,200 ft, Valley View quad., Kentucky. On USGS Map GQ-470 (Greene, 1966) this section is located along west edge at lat 37°47'30".

Section 32 (West Marble Creek). Measured for about 4,000 ft above mouth of creek on northeast side of Kentucky River. Kentucky coord., south zone: E. 2,370,000 ft, N. 554,800 ft, Valley View quad., Kentucky. Fossil collections indicated by R-CC on USGS Map GQ-470 (Greene, 1966).

Section 30B (Perryville South). In old quarry 0.4 mile south of Perryville. Kentucky coord., south zone: E. 2,222,200 ft, N. 478,550 ft, Perryville quad., Kentucky.

Section 88 (Frankfort West). Along eastbound lane of Interstate Highway 64, west of Kentucky River. Kentucky coord., north zone: E. 1,814,900 ft, N. 240,000 ft, Frankfort West quad., Kentucky.

Section 61 (Switzer A). Along Kentucky Highway 35, just south of Elkhorn Creek. Kentucky coord., north zone: E. 1,829,670 ft, N. 290,800 ft, Switzer quad., Kentucky.

To facilitate an understanding of the stratigraphic positions of the described trilobites, a simplified fence diagram is included as figure 2. Inferred correlations are based on incomplete evidence; when studies of other kinds of fossils have been completed, adjustments can be expected.

Two sections from which no trilobites are described are shown in figure 2 to facilitate tracing of lithologic units. These are:

Sections 86 and 87 combined (Frankfort East). Measured along Interstate Highway 64, east of the Kentucky River, 0.8 mile north of mouth of Glenss Creek, Frankfort East quad., Kentucky.

Section 154 (Spears Road). 1.2 miles northeast of Spears, in creek bottom on southeast side of Spears Road. Kentucky coords., north zone: E. 1,950,000 ft, N. 137,700 ft.

SYSTEMATIC PALEONTOLOGY

Family ASAPHIDAE, Burmeister
Genus ISOTELUS Dekay, 1824

Isotelus gigas Dekay

Plate 1, figures 1-11; plate 2, figures 1-4; text figure 3

Isotelus gigas Dekay, 1824, Lyceum Nat. History New York Annals, v. 1, pt. 1, p. 174-189, pls. 12, 13.

Isotelus gigas Dekay, Hall, 1847, Nat. History New York, pt. 6, Paleontology, v. 1, p. 231, pl. 61, figs. 3, 4; pl. 62, fig. 2; pl. 63, fig. 1.

The specimens of *Isotelus gigas* Dekay from the Lexington Limestone are silicified and consist of one large cranidium (fig. 3), one small cranidium, fragments of large free cheeks, one small complete free cheek, two fairly complete pygidia and numerous fragments, and several hypostomes. They include no complete individuals.

Surface of cephalon coarsely pitted (pl. 1, fig. 1). The absence of pits from the available pygidia may be due to immaturity of the specimens or peculiarities of silicification.

Cranidium of low convexity. Greatest width (trans.) at posterior margin equal to 1.18 times sagittal length. Width (trans.) at palpebral lobes equals 0.83 sagittal length. Width (trans.) immediately anterior (exsag.) from border "furrow" 0.79 cranidial length. Glabella ill defined anteriorly by a gentle change in slope which delimits flattened anterior border proximally. Axial furrows almost nonexistent; best defined between palpebral lobes where width of glabella is constricted to almost 0.7 its width at anterior. Glabellar width near anterior border "furrow" and at posterior edge of cranidium equal. A broadly triangular appendifer or articulating boss located vertically downward at posterior edge at each axial furrow. No central glabellar node present on large or small specimen. Palpebral lobes horizontal, almost as high as midline of glabella between them. Line between eye centers crosses glabella about one-third of its sagittal length from rear. Sagittal width of border on cranidium equals 0.16 sagittal cranidial length.

Fragments of large free cheeks possess rounded genal angles. A small cheek (pl. 1, figs. 3-5) of a size to fit a cranidium about 20 mm long is equipped with short, very slender genal spines. Doublure beneath front of cranidium very wide (sag.), extending back beneath glabella 0.4 sagittal length of cranidium; width of doublure (sag.) more than twice the width (sag.) of border. Posterior edge of doublure cut away to receive leading edge of hypostome. Slightly in front of genal angle on ventral side of doublure near margin an

elongate pit is located (pl. 1, fig. 3); purpose of this pit probably to receive anteroventral "corner" of pygidium during enrollment and to prevent separation of cephalic and pygidial shields by sliding them laterally. Fragments of large specimens show that these vincular pits are more elongate and narrower than on small ones.

Hypostome length (exsag.) almost same as greatest width (trans.) at suture with doublure. Proportions indicate that posterior tips of hypostome extended backward about as far as a line between the eyes. This position agrees with that in the specimen illustrated by Hall (1847, pl. 62, fig. 2). Posterior margin forked; sagittal length equaling half the exsagittal length. Posterior sagittal portion of middle body with a distinct dimple located one-fourth the distance from posterior margin to anterior suture. A pair of round, smooth, slightly indented spots constitute maculae, located closer to lateral notch than to posterior indentation of margin. Projected divergence of inner edges of forked posterior margin approximates 47°.

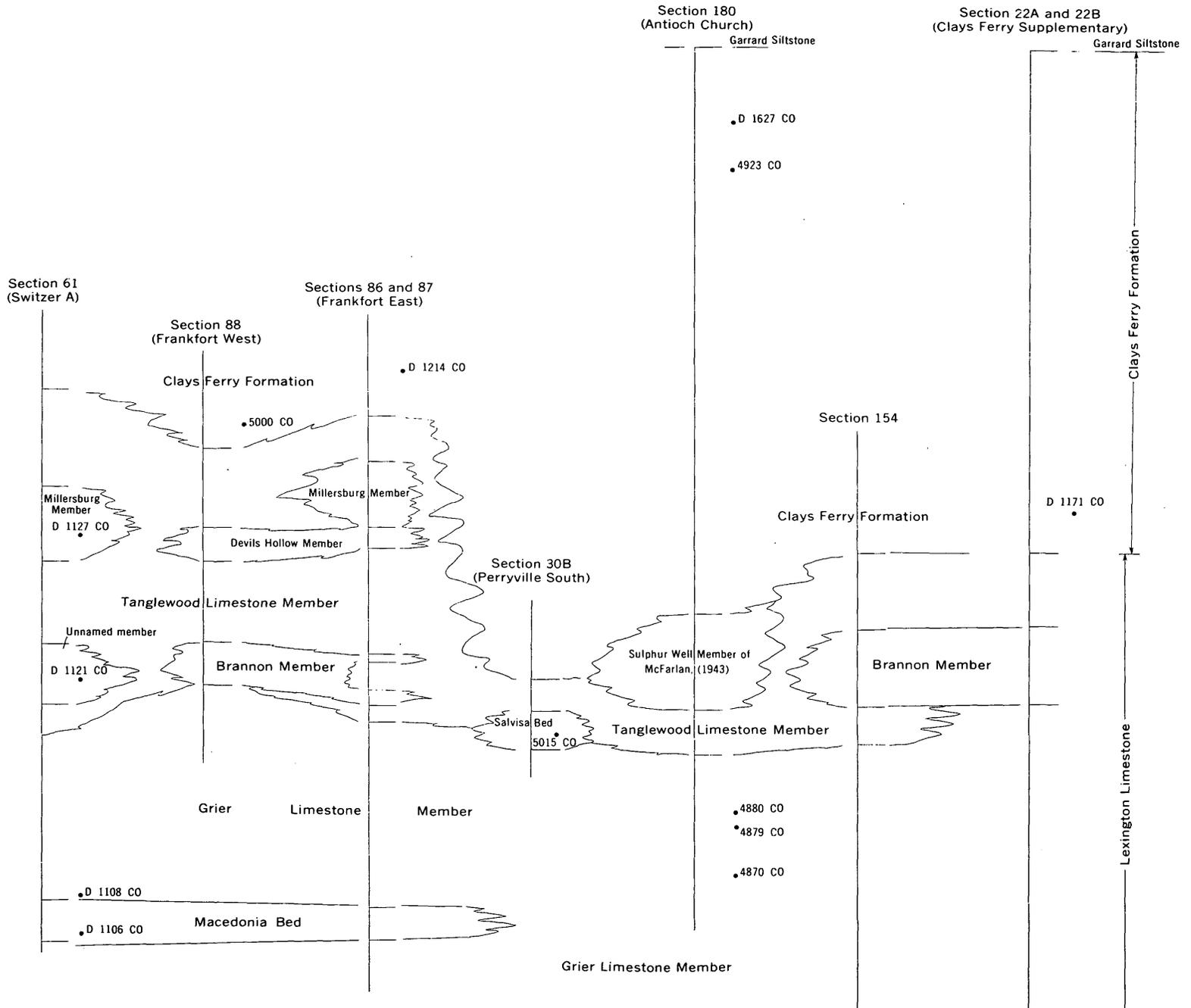
Pygidium roughly triangular in outline, moderately convex. Width of pygidium equals 1.3 its length. Surface smooth, lacking pleural furrows. Axial furrows almost nonexistent; axis defined by faint change in slope. Length of axis equals 0.86 sagittal length of pygidium; anterior width (trans.) of axis equals 0.46 greatest width (trans.) of pygidium. Border slightly flattened, separated by concave break in slope from pleural platform. Width (trans.) of border at sides of pygidium equal a little less than 0.1 the greatest width of pygidium. On ventral side doublure is folded fairly close to undersurface of border but is almost twice as wide (trans.) as border.

Figured specimens.—USNM 154375-154382.

Occurrence.—USGS colln. 5015 CO, 5 feet above base of the Salvisa Bed of the Lexington Limestone (20 ft below base of Clays Ferry Formation), section 30B (Perryville South); USGS colln. 4879 CO, Grier Limestone Member of the Lexington Limestone, 75-78 feet below base of Clays Ferry Formation, section 180 (Antioch Church); USGS colln. 4880 CO, Grier Limestone Member of the Lexington Limestone, 72 feet below base of Clays Ferry Formation, section 180 (Antioch Church).

Discussion.—The cranidium figured here (pl. 1, fig. 1) differs from that illustrated by Hall (1847, pl. 63) in that it is greater in width (trans.) between the eye centers and between the facial suture at the posterior margin relative to the sagittal length. The proportions of the pygidium are almost exactly those described by Dekay (1824).

The Kentucky specimens possess a more triangular outline of pygidium and a narrower pygidial border



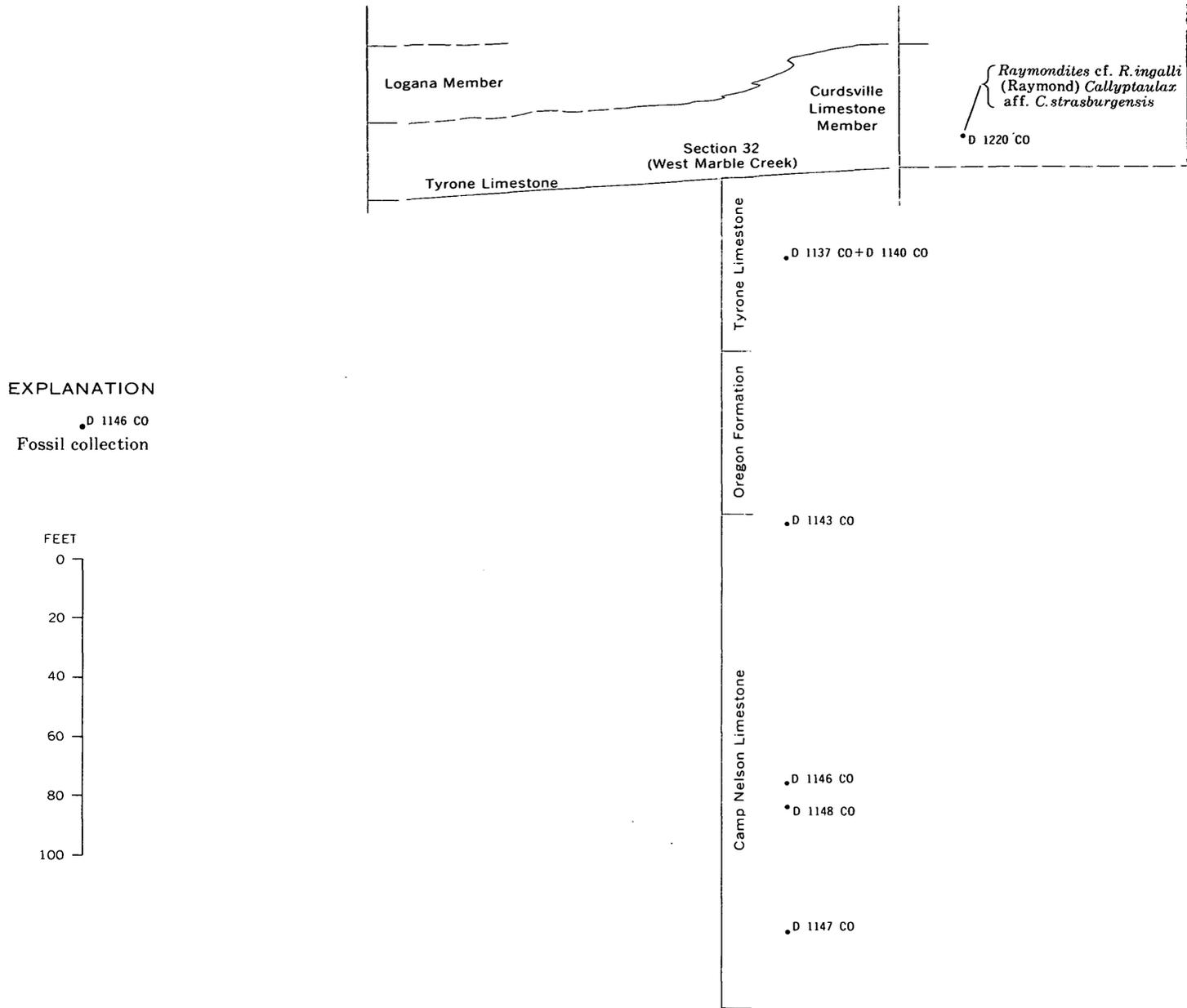


FIGURE 2.—Stratigraphic sections from which trilobites have been collected in Middle Ordovician strata of Kentucky. Tentative correlation based largely on physical stratigraphy by E. R. Cressman. Location of sections shown on figure 1.

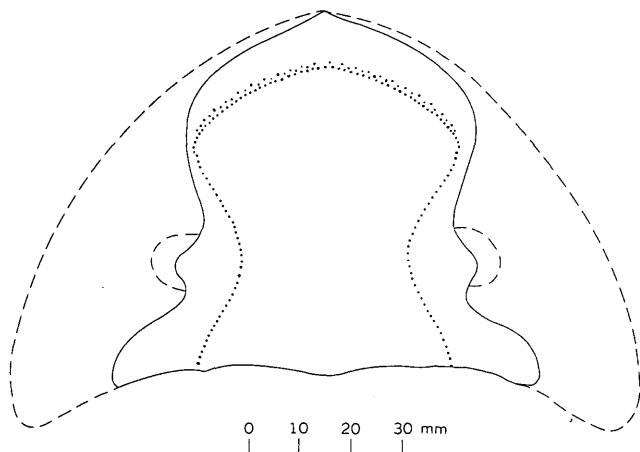


FIGURE 3.—*Isotelus gigas* Dekay. Cranium. USGS colln. 5015 CO; USNM 154375. Outline of glabella and border indicated. Shape of free cheeks estimated.

than *Isotelus platycephalus* (Stokes) (Darby and Stumm, 1965, p. 66–70, pl. 1, figs. 1–5; pl. 2, figs. 1–5). In that species, maculae of the hypostome are a little farther from the lateral notch, and the middle body is more convex. In *I. latus* Raymond the pygidium is more nearly semicircular. Overall dimensions of the pygidium of *I. ottawaensis* Wilson (1947, p. 26–27, pl. 3, fig. 5; pl. 5, figs. 1a, b) are comparable to those of the Kentucky specimens, and the shape is not very much less triangular. The eyes seem to be closer to the rear of the cephalon and considerably closer together; in this last respect they are like Hall's specimen (1847, pl. 63).

Family BATHYURIDAE Walcott
Genus BATHYURUS Billings 1859

Bathyurus? sp.

Plate 2, figures 5–7

Two pygidia from the upper part of the Camp Nelson Limestone are probably assignable to *Bathyurus*, although no cranidia were obtained to substantiate identification. The pygidia are illustrated as a matter of record.

They possess four pleura, a prominent axis with rings limited to the front part and with bluntly rounded terminus, and a concave border. Pleural furrows fade out in the border before reaching the margin.

Figured specimens.—USNM 154383, 154384.

Occurrence.—USGS colln. D1143 CO, 4 feet below top of Camp Nelson Limestone, section 32 (West Marble Creek).

Discussion.—The number of pleura, the concave border, and the manner in which pleural furrows fade out on the border suggest that these pygidia belong

to either *Bathyurus* or *Raymondites*. Distinction is impossible without cephalic parts.

If no other fossils had been collected from the Camp Nelson, the presence of *Bathyurus* might suggest a Porterfield to early Wilderness age, rather than the late Wilderness age given by Cooper (1956, chart 1).

Family PROETIDAE Salter

Genus PROETIDELLA Bancroft, 1949

Two, possibly three, species of *Proetidella* occur in the collections; identifications are based on two cranidia, four pygidia, and assorted free cheeks. The samples are far too small to be reliable; however, I do suggest that three species are represented by the four pygidia. In all the pygidia, the axis is composed of seven rings plus a small terminal piece—one more ring than in *P. fearnsidesi* Bancroft, the type species (Dean, 1963, p. 243–246, pl. 45, fig. 3). In all specimens the pygidial axis occupies 0.8 the sagittal pygidial length, and the pygidial length is equal to 0.5–0.6 the transverse pygidial width. The pygidia differ somewhat in size of the axis and in development of interpleural furrows, and these differences may have stratigraphic value.

From the "Eden Group," Caster, Dalvé, and Pope (1961, pl. II, fig. 23) illustrated as *Proetus spurlocki* Meek a specimen, which probably belongs to *Proetidella* and may be synonymous with one of the three species discussed here. However, Raymond (1914, p. 259, pl. 1, fig. 3) showed that the type specimen of Meek's species is an immature *Isotelus*, either *I. gigas* or *I. maximus*. The species name *spurlocki* is no longer available for any proetid trilobite.

Proetidella sp. 1

Plate 2, figures 8–12

Proetidella sp. 1 is represented by two pygidia and two free cheeks from USGS colln. D1106 CO. A cranidium from USGS colln. D1108 CO (pl. 2, fig. 13) may belong to the same species.

Pygidia approximately semicircular in outline, the sagittal length equaling almost half the greatest width. Axis narrowly and strongly convex, tapering to bluntly rounded terminal piece, defined clearly by lateral furrows confluent around posterior end. Sagittal length of axis approximately 0.8 pygidial length; its greatest width (trans.) equaling one-third the greatest width of pygidium. Seven axial rings diminish backward in length (sag.), the posterior two and the terminal piece of about the same length (sag.). Pleural platforms bounded distally by concave break in slope forming an ill-defined border, the radial width of which approxi-

mates 0.2 the pygidial sagittal length. Of five pairs of pleural furrows, three pairs cross the border to the margin. Four pairs of interpleural furrows, plus a very faint fifth pair, are present and are well defined proximally, as well as distally.

Figured specimens.—USNM 154385–154387.

Occurrence.—USGS colln. D1106 CO, 72 feet below top of the Grier Limestone Member of the Lexington Limestone (199 ft below base of Clays Ferry Formation). Cranidium (pl. 2, fig. 13) from USGS colln. D1108 CO, 58 feet below top of the Grier Limestone Member of the Lexington Limestone (185 ft below base of Clays Ferry Formation). Section 61 (Switzer A).

Discussion.—These pygidia differ from the pygidium of *Proetidella* sp. 2 (pl. 2, fig. 14) in their narrower, less robust axis, somewhat wider (trans.) outline, and in the better development of their interpleural furrows. *Proetidella* sp. 3 (pl. 2, figs. 16, 17) possesses a narrower axis and four pairs of interpleural furrows clearly defined distally only.

The cranidium (pl. 2, fig. 13), which may belong to *Proetidella* sp. 1, is badly damaged, lacking palpebral lobes, most of the anterior border, and part of the glabella. No glabellar furrows are evident. The width of the glabella just in front of the occipital furrow very nearly equals its sagittal length, including occipital ring. The preglabellar field is exceedingly short (sag.); the width (sag.) of the border is about one-fifth the glabellar length.

***Proetidella* sp. 2**

Plate 2, figure 14

Pygidium roughly semicircular in outline, its length (sag.) equaling 0.6 its width (trans.). Axis robust, tapering bluntly, composed of six well-defined rings, a seventh fainter ring, and a rounded terminal piece. Anterior width (trans.) of axis almost equaling 0.4 greatest pygidial width (trans.). Six pairs of pleural furrows, of which the two posterior pairs are faint. Although 4 pairs of interpleural furrows can be distinguished, only the two anterior pairs are readily discerned; these are equally developed both proximally and distally.

Figured specimen.—USNM 154389.

Occurrence.—USGS colln. D1121 CO, unnamed unit within the Tanglewood Limestone Member of the Lexington Limestone, 20 feet above top of the Grier Limestone Member (107 ft below base of Clays Ferry Formation). Section 61 (Switzer A).

Discussion.—The pygidium described here differs from pygidia of *Proetidella* sp. 1 in its more robust axis, somewhat narrower outline, and fainter development of interpleural furrows.

***Proetidella* sp. 3**

Plate 2, figures 16–18

Surface ornamented with strong Bertillion pattern. Pygidium subsemicircular in outline, about twice as wide as long. Axis prominent, its anterior width (trans.) equaling 0.3 the greatest pygidial width; composed of seven rings and a terminal piece, of which anterior four rings are more clearly delineated. Four deep pairs of pleural furrows present, plus fifth very weak pair. Anterior two pairs cross flattened border to margin, third pair reaches midway across border, and others stop at proximal edge of border. There is evidence of only three pairs of interpleural furrows, and these are impressed only distally.

Figured specimens.—USNM 154391, 154392.

Occurrence.—USGS colln. D1171 CO, 15 feet above base of Clays Ferry Formation, section 22B (Clays Ferry Supplementary).

Discussion.—This pygidium differs from those of *Proetidella* sp. 1 and *P.* sp. 2 in its very slightly narrower axis, in the poorer development of its interpleural furrows, and in the pronounced Bertillion marking of its dorsal surface.

The surface ornamentation also serves to distinguish this pygidium from the pygidia of *Proetidella* sp. 1 and *P.* sp. 2, on the exteriors of which Bertillion markings are either lacking or very poorly developed.

The associated free cheek (pl. 2, fig. 18) closely resembles the cheeks of *Proetidella* sp. 1 but possesses a somewhat longer genal spine.

A cranidium (pl. 2, fig. 15), found about 10 feet above the base of the Millersburg Member of the Lexington Limestone, in section 61 (Switzer A) (USGS colln. D1127 CO) is the only other proetid found that has such pronounced Bertillion markings. Although believed to have been found stratigraphically lower than the pygidium described here, the cranidium might belong to the same species.

Family CALYMENIDAE Burmeister

The calymenid trilobites from the Kentucky Ordovician rocks are incompletely known. As a result of the study of the collections made during the present mapping program of the Kentucky and U.S. Geological Surveys, more questions seem to have been raised than answered. Most of these questions regard stratigraphic and geographic occurrences of calymenids; some involve taxonomy.

Calymenid trilobites collected in Kentucky can be divided into two groups. One of these includes such species as *Flexicalymene meeki* (Foerste) and *F. retrorsa* (Foerste), both occurring in strata generally

considered Late Ordovician in age. A second group includes species that belong in the genus *Gravicalymene*; all specimens collected from the Lexington Limestone fall in this second group. In the course of the present program no specimens of *Flexicalymene senaria* (Conrad) were obtained from rocks of Trenton age in Kentucky.

Conrad (1841, p. 38) recognized that the calymenid from the Trenton Limestone was different from the European Silurian species *Calymene blumenbachii* to which it had previously been assigned. He (1841, p. 49) therefore proposed the name *Calymene senaria* for the species from the Trenton and presented a description; this description is very generalized by modern standards, but it does serve to distinguish Middle Ordovician forms from Silurian. Unfortunately, it is not adequate to separate the genera *Flexicalymene* and *Gravicalymene*, and Conrad published no illustration of his species that might assist in assigning "*Calymene senaria*" to one or the other.

Emmons (1842, p. 390, fig. 2) mentioned the occurrence of "*Calymene senaria*" at numerous localities where limestones of the Trenton were found, and he illustrated a complete calymenid trilobite; the illustration is a woodcut which shows two pairs of lateral glabellar lobes. Despite the inherent lack of detail in the woodcut, the figured specimen appears to be a generalized calymenid of Silurian age, and certainly not a Trenton form. Two years later, Owen (1844, p. 363-364) referred to Emmon's comments and reprinted the same woodcut.

No one seems to have heeded Vanuxem (1842, p. 48) who, in commenting on the occurrence of "*Calymene senaria*" in the Trenton Limestone, recognized that there were "two species in this rock, which are blended together in descriptions, but nevertheless require separation."

In an effort to ascertain the characteristics of type and topotype material of *Flexicalymene senaria* from Trenton Falls, N.Y., I examined collections so labeled from the U.S. National Museum and the New York State Museum at Albany. It was found that two of the National Museum collections (Acquisition Nos. 40,959, 155,678), after further preparation of specimens than had originally been attempted, include *F. cf. F. senaria* (Conrad) and probably two species of *Gravicalymene*. The same is true of the New York State Museum specimens, except that one (pl. 4, figs. 11-13) represents a species of *Flexicalymene* that is undescribed and definitely not *F. senaria* (Conrad). Furthermore, of three specimens from the American Museum of Natural History (all labeled No. 834/1), the one illustrated by Hall (1847) in plate 64, figure 3a, belongs to the genus *Gravi-*

calymene (pl. 3, figs. 22, 23). The one in Hall's figure 3b (shown here in pl. 4, figs. 1-6) is a complete but immature specimen and is the first specimen from the Trenton Limestone illustrated by anyone which belongs to *Flexicalymene* and fills the generally accepted concept of *F. senaria*. I therefore designate this specimen the neotype of the species.

It is regrettable that the exact locality and the stratigraphic position from which this specimen was obtained are not known. Much detailed work needs to be done in the area of the type Trenton Limestone of New York in order to establish the ranges of several species of *Flexicalymene* and associated species of *Gravicalymene*. Whether the seeming absence of *F. senaria* from Kentucky is real or the result of spotty collecting will have to be determined in the future.

Dean (1962, p. 111) suggested that *Calymene callicephala* Green and *Flexicalymene meeki* (Foerste) might constitute a distinct Late Ordovician genus. *F. retrorsa* (Foerste) would have to be included here, as would the new species, *F. griphus*, described below. However, *F. griphus* seems to provide an intermediate form between species like *F. senaria* and *F. meeki*, both morphologically and stratigraphically; at present, little seems to be gained by erecting another genus.

Whittington (1965, p. 57) noted that the relation of length to width of glabella is one of several criteria for distinguishing species of *Flexicalymene*. In this study I have been surprised at the uniformity of this relationship regardless of species or genus. The length of the glabella including occipital ring seems to equal the width at lateral lobes *1p*; deviations from this equality fall well within reasonable ranges of intraspecific variability even when comparing calymenid genera. Unless future studies are contradictory, I suggest that large deviations from a 1:1 proportion may be more useful in distinguishing deformed specimens than in discriminating between species.

Genus GRAVICALYMENE Shirley, 1936

Gravicalymene Shirley, 1936, Geol. Soc. London Quart. Jour., v. 92, p. 395.

Gravicalymene Shirley. Dean, 1962, British Mus. Nat. History Bull., Geology, v. 7, no. 3, p. 113-114, 116-118.

Several species from Kentucky possess the "bell-shaped" glabellar outline which Shirley (1936, p. 395) considered one characteristic of *Gravicalymene*. Dean (1962, p. 112-114) pointed out the variable nature of the "rolled" border of this genus and in assigning to it *G. praecox* (Bancroft) and *G. jugifera* Dean (1962, p. 116-118, pl. 14, figs. 3, 4, 8) emphasized that the border may be flattened dorsally or posterodorsally; the flattened surface is separated from the glabella by a

trenchlike border furrow as in ideally preserved examples of *Reacalymene*. Although both Dean (1962, p. 112) and Whittington (1965, p. 57-58) considered the development of the break between the surface of the border and the anterior side of the trenchlike border furrow to be variable in *Reacalymene*, it seems to be a remarkably consistent feature in *Gravicalymene*. Not only do *G. jugifera* Dean, *G. praecox* (Bancroft) (Dean, 1963, p. 225, pl. 39, figs. 1, 3, 9, 12-14), and *G. inflata* Dean (1963, p. 227, pl. 39, fig. 6) show this feature, but several North American species also possess both the same kind of border and a bell-shaped glabellar outline. These include:

Flexicalymene quadricapita Stumm and Kauffman (1958, p. 951-953, pl. 124, figs. 2-16) (this report, pl. 2, fig. 23).

Flexicalymene praelongicephala Stumm and Kauffman (1958, p. 953-954, pl. 123, figs. 14, 15).

Undescribed species from the Maquoketa Shale of Iowa (USGS colln. 206p. (Ulrich)), figured in this report (pl. 4, figs. 14, 15) as a matter of record.

Two undescribed species from the Trenton Limestone at Trenton Falls, N.Y., also figured (pl. 3, figs. 18-23; pl. 4, figs. 7-10) as a matter of record.

Several species from Kentucky described below.

The bell-shaped glabellar outline, which tends to be concave sided, results from the posterior pair of lateral lobes *1p* being generally larger in relation to pairs *2p* and *3p* than in species of *Flexicalymene*. The frontal lobe of the glabella tends to be bluntly rounded or subquadrate in anterior outline. In *Flexicalymene* and its subgenus *Reacalymene*, the axial furrows are tangent to all three lateral glabellar lobes, and the frontal lobe and the axial furrows are either straight or slightly curved, giving the glabella a convex-sided (parabolic) outline.

Pygidia of the Kentucky specimens bear a narrowly convex axis divided into four distinct rings, a fifth less distinct ring, and a terminal piece. The terminal piece bears one fairly distinct transverse furrow, delineating a weak anterior segment, and may bear one additional extremely faint furrow. Including the furrow next to the anterolateral facet, five pairs of pleural furrows are developed; four pairs of interpleural furrows are distinct, though narrow, both proximally and distally on the pleural platforms. The fifth pair of interpleural furrows that should correspond to the division between fifth axial ring and terminal piece is never developed.

It is probable that *Gravicalymene jugifera* Dean (1962, p. 117-118, pl. 13, figs. 9, 11; pl. 14, fig. 9), all figured specimens of which are internal moulds, possesses a pygidium similar to the Kentucky forms, whereas *G. cf. G. praecox* (Dean 1963, pl. 39, figs. 5, 8) seems to possess one more axial ring and one more pair of pleurae. The British species *Flexicalymene caractaci*

(Salter) (Dean, 1963, pl. 38, fig. 5) and *F. (Reacalymene) pusulosa* (Shirley) (Dean, 1963, pl. 37, fig. 12) possess the same basic pygidium as the Kentucky species of *Gravicalymene*, and it is probable that this generalized design amongst calymenids has little intergeneric significance in the Middle Ordovician.

The pygidia of *Gravicalymene* differ from those in *Flexicalymene retrorsa* and *F. meeki*; these two species have poorly developed interpleural furrows except distally and have a less convex axis and a shorter terminal piece than in the Kentucky specimens referred to *Gravicalymene*.

Dean (1962, p. 113-114) indicates that *Gravicalymene praecox* Bancroft and Lamont is the oldest British species of the genus occurring in the Harnagian (Middle Caradocian) and that the genus ranges into the Devonian. The species described below are probably Caradocian in age.

Gravicalymene hagani n. sp.

Plate 3, figures 1-12

Gravicalymene hagani n. sp. is represented in the collections by silicified material. The largest of three cranidia unfortunately is broken (pl. 3, figs. 3, 4); a somewhat smaller one is beautifully preserved (pl. 3, figs. 1, 2). Although the range in size between these two specimens is not so great as might be desired, it does show that some changes in proportion took place with growth. Range in size of pygidia is also limited.

Surface covered by very fine tubercles of several sizes; a few of these are raised rims around perforations as described by Evitt and Whittington (1953, p. 53); perforations seem to be better preserved on smaller than on larger cranidium, possibly because silicification of specimen is too coarse for such fine detail to be resolved. Abraded specimens such as free cheek shown in figures 9 and 10 of plate 3 and smallest cranidium (not illustrated) exhibit multitude of perforations. These perforations probably not peculiar to this species but better shown in silicified preservation.

Width (trans.) of cranidium at anterior border furrow equaling cranidial length (sag.) in a specimen 9 mm long but equaling 0.9 length in one 7 mm long. Width (trans.) at posterior margin equaling 1.8 cranidial length in smaller of these specimens.

Glabellar length (sag.) equaling 0.8 that of cranidium. Glabella bell shaped in outline. Width (trans.) of frontal lobe equals 0.5 width at lateral lobes *1p* in larger specimen and 0.6 in smaller. Length of frontal lobe equaling 0.23 length (sag.) of glabella exclusive of occipital ring in larger specimen, and 0.3 in smaller.

Greatest width (trans.) of glabella at lateral lobes *1p* equaling glabellar length, including occipital ring.

Palpebral lobes centered opposite front half of lateral glabellar lobes *2p*. Width of each fixed cheek equals 0.5 the width of glabella on a line through eye centers.

Anterior border somewhat inflated, not fully flattened, sloping downward and backward at 30°–45° from horizontal, bounded proximally by deep, trenchlike border furrow. Combined width (sag.) of border and furrow equals 0.2 total sagittal length of cranidium, seemingly regardless of size of cranidium (this may not be true of cranidia less than 5 mm long). Width (sag.) of border furrow is a third that of border in larger specimen and less than 0.2 that of border in smaller. (Compare figs. 1 and 4, pl. 3.)

No hypostome or thoracic segments found.

Pygidium with anterior outline more sharply curved than posterior, markedly convex with robust axis of five rings and terminal piece. Greatest width of pygidium 1.5–1.7 times length (sag.) exclusive of articulating half ring. Axial length (sag.) excluding articulating half ring equals 0.9 total length of pygidium. Anterior width (trans.) of axis equaling 0.7 length of axis. Terminal piece composed of one weak indistinct anterior ring, a second less distinct partial ring, and a bluntly rounded portion which, in some specimens, is very faintly creased transversely. Length of terminal piece equaling 0.4 length of axis (excluding articulating half ring) and equal to 0.8 its own greatest width. Pleural furrows deep, well developed, extending to but not crossing margin. Four pairs of interpleural furrows shallow, narrow, yet distinct proximally as well as distally; fading out as they cross margin distally.

The dimensions, in millimeters, of two cranidia and three pygidia of *Gravicalymene hagai* n. sp. are as follows:

Cranidium	Dimensions of USNM specimens, in millimeters	
	154397	154398
Length of cranidium (sag.)	9.15	6.77
Width of cranidium (trans.) at posterior margin	(?)	12.15
Width of cranidium at anterior border furrow	9.0	5.93
Length (sag.) of glabella	7.25	5.4
Length (sag.) of glabella excluding occipital ring	5.9	4.1
Length of frontal lobe of glabella	1.35	1.17
Width of glabella at lateral lobes <i>1p</i>	7.75	5.23
Width of glabella at frontal lobes	4.0	3.2
Width of anterior border (sag.)	1.5	1.17
Width of preglabellar border furrow	.5	.2

Pygidia	154401	154400	154402
Greatest width (trans.)	10.9	12.1	13.3
Length (sag.) excluding articulating half ring	7.3	7.9	7.8
Length (sag.) of axis, excluding articulating half ring	6.9	7.1	7.0
Width (trans.) of axis at front	5.0	5.0	5.0
Length (sag.) of terminal piece	2.5	2.7	2.5
Width (trans.) of terminal piece	3.1	3.4	3.3

Holotype.—USNM 154397.

Paratypes.—USNM 154398–154402.

Occurrence.—USGS colln. 5015 CO. Salvisa Bed of the Lexington Limestone, 21 feet below base of Clays Ferry Formation. Section 30B (Perryville South).

Discussion.—Although the available sample of three cranidia and five pygidia is small, it is considered representative. The variation the sample shows is mainly in changes with growth—the widening of anterior border furrow and shortening of frontal lobe of glabella.

The species is very much like *Gravicalymene* sp. 3 in USGS colln. 5000 CO from the lower part of the Clays Ferry Formation in the Frankfort West section. If enough specimens of the latter were available to show range of variation, it is possible that the two would prove synonymous. In available specimens they seem to differ only in the width (trans.) of the cranidium at the anterior border furrow.

Cranidial features of *Gravicalymene hagai* are very similar to those of *G. convolva* Shirley (1936, p. 410, pl. 29, figs. 16–18), although the eyes of the latter may be a little closer to the back of cephalon; on the pygidium of the British species pleural and interpleural furrows do not reach the margin, whereas in *G. hagai* they do. *G. jugifera* Dean (1962, pl. 13, figs. 9, 11) has a more narrowly rounded frontal lobe of the glabella and a somewhat narrower (sag.) anterior border. *G. inflata* Dean (1963, pl. 39, fig. 6) possesses much wider fixed cheeks than does the cranidium of *G. hagai*. Although overall proportions of the cranidium and glabella of *G. praecox* (Bancroft) (Dean, 1963, pl. 39, figs. 1, 3, 9, 12) are similar to those of the Kentucky species, the glabella of *G. praecox* has a less convex lateral profile, and its width at lateral lobes *3p* is no greater than at the frontal lobe; this last condition produces a markedly concave lateral outline in dorsal view. The anterior border is narrower (sag.) than in *G. hagai*.

Gravicalymene? sp. 1

Plate 2, figures 21, 22

Gravicalymene? sp. 1 is represented by a single small pygidium.

Crude outline transversely elliptical. Anterior outline more sharply curved than posterior. Greatest width about $1\frac{1}{2}$ times length. Axis robust, strongly convex; its length exclusive of articulating half ring consuming 0.9 equals sagittal length of pygidium. Anterior width of axis (trans.) equals 0.67 length of axis. Axis composed of four strong rings, a very weak fifth ring, and a terminal piece. Terminal piece itself composed of one very weak indistinct ring, and a quarter-spherical portion. Length of terminal piece equals 0.3 total length of axis, exclusive of half-ring, and 0.6 its own greatest width.

The dimensions, in millimeters, of the pygidium of *Gravicalymene?* sp. 1 are as follows:

	Millimeters
Width	8.9
Length exclusive of articulating half ring.....	5.3
Anterior width of axis.....	3.3
Length of axis.....	4.8
Length of terminal piece.....	1.4
Width of terminal piece.....	2.3

Figured specimens.—USNM 154403.

Occurrence.—USGS coll. D1106 CO. Seventeen feet above base of the Grier Limestone Member of the Lexington Limestone, section 61 (Switzer A) (199 ft below base of Clays Ferry Formation).

Discussion.—In this specimen the terminal piece of the axis is shorter relative to the length and width of the axis than in any of the other specimens assigned to *Gravicalymene* from Kentucky.

Unfortunately, no cephalic parts were found associated in this collection.

Gravicalymene sp. 2

Plate 2, figures 19, 20

Gravicalymene sp. 2 is represented by a single imperfect cranidium.

Entire surface of cranidium, except in furrows, covered by very fine granules of seemingly uniform size. Approximate width (trans.) at posterior margin of cranidium equals 1.9 cranidial length (sag.). Width at anterior border furrow equals 0.88 cranidial length (sag.).

Glabellar outline bell shaped, widest through lateral lobes *1p*, decreasing in width forward to lateral lobes *3p*, maintaining uniform width from lobes *3p* forward to anterior "corners" of frontal lobe. Length (exsag.) of frontal lobe equals 0.31 sagittal length of glabella,

excluding occipital ring. Greatest width (trans.) of glabella at lateral lobes *1p* equals total length (sag.) of glabella, including occipital ring. Width of glabella at frontal lobe equals 0.57 width at lateral lobes *1p*.

Palpebral lobes centered opposite front half of lateral glabellar lobes *2p*. Width of each fixed cheek at palpebral lobes equal to 0.5 the width of glabella on line through eye centers.

Anterior border flat, horizontal, its breadth (sag.) equals 0.22 length (sag.) of cranidium. Border furrow (synonymous with preglabellar furrow) deep, narrow.

The dimensions, in millimeters, of the cranidium of *Gravicalymene* sp. 2 are as follows:

Dimensions in millimeters:

	Millimeters
Length (sag.) cranidium.....	9.1
Width (trans.) cranidium at posterior margin.....	17.2
Width (trans.) cranidium at anterior border furrow	8.0
Length (sag.) glabella.....	7.3
Length (sag.) glabella excluding occipital ring	5.6
Length frontal lobe of glabella.....	1.75
Width glabella at lateral lobe <i>1p</i>	7.3
Width glabella at frontal lobe.....	4.2
Width (sag.) anterior border.....	2.0

Figured specimen.—USNM 154404.

Occurrence.—USGS colln. 4870 CO, Grier Limestone Member of the Lexington Limestone, 95 feet below base of Clays Ferry Formation (21 ft above base of section). Section 180 (Antioch Church).

Discussion.—This cranidium differs from all others encountered in the present study in the horizontal attitude of its anterior border. It differs strikingly from the cranidium of *Gravicalymene* sp. 4 found in USGS colln. D1627 CO (178 ft above base of Clays Ferry) (pl. 3, figs. 14–17) in the more quadrate anterior outline of its glabella and greater width of cranidium at anterior border furrow. Glabellar width at lateral lobes *1p* is slightly more than in *G. quadricapita* (Stumm and Kauffman) or in *G. aff. G. quadricapita* (pl. 4, figs. 14, 15). In shape and proportions of glabella and position of palpebral lobes it resembles all other cranidia referred to *Gravicalymene* in this study.

Gravicalymene sp. 3

Plate 2, figures 24–27

Gravicalymene sp. 3 is represented by a single incomplete cranidium and several pygidia from USGS colln. 5000 CO.

Entire surface of cranidium, except in furrows, covered by fine granules of seemingly uniform size. Width of cranidium at anterior border furrow equals 0.8 length (sag.) of cranidium.

Glabellar outline bell shaped, widest at lateral lobes *1p*, decreasing anteriorly past lobes *3p* to posterior part of frontal lobe. Outline of frontal lobe almost quadrate, its anterior very slightly curved. Width of frontal lobe equals 0.59 greatest glabellar width. Length of frontal lobe equals 0.25 length (sag.) of glabella, exclusive of occipital ring. Greatest width (trans.) of glabella at lateral lobes *1p* equals length (sag.) of glabella, including occipital ring.

Palpebral lobes seemingly centered opposite front part of lateral lobes *2p*. Width (trans.) of each fixed cheek at palpebral lobes equals 0.5 the width (trans.) of glabella on line through eye centers.

Anterior border flat, inclined downward and backward at about 45°. Its width (sag.) equaling 0.5 cranial length (sag.) Anterior border furrow, deep, undercutting front of glabella, wide compared to other dorsal furrows; width of border furrow (sag.) about one-fourth width (sag.) of anterior border.

No specimens of hypostome or thorax were found.

Pygidium crudely transversely elliptical, with anterior outline somewhat more sharply curved than posterior. Greatest width about 1.7 times the greatest length (sag.). Axis strong (excluding articulating half ring), equaling 0.91 sagittal length of pygidium. Anterior width of axis equals 0.71 length of axis. Axis composed of four strong rings and terminal piece. Terminal piece itself composed of a weak yet distinct anterior ring, a second less distinct ring, and a bluntly rounded posterior portion. Length of terminal piece equals 0.37 length of axis (excluding articulating half ring) and 0.8 its own greatest width.

Pleural furrows deep, well developed, extending to but not crossing margin. Four pairs of interpleural furrows faint, almost obsolete close to axial furrow, stronger close to margin, which they cross.

The dimensions, in millimeters, of the cranium and pygidium of *Gravicalymene* sp. 3 are as follows:

Dimensions in millimeters:

Cranidium	Millimeters
L (sag.) cranium.....	13.4
W (trans.) cranium at posterior margin...? (broken)	
W (trans.) cranium at anterior border furrow	11.0
L (sag.) glabella.....	10.6
L (sag.) glabella excluding occipital ring.....	8.0
L frontal lobe of glabella.....	2.0
W glabella at lateral lobe <i>1p</i>	10.6
W glabella at frontal lobe.....	6.3
W anterior border (sag.).....	2.0
W preglabellar border furrow (sag.).....	0.75

Pygidium	Millimeters
Length.....	6.5
Greatest width.....	10.8
Length of axis, exclusive of articulating half ring.....	5.9
Width of axis at front.....	4.2
Length of terminal piece.....	2.2
Width of terminal piece.....	2.7

Figured specimens.—USNM 154405, 154406.

Occurrence.—USGS colln. 5000 CO, Clays Ferry Formation, 8 feet above base, section 88 (Frankfort West). USGS colln. D1214 CO, Clays Ferry Formation, 16 feet above base, sections 86 and 87 (Frankfort East).

Discussion.—This species differs from *Gravicalymene* sp. 2 in colln. 4870 CO (pl. 2, figs. 19, 20) in the inclination of its anterior border, lesser width (sag.) of the border, greater width (sag.) of the preglabellar anterior border furrow, very slightly greater width (trans.) of the glabella at lateral lobes *3p*, and slightly shorter (sag.) frontal lobe of the glabella. It differs from *G.* sp. 4 found in colln. D1627 CO (pl. 3, figs. 14–17) in the more quadrate outline of the anterior of its glabella. The terminal piece of the pygidium is longer than in *G.*? sp. 1 from colln. D1106 CO (pl. 2, figs. 21, 22). Comparison with *G. hagani* n. sp. in colln. 5015 CO (pl. 3, figs. 1–12) is included under discussion of that species.

Gravicalymene sp. 4

Plate 3, figures 14–17

Gravicalymene sp. 4 is represented by two cranidia so different from others that they surely represent a distinct species.

Surface fairly coarsely pustulose, many pustules being craterlike perforations of the carapace. Posterolateral portions broken. Width of cranium at anterior border furrow equals 0.75 cranial length (sag.).

Glabella bell shaped in outline. Width of glabella greatest at lateral lobes *1p*, decreasing forward to anterolateral corners of frontal lobe. Frontal lobe subquadrate to broadly rounded in anterior outline. Length (exsag.) of frontal lobe equal to 0.27 sagittal length of glabella, excluding occipital ring. Greatest width (trans.) of glabella at lateral lobes *1p* equals 0.92–0.97 length of glabella, including occipital ring. Width of glabella at posterior of frontal lobe equals 0.55–0.58 width at lateral lobes *1p*.

Palpebral lobes semicircular, prominent; total width (trans.) of free cheek, including palpebral lobe, equal

to 0.5 width (trans.) of glabella on line through eye centers. Eyes centered opposite lateral glabellar furrow *2p* in the smaller specimen, but opposite lateral lobe *2p* in the larger.

Anterior border flattened, sloping downward and backward at about 45°. Width (sag.) equals 0.4–0.18 cranial length (sag.). Combined width of anterior border and trenchlike anterior border furrow equals 0.2–0.24 cranial length. Width of furrow equals 0.4–0.5 width (sag.) of border.

The dimensions, in millimeters, of the cranidia of *Gravicalymene* sp. 4 are as follows:

Cranidium	Dimensions of USNM specimens, in millimeters	
	154407	154408
Length (sag.) of cranidium.....	6.67	14.7
Width (trans.) of cranidium at anterior border furrow.....	5.0	11.07
Width of cranidium at posterior margin.....	(¹)	(¹)
Length of glabella (sag.).....	5.0	11.1
Length of glabella exclusive of occipital ring.....	3.86	8.3
Length of frontal lobe of glabella (exsag.).....	1.03	3.0
Width (trans.) of glabella at lateral lobe <i>1p</i>	4.9	10.2
Width (trans.) of glabella at front lobe.....	2.84	5.6
Width (sag.) of anterior border.....	1.17	2.1
Width (sag.) of border plus border furrow.....	1.6	2.9

¹ Broken.

Figured specimens.—USNM 154407, 154408.

Occurrence.—USGS colln. D1627 CO. Clays Ferry Formation, 178 feet above base. Section 180 (Antioch Church).

Discussion.—This species differs from all others described in this report in that it has a low lateral glabellar profile and its palpebral lobes are opposite lateral glabellar lobes *2p*. In the latter respect it resembles *Gravicalymene quadricapita* Stumm and Kauffman (this report, pl. 2, fig. 23). The palpebral lobes are semicircular, rather than semielliptical. The cranial width (trans.) at the anterior border furrow (relative to sagittal cranial length) is less than in other species.

Gravicalymene sp. 4 most closely resembles *G.* sp. 3 but differs in the somewhat narrower (trans.) frontal glabellar lobe and wider (sag.) anterior border furrow. If a larger sample were available, it might show that *G.* sp. 4 and *G.* sp. 3 were synonymous.

As indicated in the following section, it is possible, perhaps probable, that the pygidium designated *Gravicalymene?* sp. 5 should be assigned to this species, but the association cannot be proved.

The species *G.* sp. 4 is associated with *Flexicalymene griphus* n. sp.

Gravicalymene? sp. 5

Plate 3, figure 13

A single partially preserved pygidium is included in USGS colln. 4923 CO, taken from float which may have been derived from the same beds as USGS colln. D1627 CO. If so, the cranidia shown on plate 3, figures 14–17 probably belong with this pygidium.

Surface finely pustulose. Anterior outline more sharply curved than posterior; moderately convex, but may have been crushed. Greatest width equaling 1.6 times sagittal length, excluding articulating half ring. Length of axis equaling 0.9 total length (sag.) of pygidium. Anterior width of axis equaling 0.75 length of axis. Axis composed of five rings plus terminal piece; terminal piece itself composed of one distinct ring and bluntly rounded posterior portion. Length of terminal piece equaling 0.4 length of axis and almost equaling its own width. Pleural furrows deep and well developed; interpleural furrows poorly developed, stronger distally than proximally.

The dimensions, in millimeters, of the pygidium of *Gravicalymene?* sp. 5 are as follows:

Dimensions in millimeters:

Pygidium	Millimeters
Greatest width (approx).....	16.6
Length excluding articulating half ring.....	10.4
Length of axis, excluding articulating half ring.....	9.3
Width of axis (approx).....	7.0
Length of terminal piece.....	3.8
Width of terminal piece.....	3.9

Figured specimen.—USNM 154409.

Occurrence.—USGS colln. 4923 CO, Clays Ferry Formation, from float 161 feet above base. Section 180 (Antioch Church).

Discussion.—This solitary specimen has much in common with pygidia of *Gravicalymene hagani* n. sp., from which it differs in two respects. Relative to its own width, the length of the terminal piece is greater than in other specimens previously described. The development of the anterior ring of the terminal piece is much better than in other specimens here assigned to the genus; one is tempted to consider it a sixth axial ring rather than as a part of the terminal piece.

Genus FLEXICALYMENE Shirley 1936

Flexicalymene Shirley, 1936, Geol. Soc. London Quart. Jour., v. 92, p. 395.

Flexicalymene Shirley, Dean, 1962, British Mus. Nat. History Bull., Geology, v. 7, no. 3, p. 111–112.

The concept of *Flexicalymene* Shirley as modified by Dean (1962, p. 111–112) is used in this report for several species, which range from well above the base of the

Clays Ferry Formation into the Bull Fork Formation of the Richmond Stage. No specimens of *Flexicalymene* were obtained from the Lexington Limestone. Although *Gravicalymene* was found, the lack of *Flexicalymene* may have been because of incomplete collecting. I am reluctant without additional investigation to draw ecologic or other conclusions from its seeming absence in the Middle Ordovician part of the section. *F. senaria* is reported in the Trenton Limestone at Trenton Falls, N.Y., and has been reported by Stumm and Kauffman (1958, p. 945, 949-950) from Michigan. This species, or a very similar one, is also known from the "top of the Trenton" near Reedsville Pa. (USGS colln. 425M5 (Ulrich)).

As used in this report, *Flexicalymene* includes species with parabolic to subparabolic glabellar outlines. Whittington (1941, p. 493) described this shape as "subtriangular in outline, with rounded anterior end." The axial furrows are nearly straight approximating tangency to the lateral glabellar lobes *1p* and to the sides of the frontal glabellar lobe. In contrast, the bell-shaped glabellar outline of *Gravicalymene* is caused by curving axial furrows that make glabellar sides seem concave, rather than straight or convex, and by the subquadrate rather than anteriorly rounded frontal lobe.

In the North American species of *Flexicalymene* the palpebral lobes are centered opposite lateral glabellar furrow *2p* or some part of lateral lobes *3p*. All the species here referred to *Gravicalymene* as well as *G. quadricapita* Stumm and Kauffman seem to have eyes centered opposite the anterior part of lateral lobes *2p* but behind furrow *2p*.

A specimen, chosen as neotype of *Flexicalymene senaria* (Conrad), from Trenton Falls is illustrated (pl. 4, figs. 1-6) for purposes of ready comparison. The anterior border is smooth without a pronounced preglabellar anterior border furrow. The pygidium is subtriangular with a long axial terminal piece similar to that shown in *Gravicalymene?* sp. 5 (pl. 3, fig. 13) but like no specimens assigned in this report to *Gravicalymene*.

***Flexicalymene meeki* (Foerste)**

Plate 5, figures 4-7

Calymene meeki Foerste, 1910, Denison Univ., Sci. Lab., Bull., v. 16, art. 2, p. 84, pl. 3, fig. 18.

Surface covered by extremely finely granular texture except in furrows.

Width (trans.) of cranium at anterior border furrow equaling 0.81 length (sag.); width (trans.) at posterior border equaling 2.1 times cranial length (sag.). Length (sag.) of glabella equaling 0.78 cranial

length. Greatest width (trans.) of glabella at lateral lobes *1p* equals glabellar length. Width (trans.) at frontal lobe equals 0.54 greatest glabellar width. Length (sag.) of frontal lobe equal to 0.2 sagittal length of glabella exclusive of occipital ring.

Anterior border inclined upward and forward at high angle, although not so steeply as in *F. retrorsa*. Width (sag.) of border equal to 0.18 total length (sag.) of cranium.

Thorax composed of 13 segments. Dorsal surface of axis becomes increasingly flattened toward rearmost segments.

Pygidium composed of steeply sloping pleural areas with low axis, flattened along crest. Axial and pleural furrows clearly incised. Interpleural furrows very faint, being best defined close to axial furrows and near margin; interpleural furrows probably would not be visible on any but best preserved specimens. Axis composed of four rings, very short (sag.), very weak fifth ring, and terminal piece. Terminal piece itself composed of mere suggestion of vestigial ring merging into subquadrate posterior portion. Greatest width of pygidium equals 1.6 its sagittal length. Axis consumes 0.89 pygidial length (sag.). Anterior width (trans.) of axis equal to 0.44 of pygidial width (trans.) and equal to 0.81 of its own length. Length (sag.) of terminal piece 0.3 length of axis and 0.58 its own width.

The dimensions, in millimeters, of the cranium and pygidium of *Flexicalymene meeki* (Foerste) are as follows:

<i>Cranidium</i>	<i>Millimeters</i>
Width (trans.) cranium at anterior border furrow.....	10.5
Width (trans.) cranium, posterior border.....	27.8
Length (sag.) cranium.....	13.1
Length (sag.) glabella.....	10.7
Length (sag.) glabella, exclusive occipital ring.....	8.1
Width (trans.) glabella, lateral lobes <i>1p</i>	10.7
Width (trans.) glabella, lateral lobes <i>2p</i>	8.3
Width (trans.) glabella, frontal lobe.....	5.7
Length (sag.) frontal lobe.....	1.7
Width (sag.) of anterior border.....	2.3
<i>Pygidium</i>	<i>Millimeters</i>
Length (sag.) pygidium exclusive articulating half ring.....	8.8
Width (trans.) pygidium.....	14.3
Length (sag.) axis, exclusive articulating half ring.....	7.8
Length (sag.) terminal piece.....	2.3
Width (trans.) axis.....	6.3
Width (trans.) terminal piece.....	4.0

Figured specimen.—USNM 154420.

Occurrence.—Bellevue Limestone Member of the McMillan Formation, in excavation for Liberal Supermarket, 1,050 feet south of Galbraith road and 350 feet east of Hamilton Ave., Cincinnati, Ohio. Ohio co-

ordinates, south zone: E. 1,419,800 feet, N. 448,930 feet. Collected by Dr. John Pojeta.

Discussion.—This species can be distinguished from *Flexicalymene retrorsa* only on the basis of the anterior border which is considerably wider (sag.) and less steeply inclined. From *F. senaria* it is readily distinguished by glabellar outline as well as configuration of the anterior border. In *F. senaria* the border is even wider (sag.) and less steeply inclined; the glabella is convex in lateral outline; furthermore, its pygidium is characterized by a more convex axis and distinct well-formed interpleural furrows. In this connection it should be noted that *F. meeki* is sometimes incorrectly stated to lack interpleural furrows; as shown on plate 5, figures 6 and 7, they are indeed very faint but are not completely lacking.

A species, *Flexicalymene griphus* n. sp., intermediate between *F. meeki* and *F. retrorsa* in development of the anterior border, occurs in the upper part of the Clays Ferry Formation at the Antioch Church section (USGS colln. D1627 CO).

Flexicalymene cf. *F. retrorsa* (Foerste)

Plate 5, figures 8–12

Calymene meeki-retrorsa Foerste, 1910, Denison Univ. Sci. Lab. Bull., v. 16, art. 2, p. 85, pl. 3, fig. 19; 1919, v. 19, art. 5, pl. 18, fig. 2.

Foerste's original type specimen came from the middle beds of the Waynesville Shale of Richmond age in Indiana. It, like most of Foerste's types, is no longer available. For purposes of comparison a specimen is illustrated here (pl. 5, figs. 8–12) that was collected by G. W. Weir from the base of the type section of Foerste's Arnheim Formation in Ohio. It differs from the type specimen in possessing blunt genal spines but is believed to be similar in all other respects.

Surface of carapace having an exceptionally finely granular texture. Width (trans.) of cranidium at anterior border furrow equals 0.8 sagittal cranidial length; width at posterior margin equals 2.1 cranidial length. Glabellar length (sag.) equals 0.84 cranidial length (sag.). Glabellar width (trans.) at lateral lobe *1p* equals 1.08 length of glabella. Width at frontal lobe equals 0.54 width at lateral lobes *1p*. Length (sag.) of frontal lobe equal to 0.21 length (sag.) of glabella, exclusive of occipital ring.

Palpebral lobes centered opposite glabellar lateral lobe *3p*. Width (trans.) of each fixed cheek at palpebral lobes equals one-half width (trans.) of glabella on line through eye centers.

Anterior border narrow (sag.), turned upward to nearly vertical, bounded proximally by very faint bor-

der furrow; in front of glabella this furrow defined more by lack of granular surface texture than by topography. Width (sag.) of border equals 0.12 total length of cranidium.

Thorax composed of 13 segments.

Pygidium small, strongly convex. Axis depressed, composed of four distinct rings, fifth indistinct, short (sag.) ring, and terminal piece. Pleural furrows distinct, well developed. Interpleural grooves discernible distally only, if at all. Width of pygidium 2.0 times its length. Axis consuming 0.9 sagittal length. Length (sag.) of terminal piece equals 0.3 length of axis and 0.5 its own width. Terminal piece bears very weak anterior ring and blunt, almost quadrate, posterior portion.

The dimensions, in millimeters, of the cranidium and pygidium of *Flexicalymene* cf. *F. retrorsa* (Foerste) are as follows:

Dimensions in millimeters:

<i>Cranidium</i> (USNM 154421)	<i>Millimeters</i>
Length (sag.) of cranidium-----	8.7
Width (trans.) of cranidium at anterior border furrow-----	7.1
Width (trans.) of cranidium at posterior border-----	18.5
Length (sag.) of glabella-----	7.3
Length (sag.) of glabella, exclusive of occipital ring-----	5.7
Width (trans.) of glabella at lateral lobes <i>1p</i> ---	7.9
Width (trans.) of glabella at lateral lobes <i>2p</i> ---	5.75
Width (trans.) of glabella at frontal lobe-----	4.3
Length (sag.) of frontal lobe of glabella-----	1.2
Width (sag.) of anterior border-----	1.0
<i>Pygidium</i>	<i>Millimeters</i>
Length (sag.) of pygidium, exclusive articulating half ring-----	4.6
Width (trans.) of pygidium-----	9.3
Length (sag.) of axis, exclusive articulating half ring-----	4.3
Width (trans.) of axis-----	4.0
Length (sag.) of terminal piece-----	1.3
Width (trans.) of terminal piece-----	2.6

Figured specimens.—USNM 154421–154425.

Occurrence.—32–38 feet above base of Foerste's original section of "Arnheim" (Foerste, 1905, p. 150; 1912, p. 442); collected by G. W. Weir from measured section 301–C. The species also occurs (pl. 5, figs. 13–18) in the Bull Fork Formation of Richmond age, 58 feet above base, in USGS colln. D1250 CO, on east side of road north of Camp Creek along boundary between Mason and Lewis Counties, 1.6 miles east of mouth of Camp Creek. Kentucky coordinates, north zone: E. 2,176,100 feet, N. 408,950 feet, Orangeburg 7½-minute quadrangle (northeast corner).

Discussion.—*Flexicalymene* cf. *F. retrorsa* (Foerste) has little to distinguish it from *F. meeki* except the size, shape, and inclination of the anterior cranidial border.

Foerste's original criteria included these and, in addition, lesser cranial width (trans.) at the posterior border and lack of vestiges of genal spines; I have been unable to substantiate either of these.

From *Flexicalymene senaria* this species does differ in its wider cranidium, straight rather than convex lateral outline of the glabella, inclination and shape of the anterior border, depressed axis of pygidium, and short terminal piece of pygidial axis.

The species may have limited stratigraphic use. One specimen illustrated here (pl. 5, figs. 8-12) is from Foerste's Arnheim, presumably earliest Richmond. The original type was from the Waynesville Shale (Foerste, 1910, p. 85), also early Richmond. The specimens (USGS colln. D1250 CO) shown on plate 5, figures 13-18, are from the lower part of the Bull Fork Formation, also of early Richmond age.

Specimens assigned to the new species *Flexicalymene griphus* are very similar to *F. retrorsa*. They occur in the upper part of the Clays Ferry Formation in the Antioch Church section.

Flexicalymene griphus n. sp.

Plate 4, figures 16-21; plate 5, figures 1-3

Flexicalymene griphus, n. sp. is represented by eight cranidia and three pygidia. The specimens are much like *F. retrorsa* (Foerste) and *F. meeki* (Foerste) in most proportions.

Surface of carapace very finely granular in texture except in furrows; granules seemingly of approximately uniform size. Width (trans.) of cranidium at anterior border furrow averaging 0.84 cranial length (sag.), but varying from 0.72 to 0.94 (median: 0.83). Width (trans.) at posterior border averaging 2.3 times cranial length (sag.) but ranging from 2.0 to 2.4. Glabellar length (sag.) averaging 0.85 cranial length but ranging from 0.84 to 0.87 (median: 0.85). Width (trans.) of glabella at lateral lobes *1p* averaging 1.02 times length (sag.) of glabella but ranging from 0.96 to 1.1. Width (trans.) of glabella at lateral lobes *2p* is 0.8 width at lobes *1p*. Width at frontal lobe equals 0.53 width at lobes *1p*.

Palpebral lobes centered opposite lateral glabellar furrows *2p*. Width (trans.) of each fixed cheek at palpebral lobes equals somewhat less than half width of glabella on line through eye centers in most specimens though equaling half width in a few.

Anterior border turned upward until nearly vertical, bounded proximally by shallow border furrow. Furrow defined in front of glabella more by lack of granular surface than by topography. Width (sag.) of border about 0.16 cranial length (sag.), range from 0.13 to 0.19.

Hypostome not known. Thorax unknown.

Pygidium subtriangular in outline, strongly convex with axis of moderate height. Axis composed of four distinct rings, fifth indistinct ring, and terminal piece. Pleural furrows well developed, distinct to margin. Interpleural furrows very weak, indistinct proximally but distinct distally close to margin. Width (trans.) of pygidium equals approximately 1.8 times length (sag.), excluding articulating half ring. Axis equals 0.9 pygidial length. Length (sag.) of terminal piece equals 0.3-0.4 of axis and about 0.7 its own width. Terminal piece bears single very weak anterior ring and a bluntly round posterior portion.

The dimensions, in millimeters, of six cranidia and three pygidia of *Flexicalymene griphus* n. sp. are as follows:

Cranidium	Dimensions of USNM specimens, in millimeters					
	154416	154418	154412	154411 (holotype)	154417	154413
Length (sag.) cranidium.....	8.3	10.3	7.1	7.2	7.7	8.2
Width (trans.) at anterior marginal furrow.....	7.8	8.9	6.2	6.1	6.4	5.9
Width (trans.) at posterior margin.....	19.8	16.3	17.0	16.7	18.7	16.7
Length (sag.) glabella.....	7.0	8.5	6.2	6.1	6.5	6.8
Length (sag.) glabella excluding occipital ring.....	5.4	6.3	4.7	4.6	4.9	5.5
Width (trans.) glabella at lateral lobes <i>1p</i>	7.8	8.9	6.0	6.1	6.7	6.5
Width (trans.) glabella at lateral lobes <i>2p</i>	6.5	6.8	4.9	4.9	5.4	5.2
Width (trans.) glabella at lateral lobes <i>3p</i>	5.1	5.5	4.1	3.8	4.4	4.2
Width (trans.) glabella at frontal lobe.....	4.0	4.7	3.2	3.2	3.5	3.5
Length (sag.) frontal lobe.....	1.3	1.4	1.0	0.8	1.0	0.9
Width (sag.) anterior border.....	1.6	1.4	0.9	1.2	1.2	1.3

Pygidium	154419	154414	154415
Length (sag.) of pygidium.....	6.4	5.8	6.7
Greatest width (trans.) of pygidium.....	11.0	10.8	10.8
Length (sag.) of axis.....	6.1±	5.3	6.0
Width (trans.) of anterior of axis.....	4.8	4.3	4.4
Length (sag.) of terminal piece.....	2.2	1.6	2.0
Width (sag.) of anterior of terminal piece.....	3.0	2.8	2.8

Holotype.—USNM 154411.

Paratypes.—USNM 154412-154419.

Occurrence.—USGS colln. D1627 CO. Clays Ferry Formation, 17 feet above base. Section 180 (Antioch Church).

Discussion.—This species differs from *F. cf. F. retrorsa* (Foerste) and *M. meeki* (Foerste) in the outline of the glabella, in the configuration of anterior cranial border, and in the shape of the terminal piece of the pygidial axis.

The difference in form of the glabella stems from two factors. First, the glabella is more inflated than in *Flexicalymene cf. F. retrorsa* and *F. meeki*, an observation which is unfortunately difficult to express mathematically and therefore bound to be somewhat subjective. Second, the sides of the glabella are somewhat

convex in outline—not straight. In *F. meeki*, a straight line tangent to both the frontal lobe and lateral lobe *1p* is tangent also to lobes *2p* and *3p*. In *F. cf. F. retrorsa* a similar line very nearly misses tangency with lateral lobes *2p* and *3p*. In *F. griphus* the glabellar width at lateral lobes *2p* is greater than in either of the other species; it is 0.8 the glabellar width at lobes *1p*, as contrasted with 0.7 in *F. cf. F. retrorsa*.

Therefore the glabellar outline is more like that of *F. senaria* than like that of *F. meeki* or *F. cf. F. retrorsa*.

The shape, width (sag.), and inclination of the anterior cranial border is intermediate between that of *Flexicalymene meeki* and *F. cf. F. retrorsa*.

The position of the eyes opposite or ahead of glabellar lateral furrow *2p* does not ally this species with *Flexicalymene meeki* and *F. cf. F. retrorsa* more strongly than with *F. senaria*, but the longer (and relatively narrower) glabella distinguishes it readily from *F. senaria*.

The length of the terminal piece of the pygidial axis is less than its own width; the ratio falls in the range 0.6 to 0.7. The same ratio in the figured specimen of *Flexicalymene meeki* (pl. 5, fig. 6) is a little less than 0.6, and in *F. cf. F. retrorsa* (pl. 5, fig. 11) it is 0.5. The posterior end of the terminal piece tends to be rounded in *F. griphus* and rectangular or quadrate in these other two species.

The species possesses a glabella intermediate between *Flexicalymene senaria* and *F. meeki*. Its anterior cranial border is intermediate between that of *F. meeki* and that of *F. cf. F. retrorsa*. Although the glabella possesses a form much like that of *F. cf. F. caractaci* (Salter) (Whittington, 1965, pl. XVIII, fig. 9), the eyes of *F. griphus* are located farther forward. A similar comment applies in a comparison with *F. planimarginata* (Reed).

Family ODONTOPLEURIDAE Burmeister, 1843

Genus ACIDASPIS Murchison, 1839

Acidaspis Murchison. Prantl and Pribyl, 1949, Rozpravy statniho geologickeno ustavu Republiky Ceskoslovenske, v. 12, p. 1-110 (Czech. text), p. 111-115 (Russian summary), p. 117-221 (English summary), pl. I-XI.

Whittington's (1956, p. 232) generalization that all Ordovician species of the genus *Acidaspis* bear three rather than two lateral glabellar lobes is not correct. *Acidaspis anchoralis* Miller, 1875b, and specimens noted below possess only two pairs.

Acidaspis sp.

Plate 5, figures 19, 20

The species of *Acidaspis* represented by the two specimens illustrated are probably conspecific with at least one of the two specimens figured by Meek (1873, p. 106, pl. 14, figs. 6, 7). According to Meek, these specimens were found "15-20 feet above low water of the Ohio, at Cincinnati," a level which is now below water; the fossils may have come from the "Eden Shale" or the underlying Middle Ordovician limestone beds.

It is not known what the characteristics of the free cheeks, thorax, or pygidium may have been, and no specific determination can be made. However, the species does seem to be a true *Acidaspis* in the restricted sense.

The species bears a very strong resemblance to a specimen from the upper part of the Catheys Formation of Tennessee, illustrated by Bassler (1932, p. 114, fig. 3) as *Acidaspis rebecca* but never described. The Kentucky form bears a much longer occipital spine, however.

Acidaspis asteroidea Reed (1914, p. 31-33, pl. V, figs. 3, 7) seems to possess three pairs of lateral glabellar lobes, instead of the two present in the Kentucky species. However, illustrations of actual cranium (Reed, 1914, pl. V, fig. 3) do not show lobes *3p* as clearly as the restoration (Reed, 1914, pl. V, fig. 7), and Reed (1914, p. 32) states that lobes *3p* may be obsolete. This species occurs in the Starfish Bed of the Drummuck Group (Upper Bala) (Ashgill) and is probably somewhat younger than the Kentucky species.

Like that of *Acidaspis asteroidea*, the glabella of *Acidaspis viruana* Öpik (1937, p. 43-45, text fig. 10, pl. 5, fig. 1) possesses a very small pair of lateral lobes *3p* and seems to lack an occipital furrow. In the Kentucky specimens, the glabellar lobes *3p* are lacking and the occipital furrow present; in both respects they resemble *A. magnospina* Stubblefield, but this British species possesses a much longer occipital spine.

The type specimens of *Acidaspis anchoralis* Miller (1875b) and *A. onealli* Miller (1875a) cannot be located for comparison, but it is probable that the specimens figured here belong to one or the other of those species.

Figured specimens.—USNM 154426, 154427.

Occurrence.—USGS colln. D1627 CO, 178 feet above base of Clays Ferry Formation. USGS colln. 4923 CO, 161 feet above base of Clays Ferry Formation. Section 180 (Antioch Church).

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		<i>Raymondites</i>	6
		<i>Reacalymene</i>	9
		(<i>Reacalymenez</i>) <i>pusulosa, Flexicalymene</i>	9
		<i>rebecca, Acidaspis</i>	17
		<i>retrorsa, Flexicalymene</i>	1, 7, 8, 9, 15, 16, 17; pl. 5
		<i>senaria, Calymene</i>	8
		<i>Flexicalymene</i>	1, 2, 8, 14, 15, 17; pls. 3, 4
		<i>spurlocki, Proetus</i>	6
		Systematic paleontology.....	3
		Tanglewood Limestone Member.....	7
		Trenton Limestone.....	1, 8, 14
		<i>viruana, Acidaspis</i>	17
		Waynesville Shale.....	15

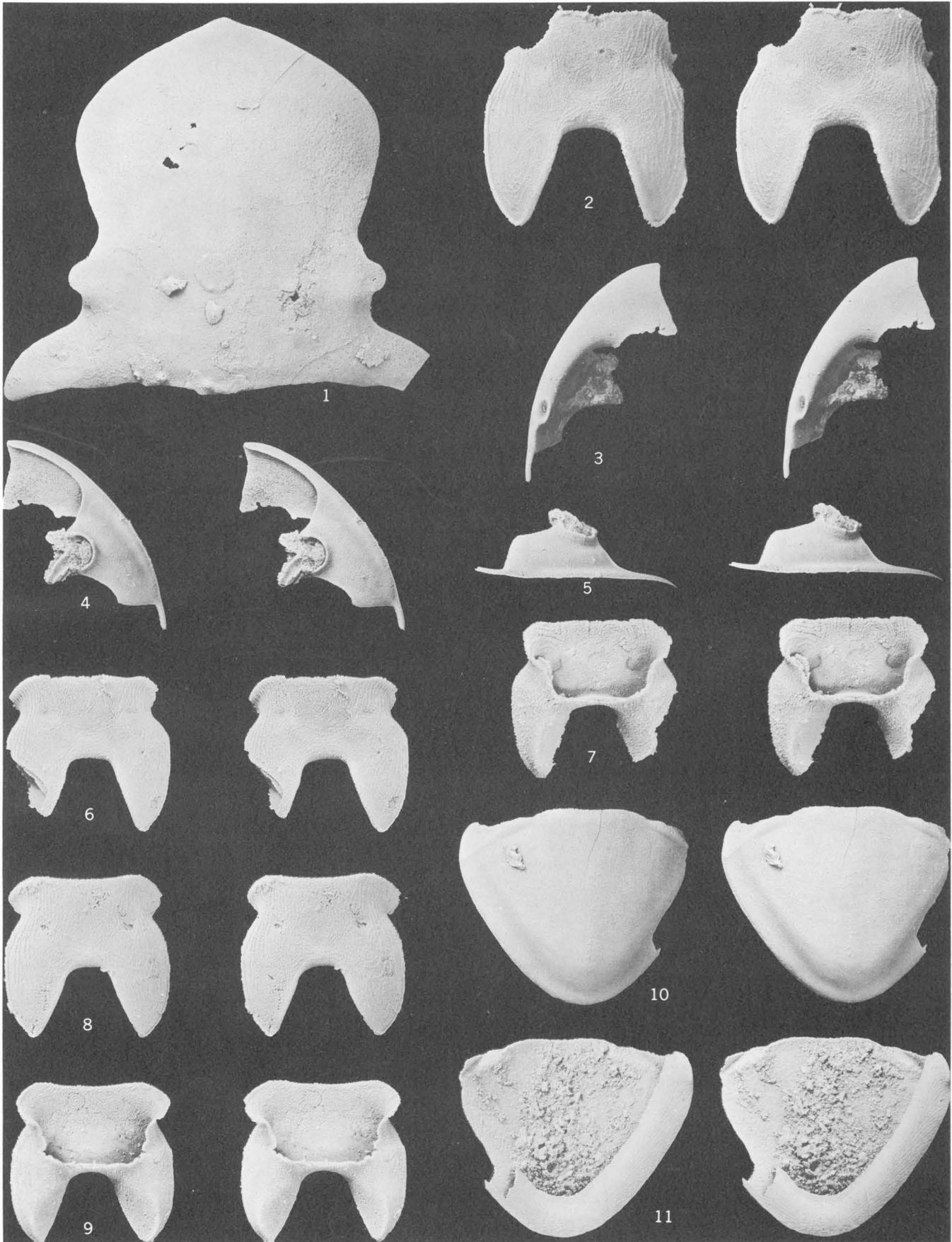
PLATES 1-5

PLATE 1

[All illustrations are stereophotographs except fig. 1]

FIGURES 1-11. *Isotelus gigas* DeKay. All from Lexington Limestone. (p. B3).

1. Cranidium, $\times 1$, USNM 154375. USGS colln. 5015 CO, Perryville South section.
2. Hypostome, ventral view, $\times 2$, USNM 154381. USGS colln. 4880 CO, Antioch Church section.
- 3, 4, 5. Free cheek, ventral, dorsal, and lateral views, $\times 1.5$, USNM 154377. USGS colln. 5015 CO, Perryville South section. In fig. 3, note sockets in doublure to receive flanges on anterior "corners" of doublure of pygidium during enrollment.
- 6, 7. Hypostome, ventral and dorsal views, $\times 3$, USNM 154380. USGS colln. 5015 CO, Perryville South section.
- 8, 9. Hypostome, ventral and dorsal views, $\times 3$, USNM 154382. USGS colln. 4879 CO, Antioch Church section.
- 10, 11. Pygidium, dorsal and ventral views, $\times 1$. USNM 154376. USGS colln. 5015 CO. Perryville South section. In fig. 11, note protruding flanges on anterior "corners" for insertion in sockets (fig. 3) in doublure of free cheeks during enrollment.

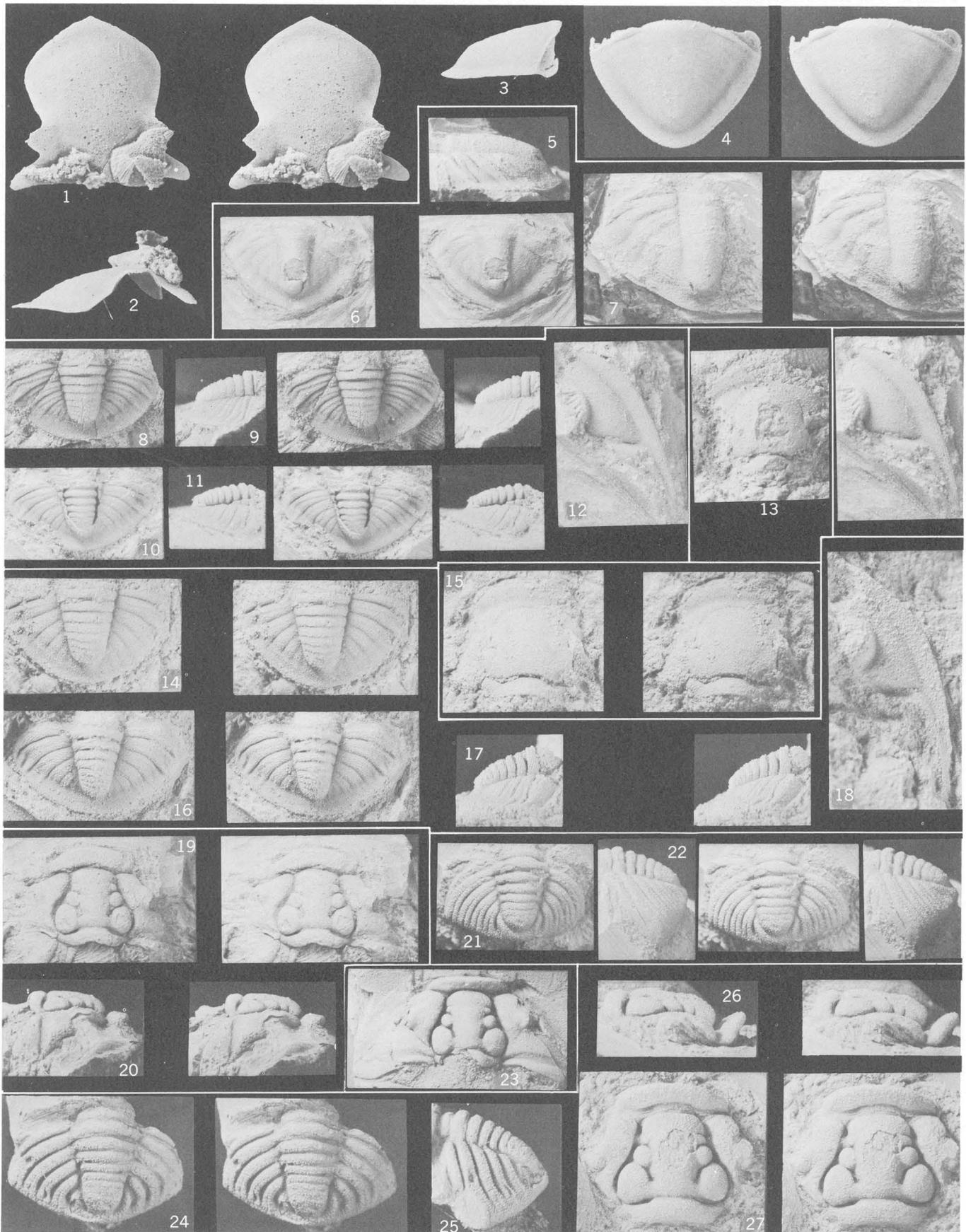


ISOTELUS GIGAS DEKAY

PLATE 2

[All illustrations are stereophotographs except figs. 2, 3, 5, 13, 18, 23, 25]

- FIGURES 1-4. *Isotelus gigas* Dekay. All from Lexington Limestone. USGS colln. 5015 CO, Perryville South section (p. B3).
1, 2. Cranium, dorsal and lateral views, $\times 2$. USNM 154378. Encrusted with silicified fragments that cannot be removed.
3, 4. Pygidium, lateral and dorsal views, $\times 2$. USNM 154379. Faint segmentation shows on this immature specimen.
- 5-7. *Bathyurus?* sp. Camp Nelson Limestone, USGS colln. D1143 CO, West Marble Creek section (p. B6).
5, 7. Pygidium, lateral and dorsal views, $\times 2$. USNM 154384.
6. Pygidium, dorsal view, $\times 2$, USNM 154383.
- 8-12. *Proetidella* sp. 1. Lexington Limestone, Grier Limestone Member, 72 ft below top, (199 ft below base of Clays Ferry Formation), USGS colln. D1106 CO, Switzer A section (p. B6).
8, 9. Pygidium, dorsal and lateral views, $\times 4$, USNM 154385.
10, 11. Pygidium, dorsal and lateral views, $\times 5$, USNM 154386.
12. Free cheek, dorsal view, $\times 5$, USNM 154387.
13. *Proetidella* sp. 1(?). Lexington Limestone, 58 ft below top of Grier Limestone Member (185 ft below base of Clays Ferry Formation), USGS colln. D1108 CO, Switzer A section. Cranium, dorsal view, $\times 5$, USNM 154388 (p. B7).
14. *Proetidella* sp. 2. Lexington Limestone, Tanglewood Limestone Member, 20 ft above top of Grier Limestone Member (107 ft below base of Clays Ferry Formation), USGS colln. D1121 CO, Switzer A section. Pygidium, dorsal view, $\times 4$, USNM 154389 (p. B7).
15. *Proetidella* sp. 3(?). Lexington Limestone, about 10 ft above base of Millersburg Member (53 ft below base of Clays Ferry Formation), USGS colln. D1127 CO, Switzer A section. Cranium, dorsal view, $\times 5$. USNM 154390 (p. B7).
- 16-18. *Proetidella* sp. 3. Clays Ferry Formation, 15 ft above base, USGS colln. D1170, Clays Ferry Section (p. B7).
16, 17. Pygidium, dorsal and lateral views, $\times 5$. USNM 154391.
18. Free cheek, dorsal view, $\times 5$, USNM 154392.
- 19, 20. *Gravicalymene* sp. 2. Lexington Limestone, Grier Limestone Member, USGS colln. 4870 CO, Antioch Church section. Cranium, dorsal and lateral views, $\times 2$, USNM 154404 (p. B11).
- 21, 22. *Gravicalymene?* sp. 1. Lexington Limestone, Grier Limestone Member, USGS colln. D1106 CO, Switzer A section. Pygidium, dorsal and lateral views, $\times 3$, USNM 154403 (p. B11).
23. *Gravicalymene quadricapita* (Stumm and Kauffman), holotype, cranium, dorsal view, $\times 2$. Univ. Mich. No. 30066. Bill's Creek Shale, at Bill's Creek, sec. 7, T. 41 N., R. 20 W., Delta County, Mich. (Stumm and Kauffman, 1958, pl. 124, fig. 5). Note close resemblance to specimen shown on pl. 4, fig. 15) (p. B9).
- 24-27. *Gravicalymene* sp. 3. Clays Ferry Formation, USGS colln. 5000 CO, Frankfort West section (p. B11).
24, 25. Pygidium, dorsal and lateral views, $\times 3$, USNM 154406.
26, 27. Cranium, lateral and dorsal views, $\times 2$, USNM 154405.

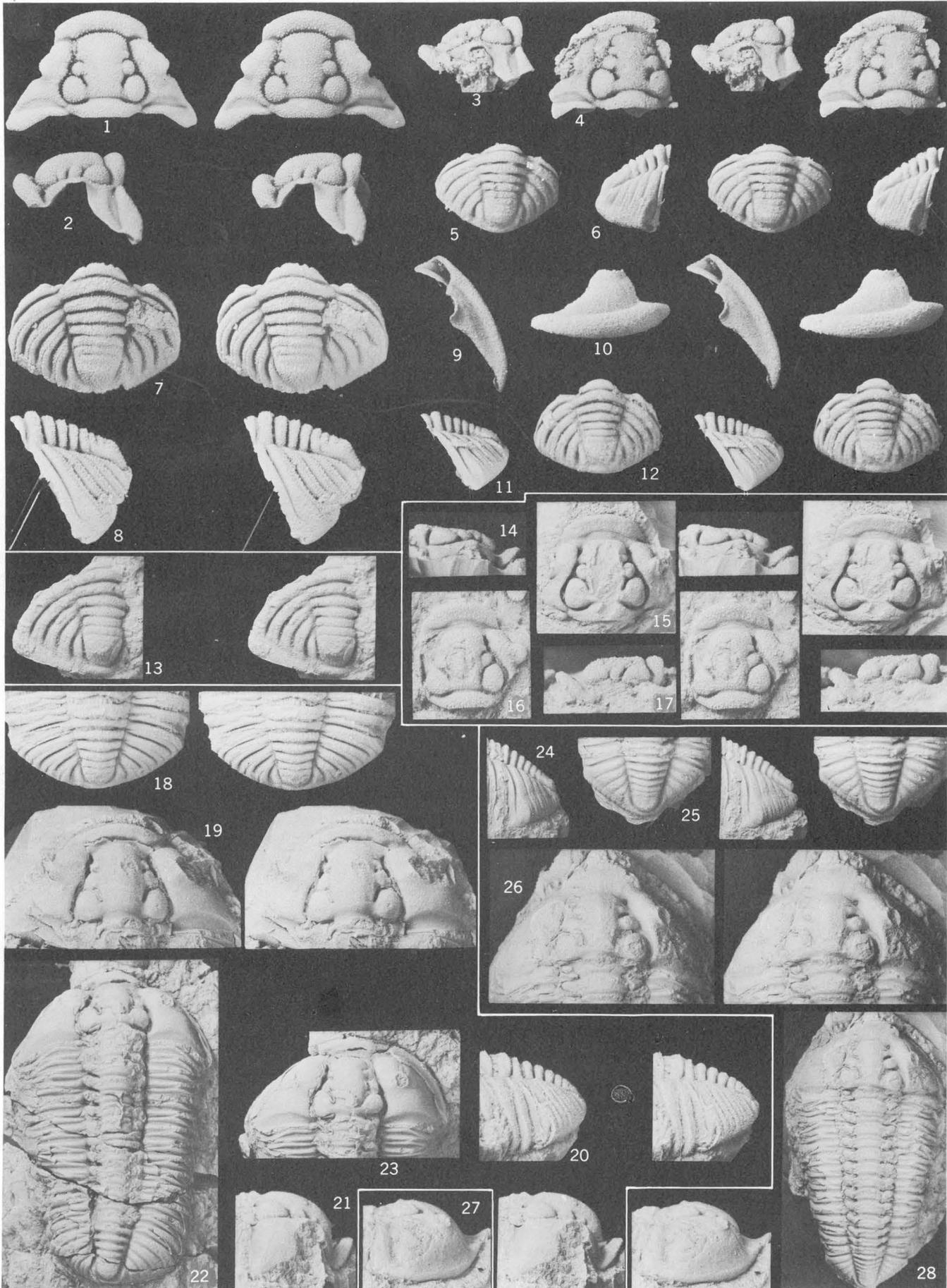


ISOTELUS, BATHYURUS?, PROETIDELLA, AND GRAVICALYMENE

PLATE 3

[All illustrations are stereophotographs except figs. 22, 23, 28]

- FIGURES 1-12. *Gravicalymene hagani* Ross, n. sp. Lexington Limestone, Salvisa Bed, 21 ft below base of Clays Ferry Formation, USGS colln. 5015 CO, Perryville South section (p. B9).
- 1, 2. Cranidium, paratype, immature, dorsal and lateral views, $\times 3$, USNM 154398.
 - 3, 4. Cranidium, holotype, incomplete, lateral and dorsal views, $\times 2$, USNM 154397.
 - 5, 6. Pygidium, paratype, dorsal and lateral views, $\times 2$, USNM 154402.
 - 7, 8. Pygidium, paratype, dorsal and lateral views, $\times 3$, USNM 154401.
 - 9, 10. Free cheek, paratype, dorsal and lateral views, $\times 2$, USNM 154399.
 - 11, 12. Pygidium, paratype, lateral and dorsal views, $\times 2$, USNM 154400.
13. *Gravicalymene?* sp. 5. Clays Ferry Formation, from float 161 ft above base, USGS colln. 4923 CO, Antioch Church section. Pygidium, dorsal view, $\times 2$, USNM 154409, (p. B13).
- 14-17. *Gravicalymene* sp. 4. Clays Ferry Formation, 178 ft above base, USGS colln. D1627 CO, Antioch Church section, (p. B12).
- 14, 15. Cranidium, lateral and dorsal views, $\times 1.5$, USNM 154408.
 - 16, 17. Cranidium, dorsal and lateral views, $\times 3$, USNM 154407.
- 18-23. *Gravicalymene* sp. Trenton Limestone, vicinity of Trenton Falls, N.Y. One of two species (contrast with pl. 4, figs. 7-9) associated with *Flexicalymene* in collections of Trenton Limestone.
- 18, 20. Pygidium, dorsal and lateral views, $\times 1.5$, Hurlburt colln. (USNM Accession No. 155678), USNM 154394.
 - 19, 21. Cranidium, dorsal and lateral views, $\times 1.5$, Hurlburt colln. (USNM Accession No. 155678), USNM 154395.
 - 22, 23. Complete specimen, dorsal view, and its cranidium rotated to horizontal position, $\times 1$. AMNH 843/1, Middleville, N.Y. This specimen illustrated by Hall (1847, pl. 64, fig. 3a). Note that right side of glabella has been restored subsequent to publication of Hall's illustration.
- 24-28. *Flexicalymene* cf. *F. senaria* (Conrad). Trenton Limestone, Trenton Falls, N.Y. USNM Accession No. 40959. USNM 154410. This specimen completely decorticated.
- 24, 25. Pygidium, lateral and dorsal views, $\times 1.5$.
 - 26, 27. Cranidium, dorsal and lateral views, $\times 1.5$.
 - 28. The complete specimen, dorsal view, $\times 1$.

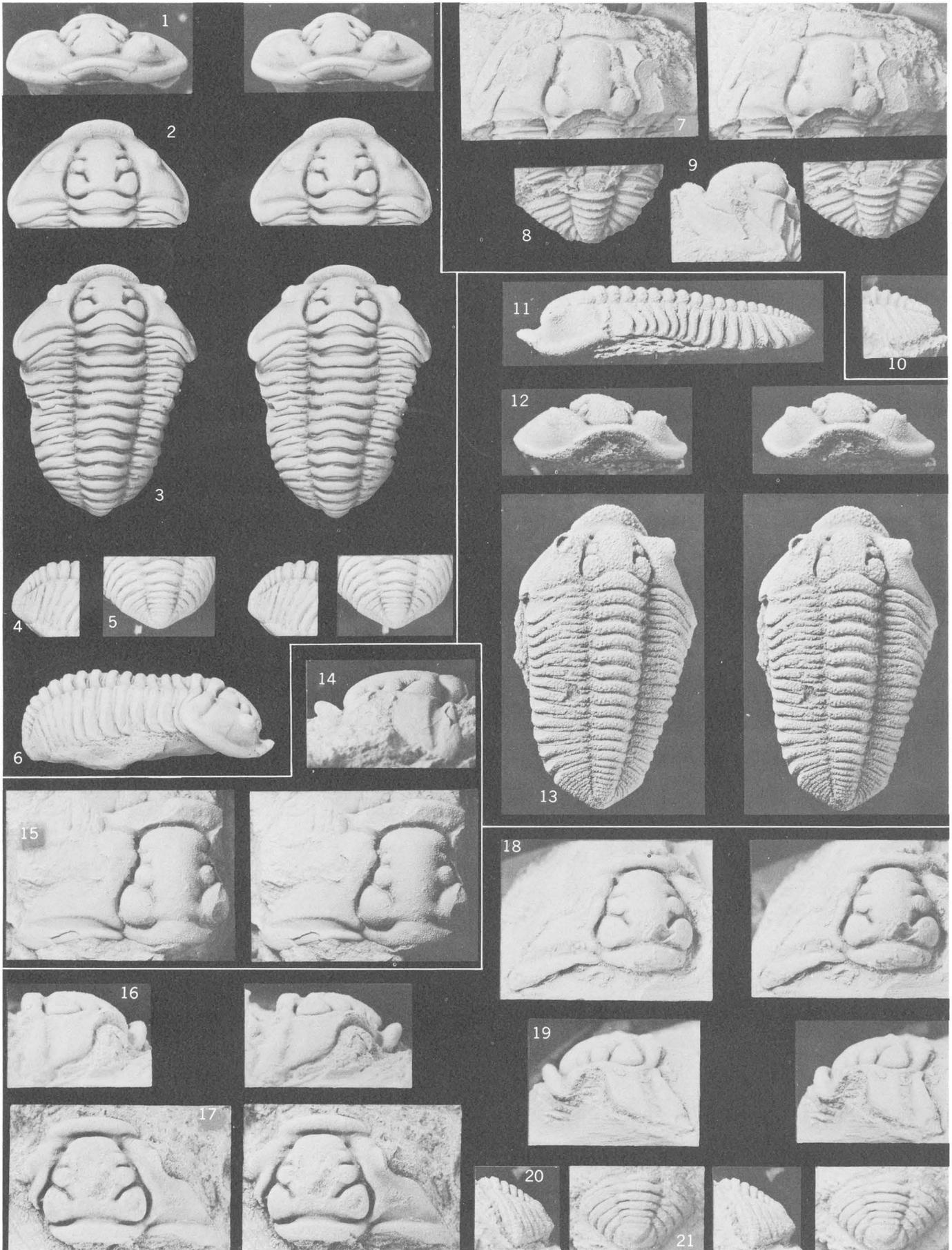


GRAVALYMENE AND FLEXICALYMENE

PLATE 4

[All illustrations are stereophotographs except fig. 6, 9, 10, 14]

- FIGURES 1-6. *Flexicalymene senaria* (Conrad). Neotype. AMNH 843/1. Trenton Limestone, Middleville, N.Y. All views of same specimen, $\times 2$ (p. B14).
1, 2. Cranidium, anterior, dorsal views.
3, 6. Complete specimen, partly enrolled, dorsal view and lateral views.
4, 5. Pygidium, dorsal and lateral views.
- 7-10. *Gravicalymene* sp. Trenton Limestone, Trenton Falls, N.Y. I. H. Harris colln. USNM Accession No. 40959. A complete specimen, $\times 2$. USNM 154393.
7, 9. Cranidium, dorsal and lateral views showing wide (sagittal) anterior border; compare with pl. 3, fig. 19, 21, 23.
8, 10. Pygidium, dorsal and lateral views; compare with pl. 3, fig. 18, 20.
- 11-13. *Flexicalymene* sp. Trenton Limestone, Trenton Falls, N.Y. New York State Mus. No. E 3025. A complete specimen, all views $\times 3$. Clearly not the same species as *F. senaria* (Conard). Compare with pl. 4, fig. 1-6.
11, 13. Lateral and dorsal views of whole specimen.
12. Anterior view of cephalon.
- 14, 15. *Gravicalymene* aff. *G. quadricapita* (Stumm and Kauffman). Lower part of Maquoketa Shale, $2\frac{1}{2}$ miles north of Postville, Iowa. USGS colln. 206p. (Ulrich). Cranidium, lateral and dorsal views, $\times 2$. USNM 154396.
- 16-21. *Flexicalymene griphus* n. sp. USGS colln. D1627 CO, Clays Ferry Formation, 194 ft above base, Antioch Church section, (p. B16).
16, 17. Cranidium, paratype, lateral and dorsal views, $\times 3$, USNM 154413.
18, 19. Cranidium, paratype, dorsal and lateral views, $\times 3$, USNM 154412.
20, 21. Pygidium, paratype, lateral and dorsal views, $\times 2$, USNM 154415.

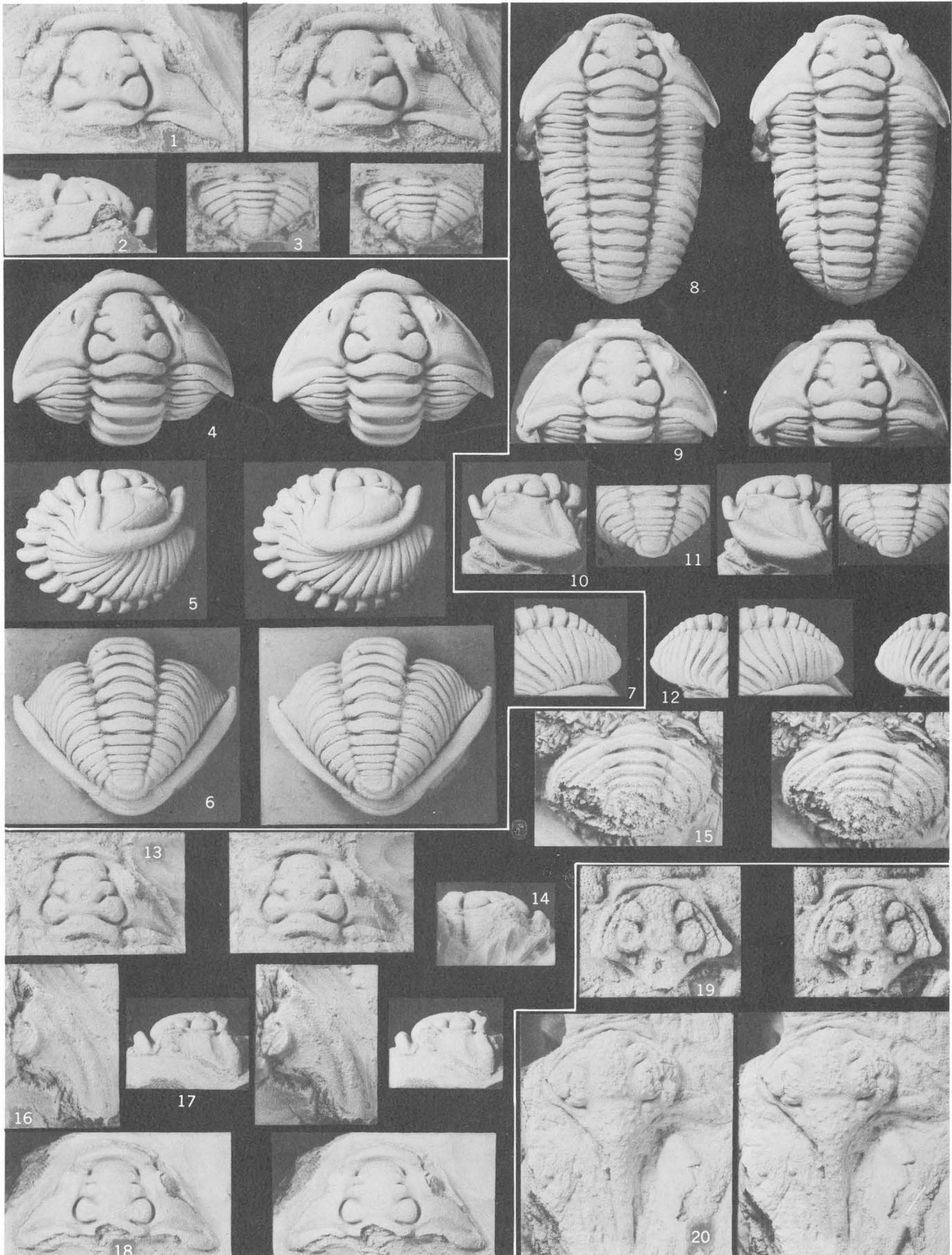


FLEXICALYMENE AND GRAVICALYMENE

PLATE 5

[All illustrations are stereophotographs except figs. 2, 14]

- FIGURES 1-3. *Flexicalymene griphus* n. sp. USGS colln. D1627 CO, Clays Ferry Formation, 178 ft above base, Antioch Church section (p. B16).
1, 2. Cranidium, holotype, dorsal and lateral views, $\times 3$, USNM 154411.
3. Pygidium, paratype, dorsal view, $\times 2$, USNM 154414.
- 4-7. *Flexicalymene meeki* (Foerste). Bellevue Limestone Member, McMillan Formation, in excavation for Liberal Supermarket, 1,050 ft south of Galbraith road and 350 ft east of Hamilton Ave., Cincinnati, Ohio. Complete, enrolled specimen, $\times 1.5$, USNM 154420 (p. B14).
4, 5. Cephalon, dorsal and lateral views.
6, 7. Pygidium, dorsal and lateral views.
- 8-12. *Flexicalymene* cf. *F. retrorsa* (Foerste). Fig. 8-12 are same complete enrolled individual, $\times 2$, USNM 154421, /32-38 ft above base of Foerste's original section of Arnheim Formation (Foerste, 1912, p. 442); collected by G. W. Weir (p. B15).
8. Complete specimen, dorsal view.
9, 10. Cephalon, rotated back of dorsal and lateral views.
11, 12. Pygidium, dorsal and lateral views.
- 13-18. *Flexicalymene retrorsa* (Foerste) USGS colln. D1250 CO, Bull Fork Formation of Richmond age, about 58 ft above base, along road north of Cabin Creek, near line between Lewis and Mason Counties, 1.6 miles east of mouth of Cabin Creek, Orangeburg quad. (northeast corner), Kentucky coord., north zone: E. 2,176,100 ft; N. 408,950 ft).
13, 14. Cranidium, dorsal and lateral views, $\times 2$, USNM 154422.
15. Pygidium, with terminal piece damaged, dorsal view, $\times 3$, USNM 154424.
16. Free cheek, dorsal view, $\times 3$, USNM 154425.
17, 18. Cranidium, lateral and dorsal views, $\times 1.5$, USNM 154423.
- 19, 20. *Acidaspis* sp., Clays Ferry Formation, Antioch Church section (p. B17).
19. Cranidium, dorsal view, $\times 3$, USNM 154427. USGS colln. D1627 CO, 177 ft above base of Clays Ferry Formation.
20. Cranidium, dorsal view, $\times 2$, USNM 154426. USGS colln. 4923 CO, float 161 ft above base of Clays Ferry Formation.



FLEXICALYMENE, ACIDASPIS