Additional Trilobites from the Ordovician of Kentucky

By REUBEN JAMES ROSS, JR.

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

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Species of the trilobites *Triarthus, Decorproetus, Isotelus, Gravicalymene, Platylichas, Primaspis,* and *Acidaspis,* are described from Orvodician strata of Kentucky

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SYSTEM OF MEASUREMENT UNITS

The investigations underlying this series of reports were made over a period of years, and distances and stratigraphic measurements appear fairly uniformly in English units. Measurements of fossil specimens, on the other hand, follow the long-standing convention of appearing in metric units. Because of the dates of the investigations and the amount of resulting data, the English measurements have been retained. Conversions to metric units may be made by using the following conversion table:

To convert English unit:	To metric unit:	Multiply by:
Mile (mi)	Kilometer (km)	1.61
Foot (ft)	Meter (m)	.305

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ADDITIONAL TRILOBITES FROM THE ORDOVICIAN OF KENTUCKY

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ABSTRACT

Trilobites collected from Ordovician limestones in Kentucky supplement earlier collections reported by Ross in 1967. Included are olenids, proetids, asaphids, calymenids, lichids, and odontopleurids. A remarkable specimen of *Primaspis* shows traces of the ventral appendages crudely silicified.

INTRODUCTION

Preparation of large samples of Ordovician limestones from Kentucky for silicified brachiopods and pelecypods has also provided a limited number of trilobites. These supplement the few trilobites previously reported (Ross, 1967).

The generic assemblage of trilobites from the Ordovician rocks of Kentucky resemble those of the Caradocian of England, Scandinavia, and to a lesser extent Bohemia. The genera described and illustrated here include *Triarthrus, Decoroproetus, Isotelus, Gravicalymene, Flexicalymene, Platylichas, Primaspis,* and *Acidaspis.*

These genera do not all occur in the same stratigraphic units. Care should be taken to ally each genus and species with the stratigraphic interval to which it belongs. Collections and localities are indicated so that the reader may refer to the stratigraphic summary.

Most collections were made under the direction of John Pojeta. However, two collections not made by U.S. Geological Survey personnel have yielded important material. S. M. Warshauer and J. M. Warn of the University of Cincinnati found exceptionally fine specimens of *Triarthrus* that are not silicified. A new species, *Gravicalymene truncatus,* is represented by unsilicified specimens collected by D. M. Lorenz, of the University of California, Los Angeles.

The genus *Cryptolithus* was found in six collections, but because only fragments of fringes were present, no effort was made to describe or illustrate the specimens. The six collections are:

5073 CO—Logana Member, Lexington Limestone—Frankfort East quadrangle.

5092 CO—Logana Member, Lexington Limestone—Tyrone quadrangle.

7791 CO—Logana Member, Lexington Limestone—Salvisa quadrangle.

7793 CO—Tanglewood Limestone Member, Lexington Limestone—Ford quadrangle.

6211 CO—Kope Formation, lowermost beds—Moscow quadrangle.

7806 CO—Point Pleasant Tongue of the Clays Ferry Formation—Moscow quadrangle.

Six species are given letter designations rather than being named formally. The two species of *Acidaspis* are represented by one cranidium and one pygidium each—hardly an adequate sample on which to base a species. The species of *Decoroproetus* and *Primaspis* are represented by enough specimens to indicate that they belong to four different species but by too few to be sure that one or more previously described species are not synonyms.

Museum numbers are abbreviated as follows:

AMNH—American Museum of Natural History
NYSM—New York State Museum
UCM—University of Cincinnati Museum
USNM—U.S. National Museum

ACKNOWLEDGMENTS

Niles Eldredge of the American Museum of Natural History loaned specimens of *Triarthrus becki* and *Primaspis trentonensis* described and illustrated by James Hall (1847). Specimens on the basis of which Ruedemann (1926) revised *Triarthrus becki* and *T. eatoni* were furnished by Donald W. Fisher of the New York State Museum at Albany, who also provided the loan of specimens of *Primaspis eatoni* from the Trenton Group.

DESCRIPTIONS OF TRILOBITES

Class TRILOBITA Walch, 1771
Order PTYCHOPARIIDA Swinnerton, 1915
Superfamily OLENACEA Burmeister, 1843
Family OLENIDAE Burmeister, 1843

Genus TRIARTHRUS Green, 1832

Ruedemann (1926, p. 115–121) compared and revised the two common North American species *Triarthrus becki* Green and *Triarthrus eatoni* Hall and emphasized the stratigraphic significance of their taxonomic differences. Examination of the specimens illustrated by Ruedemann (1926, pl. 21, figs. 7, 8, 12) and by Hall (1847, pl. 64, figs. 2b, c) confirms these differences.

The specimens described herein are assigned to *Triarthrus eatoni* rather than being assigned to a new species. All these Kentucky specimens from the Kope Formation are beautifully preserved, retaining their original convexity, whereas the specimens available to me from the Utica Shale are flattened. Such differences as exist between the Utica and the Kope specimens are probably caused more by preservation than by biology.

In describing these olenid specimens I have tempered the terminology of Henningsmoen (1957, p. 12–14) with that of Harrington, Moore, and Stubblefield (1959, p. 0117–0126).

Triarthrus eatoni (Hall)

Plate 1, figures 1–13

Triarthrus eatoni (Hall) Ruedemann, 1926, New York State Mus. Bull., no. 272, part 2, p. 115–121, pl. 21, figs. 7–9.

The beautiful little specimens of *Triarthrus eatoni* collected by S. M. Warshauer and J. M. Warn are all enrolled and preserve the convexity that is usually lost by flattening in shale. The average sagittal length of cephala is a little more than 3 mm.

Cephalon is 1.5 times as wide as long, without genal angles or spines. Except at occipital ring, border is continuously subtubular, of almost uniform width, and bounded by shallow furrow. Preglabellar field lacking. Cephalic axis constitutes 0.9 sagittal length of cephalon; glabellar length (sag) exceeds 0.7 length of cephalon, and length (sag) of occipital ring is 0.2 sagittal length of cephalic axis.

Glabellar outline is bluntly rounded in front; axial furrows only approximately parallel because glabella is widest at lateral lobe 2*p*. Sagittal length of cephalic axis 1.1 times greatest width of glabella. Length of glabella equals 0.86 its greatest width. Anterior width (tr) of occipital ring is 0.93 greatest width of glabella.

Posterior courses of facial sutures divergent convex; length of cranidium more than 0.7 width (tr) at posterior margin. Width (tr) of fixigena immediately behind palpebral lobe is 0.21 greatest width of glabella; width of fixigena at posterior border equals 0.36 greatest width of glabella. Anteriorly facial sutures cross border diagonally inward meeting at median suture.

Thorax composed of 14 segments. Like occipital ring, each bears median tubercle. Axis constitutes slightly more than one-third thoracic width. Pleurae slope steeply ventrolaterally. Tip of each pleura blunt, flattened, with lateral projection (pl. 1, figs. 3, 13), which produces a tight fit against doublure of cephalon. Pleural furrows deep, terminating distally at the lateral projection.

Pygidium small; in every specimen, border is enrolled against cephalon so that its characters are partly hidden. However, it seems that at least the front three segments of the pygidium bear the same lateral projections as the tips of the thoracic segments. Axis composed of four rings and minute, transverse terminal piece.

Illustrated specimens.—UCM 40633a–e.

Occurrence.—Kope Formation, 23 ft above contact with underlying Point Pleasant Tongue of Clays Ferry Formation. North side of 12 Mile Creek, 75 ft east of bridge (Twelve Mile Road) across creek, Laurel 7½-minute quadrangle, Kentucky. Collected by John M. Warn and Steven M. Warshauer.

Discussion.—*Triarthrus parchaensis* Harrington and Leanza and *T. rectifrons* Harrington both possess a preglabellar field discrete from anterior border and in both the glabella is much broader than in *T. eatoni*. *T. gachalensis* Harrington and Leanza has a much wider glabella and narrower cephalon. None of the Early Ordovician species from Argentina (Harrington and Leanza, 1957, p. 115–119) is very similar to *Triarthrus eatoni* from the Kope Formation. *Triarthrus convergens* Whittard (1961, p. 190–191, pl. XXIV, figs. 16–18) has a broader glabella and acute genal angles. According to Cooper (1953, p. 9, pl. 2, figs. 7–10), *Triarthrus* (*Porterfieldia*) *caecigenus* Raymond has only 11 thoracic segments and 7 axial rings on the pygidium as well as somewhat different features of the cephalon.

A comparison of the specimens from the Kope with those collected by Hall from the Trenton at Middleville, N. Y., (Hall, 1847, p. 237, pl. LXIV, fig. 2; Ruedemann, 1926, p. 119–121) shows not only that the cephalic axis is wider and shorter in the Trenton species but also that it bears abbreviated

glabellar furrows 3*p* that do not intersect the dorsal furrows; this anterior pair of furrows is virtually lacking in the Kentucky specimens. In the few specimens on which furrows 3*p* do appear they are visible only as faint traces—but the traces extend to the dorsal furrow.

Glabellar proportions of the Kope specimens agree exactly with those of specimens of comparable size in the Columbia University collections from the Utica Shale of Rome, N. Y. Those specimens are now considered to belong to *Triarthrus eatoni*. Such seeming differences as exist in proportions of the cephalon are readily explained by mode of preservation.

Superfamily PROETACEA Salter, 1864
Family PROETIDAE Salter, 1864
Genus DECOROPROETUS Pribyl, 1946

Decoroproetus Pribyl. Owens, 1973a, Norsk Geol. Tiddskr. v. 53, p. 134.

Decoroproetus Pribyl. Owens, 1973b, British Ordovician and Silurian Proetidae (Trilobita). Palaeontographical Soc., pub. no. 535, p. 41.

Proetidella Bancroft. Ross, 1967, U.S. Geol. Survey Prof. Paper 583–B, p. B6–B7.

Species previously assigned to *Proetidella* (Ross, 1967) must be redesignated *Decoroproetus* following the excellent revisions of Owens (1970, 1973a, 1973b).

Previously *Decoroproetus* (as *Proetidella*) has been reported in the Grier and Tanglewood Limestone Members of the Lexington Limestone and in the Clays Ferry Formation. Here it is recorded in the Perryville Limestone Member of the Lexington as well as at another locality in the Clays Ferry Formation.

Decoroproetus sp. x

Plate 2, figures 1–6

In the collection (USGS colln. 6143 CO) from the Clays Ferry of the Cynthiana quadrangle are 22 partly enrolled silicified specimens of *Decoroproetus*. All are incomplete. Most are composed of the hypostoma, glabella, thoracic axis, and pygidial axis. Four specimens retain most of one or both librigenae, but in three others only the silicified border and doublure of a librigena remains. No complete pygidium remains.

Cephalon essentially semicircular in outline if the genal spines are disregarded. The spines extend backward as far as the third thoracic segment. Glabella widest between palpebral lobes and at occipital ring; width exceeds 0.9 sagittal glabella length including occipital ring. The width of glabella slightly more than one-third the width of cephalon. Glabellar outline constricted between fronts of palpebral lobes and rounded at anterior end. Occipital ring a flattened band set off by distinct occipital furrow. Occipital furrow curves forward sagittally and at junction with axial furrow. Occipital lobes are faint swellings adjacent to the axial furrows. Length (sag) of anterior border is less than 0.2 glabellar length. Length (exsag) of eyes is 0.45 glabellar length but length (exsag) of slender palpebral lobes is less than 0.3 glabellar length.

Hypostoma is strongly and narrowly convex, widest at anterior wings; width at wings only slightly less than sagittal length. Width of middle body two-thirds sagittal length. Middle body indistinctly divided into large anterior and short (sag) lobe by a pair of diagonal creases rather than maculae. Behind anterior wings, subtubular border surrounds hypostoma and is set off by a distinct border furrow. The anterior edge of the hypostoma lies beneath the rounded front of the glabella. The rounded posterior margin of the hypostoma extends to the middle of the occipital ring.

There are 10 segments in the thorax and 6 rings in the pygidial axis, plus a narrowly rounded terminal piece. Pleural furrows on the thorax are straight and extend outward from the axial furrow at least as far as the pleural lobe is flat; all tips of pleurae are broken.

The outlines of three pygidia are crudely indicated by partial silicification of border and doublure, but not a single specimen retains the pleural field. The outline seems to be broadly parabolic and about 2½ times as wide (tr) as long (sag). Length of axis is 0.85 length (sag) of pygidium.

Illustrated specimens.—USNM 206836, 206837.

Occurrence.—USGS collection 6143 CO, Upper tongue of Clays Ferry, 30–35 ft above base of section, roadcut on east side of Kentucky Highways 32 and 36, Cynthiana quadrangle, Kentucky.

Discussion.—Comparison with previously described species is hampered by the erratic nature of silicification. Such features as are preserved are similar to those of *Decoroproetus fearnsidesi* (Bancroft) from lower Caradocian of Shropshire, as described by Dean (1963, p. 243–246); the glabellar outline, occipital lobes, dimensions of the preglabellar field, and outline of the pygidium are similar to those of the English species, but definition of the anterior border is poorer than in *D. fearnsidesi*.

D. subornatus (Cooper and Kindle, 1936, p. 364–365, pl. 42, figs. 16, 24) is based on a pygidium and

fragmentary cranidium; reasonable comparison cannot be made with that species from Quebec.

Decoroproetus marri Dean (1962, p. 124–126, pl. 17, figs. 5, 8) possesses a more bluntly rounded glabellar outline, a longer (sag) preglabellar field, and a more prominent and narrower anterior border than the Kentucky specimens. Owens (1973b, p. 44–45) placed *D. marri* in synonymy with *D. calvus* (Whittard). Illustrations of the type and other specimens of *D. calvus* (Owens, 1973b, pl. 8, figs. 1a, 1b, 7) show that the preglabellar field is more convex (sigmoidal) in sagittal profile than in the specimens from Kentucky.

Owens (1973a, table 3) summarized the diagnostic features of Scandinavian species of *Decoroproetus*. Inasmuch as *D.* sp. x possesses a constricted glabellar outline, lacks glabellar furrows, and has a straight longitudinal profile of the preglabellar field, it is best compared with *D. gyratus* Owens (1970, p. 316, 319–20, fig. 6A, B, D). The Scandinavian species has a longer (sag) preglabellar field and a less well defined border.

Decoroproetus sp. x differs from all British species (Owens, 1973b) with unfurrowed glabellae in having a flat rather than sigmoidal (sag) preglabellar field, a distinct flat-topped border defined proximally by a break in slope, narrowly rounded frontal lobe of glabella, and gentle constriction of the glabella.

Decoroproetus has also been described from the "Confinis" Flags (Tripp, 1962, p. 13, pl. II, fig. 15) and from the Upper Stinchar Limestone (Tripp, 1967, p. 52–53, pl. II, figs. 13–17) of the Girvan District, southwest Scotland. The specimens from the "Confinis" Flags are too incomplete for comparison; both of the two species from the Upper Stinchar Limestone have a much longer (sag) preglabellar field and one has a longer (sag) pygidial axis than the species from the Clays Ferry. The two Scottish formations were correlated by Williams (1962, p. 58–62) with the Porterfieldian of Cooper.

In Kentucky, a few specimens of *Decoroproetus* (under the name of *Proetidella*) were reported and illustrated (Ross, 1967, p. B6–B7) from the Lexington Limestone and the Clays Ferry Formation. The cranidium from the Millersburg Member of the Lexington Limestone (*P.* sp. 3, Ross, 1967, pl. 2, fig. 15) may be conspecific with the species described here, but none of the pygidia can be compared with the present incomplete material.

Decoroproetus sp. 2

Plate 2, figures 7–16

Proetidella sp. 2. Ross, 1967, U.S. Geol. Survey Prof. Paper 583–B, p. B7, pl. 2, fig. 14.

Four fragments of cranidia included in sample, three of which are only the preglabellar field and border; the fourth is only the posterior third of a glabella. Nine librigenae are fairly well preserved. No hypostoma is confidently assigned to this species. Of the six pygidia only two are worthy of illustration.

Librigenae bear long (exsag) eyes above smooth surface that slopes gently to anterior border furrow. Narrow anterior border gently convex. Anterior and posterior border furrows intersect at acute angle and continue as single furrow onto dorsal surface of genal spine.

Pygidium broadly parabolic in outline, its length (sag) equaling 0.62 its width (tr). Axis robust, tapering, bluntly rounded at posterior end. Length of axis approximately 0.8 length (sag) of pygidium; anterior width (tr) of axis about 0.4 greatest pygidial width (tr). Axis composed of seven rings and terminal piece in largest specimen (pl. 2, figs. 7–9) but of six rings plus terminal piece in a slightly smaller pygidium (pl. 2, figs. 10–12). Axial furrow distinct but shallowing at confluence around end of axis. Three pairs of interpleural furrows almost reach margin, but only the anterior two pairs are readily discernible. Six pairs of pleural furrows traverse pleural field to approach margin but posterior two pairs very faint. Discrete border and border furrow lacking; pleural region distally concave immediately inside the margin.

Occurrence.—USGS collection 5015 CO, Perryville Limestone Member of Lexington Limestone, 5 ft above base of Salvisa Bed. In quarry 0.4 mi south of Perryville. Kentucky coordinates, north zone: E. 2,232,250 ft, N. 478,400 ft. Perryville quadrangle, Kentucky.

Illustrated specimens.—USNM 206838–206841 inclusive.

Discussion.—The difference in number of axial rings on the two illustrated pygidia might be considered the basis for distinguishing two species. Without a larger sample, no measure of variability is practical. In other respects the pygidia seem most similar to that designated as *Proetidella* sp. 2 (Ross, 1967, p. B7, pl. 2, fig. 14) from the Tanglewood Limestone Member of the Lexington Limestone in the Switzer quadrangle, Kentucky. It is unfortunately impossible to make a meaningful comparison with the pygidia of *Decoroproetus* sp. x described here.

Superfamily ASAPHACEA Burmeister, 1843
Family ASAPHIDAE Burmeister, 1843
Subfamily ISOTELINAE Angelin, 1854
Genus ISOTELUS DeKay, 1824

No genus is more widely represented in the collections from Kentucky than *Isotelus*. Unfortunately, only fragments remain in the great majority of the collections, making identification as to species impossible. The genus is present in 22 collections. These are 6139 CO, 6145 CO, 6146 CO, 6412 CO, 6414 CO, 6418 CO, 7458 CO, 6909 CO, 6916 CO, 6915 CO, 7471 CO, 7079 CO, 7454 CO, 7834 CO, 6136 CO, 5067 CO, 6417 CO, 7456 CO, 7457 CO, 7448 CO, 4852 CO, 7792 CO and 5015 CO. The best silicified preservation is in collection 5015 CO; this collection also showed the best silicification of a group of collections treated in a previous study (Ross, 1967).

Isotelus gigas DeKay

Plate 1, figures 14, 15

Isotelus gigas DeKay. Ross, 1967, U.S. Geol. Survey Prof. Paper 583–B, p. B3, B6, pl. 1. pl. 2, figs. 1–4.

Henningsmoen (1975, p. 196, fig. 13) in a review of methods of trilobite ecdysis reported the discovery of a specimen of *Isotelus* in which the median suture between the librigenae was obsolete; his specimen was from the Trenton Group of New York.

In the material from USGS collection 5015 CO prepared since 1966 are two examples of librigenae yoked together (pl. 1, figs. 14, 15). In both, the median suture is merely a slit extending 5 mm back from the front margin; otherwise the doublure is continuous. Specimens smaller than these two have librigenae separated by the median suture. Probably, when the animal reached such a size that the cephalon was approximately 60 mm long, it was able to withdraw from its carapace without splitting the cheeks apart.

Illustrated specimens.—USNM 206844, 206845.

Megalaspid(?) pygidium

Plate 1, figures 16–18

A single pygidium without associated cephalic parts has been collected from the Camp Nelson Limestone. Asaphid pygidia of this generalized type are almost impossible to identify as to genus without supporting information. This specimen may belong to a megalaspid. Future collectors may discover the needed cephalic evidence.

Illustrated specimen.—USNM 206846.

Occurrence.—Camp Nelson Limestone, USGS collection 7875 CO, Wilmore quadrangle, Kentucky.

Order PHACOPIDA Salter, 1864
Family ENCRINURIDAE Angelin, 1854
Cybelinid cranidium

Plate 2, figure 20

A fragmentary cranidium, possibly belonging to the genus *Paracybeloides*, is illustrated as a matter of record. The specimen is a silicified cast of the ventral side of the carapace. No cybelinid pygidium was found associated.

Illustrated specimen.—USNM 206842.

Occurrence.—USGS collection 6419 CO, lower part of Logana Member of Lexington Limestone, Wilmore quadrangle, Kentucky.

Family CALYMENIDAE Burmeister
Genus GRAVICALYMENE Shirley 1936

The importance of the genus *Gravicalymene* in the Middle Ordovician of Kentucky has been reviewed by Ross (1967, p. B8–B9). Collection 7984 CO includes a species assigned to *Gravicalymene;* however, it is so distinctive that it might be the basis of a new genus or might be assigned to *Diacalymene.*

The lateral glabellar lobes 3*p* are very small. The front of the glabella is transversely rectilinear; the width (tr) at the front is at least as wide as the width of the glabella at lobes 3*p*. The preglabellar furrow is extremely deep and undercuts the front of the glabella. The anterior border is flat topped and has the kind of lateral profile associated by Shirley (1936, fig. 2; pl. XXIX, figs. 19–23 with *Diacalymene.* I have found no description of a species with the truncated anterior glabella.

The thickness of the carapace suggests that comparison with internal casts could be very difficult and misleading.

A correction in my previous interpretation of pygidial segmentation (Ross, 1967, p. B9) is in order. In all species of *Gravicalymene* described from Kentucky—including *G. truncatus* n. sp.—the first four rings of the pygidial axis are distinct. On the pleural regions there are five pairs of pleural furrows but only four pairs of interpleural furrows. Because the fundamental segmentation of the pygidium is shown by the interpleural furrows (Harrington, 1959, p. O73), the front four rings should be considered axial rings. The terminal piece therefore bears two faint furrows and in some specimens an indistinct dimple. The fifth pleural furrow belongs to the front faint ring in the terminal piece.

Gravicalymene hagani Ross

Plate 2, figures 18, 19; plate 3, figures 1–9

Gravicalymene hagani Ross, 1967, U.S. Geol. Survey Prof. Paper 583–B, p. B9–B10, pl. 3, figs. 1–12.

In the new material for USGS collection 5015 CO many beautifully silicified parts of *Gravicalymene hagani* are preserved. Four cranidia of different sizes, a hypostoma, and the tip of a thoracic segment are illustrated partly as a matter of record and partly to supplement the previous description.

Hypostoma typical for the family Calymenidae. The specimen illustrated in plate 3, figure 5 shows the anterior downward flexure to fit the rostral plate along the connective suture and the deep elongate pits on the ventral surface that correspond to the anterior wing processes on the inner dorsal side. The middle body is 1.5 times as long as wide. Length (sag) of anterior lobe about 0.70 length of middle body.

Left side of a thoracic segment is illustrated to show the smooth facet on the outside and the vincular stop on the front edge near the tip.

The insides of two cranidia show the fossular apodemes (pl. 3, figs. 4, 9). In larger, possibly gerontic, specimens the fossula seems to extend so deeply into the apodeme that a canal is present into the inner side of the integumen. This feature may be the result of some vagary of silicification or maybe an original feature; if the latter, it would indicate a connection with the dorsal surface for purposes about which we can only speculate.

Illustrated specimens.—USNM 206847–206852 inclusive.

Occurrence.—Perryville Limestone Member, Lexington Limestone, USGS collection 5015 CO.

Gravicalymene truncatus n. sp.

Plate 3, figures 11–20

This species is characterized by the transversely truncated anterior end of the glabella, small lateral lobes 3*p*, and deep preglabellar furrow. Outline of glabella would be bellshaped if anterior end were not truncated.

The cephalon approximately semicircular in outline and its height only slightly less than its sagittal length. Length (sag) of glabella including occipital ring almost 0.75 length of cranidium. Length (sag) of occipital ring equals 0.2 length of glabella including ring. Width (tr) at frontal lobe equals width at lateral lobes 3*p* and 0.6 width (tr) at lobes 1*p*. Greatest width of glabella at lobes 1*p* equals 1.0–1.2 times glabellar length including occipital ring.

Palpebral lobes centered opposite glabellar lobes 2*p*. Width (tr) of fixed cheeks at palpebral lobes only 0.4 width of glabella at lobes 2*p*.

Anterior border elevated, higher than wide (sag). Dorsal surface somewhat flattened and sloping backward. Anterior face of margin steeply inclined downward and backward. Border furrow extremely deep; in one specimen undercutting front of glabella, in another vertically sided. Furrow widest sagittally. Combined width (sag) of border and border furrow equals 0.25 length of glabella including occipital ring.

Length (exsag) of lateral lobes 3*p* only 0.09 length (sag) of glabella including occipital ring.

Hypostoma not known.

Thorax composed of 13 segments of which the tips are flattened and rounded from front to back.

The pygidium strongly convex of a generalized design common to all Kentucky species of *Gravicalymene*. Sagittal length of pygidium equals 0.6 its greatest width. Length of axis 0.9 pygidial length and 0.75 its own width (tr). Width of axis (tr) about 0.4 width of pygidium. Axis consists of four well-defined anterior rings and terminal piece; terminal piece takes up almost half the sagittal length of axis. Terminal piece bears two faint transverse furrows delimiting two weak rings. A small median dimple may be present on some specimens in the back half of the terminal piece. Five pairs of pleural furrows but only four pairs of interpleural furrows present in pleural regions.

Illustrated specimens.—USNM 206853–206855 inclusive.

Occurrence.—USGS collection 7984 CO, Kope Formation, 57 ft 1 in. above Point Pleasant—Kope contact, Moffett Road section, Demossville quadrangle, Kentucky.

Discussion.—Although the glabella of a species like *Gravicalymene praecox* (Bancroft) may be no wider (tr) at the frontal lobe than at lobes 3*p*, in no species described to date is the front of the glabella so abruptly terminated. One is inclined to think the specimen deformed until he find others that are similar. The anterior truncation of the glabella, smallness of glabellar lobes 3*p*, enormously high anterior border, and deep border furrow distinguish this species.

Genus FLEXICALYMENE Shirley, 1936

Flexicalymene sp.

Plate 3, figure 10

A single fragmentary cranidium in the new collections is assignable to *Flexicalymene*. It is illustrated as a matter of record.

Illustrated specimen.—USNM 206856.

Occurrence.—Gilbert Member of Ashlock Formation, USGS Collection 6129 CO.

Order LICHIDA Moore
Family LICHIDAE Hawle and Corda, 1847
Subfamily HOMOLICHINAE Phleger

Genus PLATYLICHAS Gurich, 1901

Because a pygidium is lacking, the assignment of specimens described here to a genus is uncertain. However, the association of a fragmentary hypostome with the middle body wider than long and bounded posteriorly by a furrow rules out assignment to *Lichas* as shown by Tripp (1957, fig. 4). The posterior courses of longitudinal and axial furrows are similar to those of *Platylichas halli* (Foerste) from the Cincinnatian of Ohio and of *Platylichas laxatus* (McCoy) as illustrated by Warburg (1939, pl. 12, figs. 2, 3, 5, 6, 10), from the *Chasmops* beds. The axial furrow runs almost straight from the front of the palpebral lobe to the inner end of the occipital lobe; the posterior "hooked" end of the longitudinal furrow is connected by a short, shallow furrow to the axial and occipital furrows also at the inner end of the occipital lobe.

A case might be made for assigning this species to *Metopolichas*, but in all illustrations of *M. hubneri* (Eichwald) (the type species) and *M. verrucosus* Eichwald the axial furrow is shown intersecting the occipital furrow on the outer side of the occipital lobe, and no connecting furrow from the end of the longitudinal furrow is present.

As noted by Tripp (1957, p. 116) a theoretical evolutionary sequence was proposed for *Platylichas* by Öpik (1937, p. 55–62) involving in particular migration of the posterior end of the axial furrow. The Kentucky specimens represent an early step in Öpik's scheme.

Platylichas is present in Caradocian deposits (Yugorskiy horizon) of southern Vaigach Island and northern Pay-Khoy peninsula north of the Urals (Bondarev and others, 1968). The genus is reported by Jaanusson (1964, p. 30) from the Caradocian (Viruan) Skagen Formation of Västergotland, Sweden. *Platylichas* is also to be found in the Caradocian strata of Lithuania (Modlinski, 1967). In Wales it is reported from Caradocian and Ashgillian strata (Whittington, 1962). Lesperance (1968) has recorded *Platylichas* at Percé, Quebec, from beds of either Caradocian or Ashgillian age.

Platylichas halli (Foerste)

Plate 4, figures 1–7

Lichas halli Foerste, 1888, Denison Univ. Sci. Lab. Bull., v. 3, p. 118–120, pl. XIII, fig. 4.

This species is represented by six fragmentary cranidia and one partial hypostoma.

Greatest width of glabella positioned slightly posterior to anterior pits, although width at the occipital ring is essentially its equal. Glabella is narrowest immediately in front of occipital furrow; there its width (tr) is less than half the greatest width. At its intersection with the occipital furrow each axial furrow is essentially tangent to the inner end of the occipital lobe; each axial furrow runs forward and outward in a nearly straight course to the front of the palpebral furrow; it then curves inward and downward to the anterior pit. From the anterior pit each longitudinal furrow continues the course of the axial furrow, curves inward and backward. At a distance in front of the occipital furrow equal to one-eighth the sagittal glabellar length each longitudinal furrow curves abruptly outward to assume a "hooked" course. The length (exsag) of composite lateral lobes thus defined is approximately six-tenths the sagittal glabellar length. Composite lobes moderately inflated. Frontal and median lobes less inflated than composite lobes. Frontal lobe slopes evenly forward to very narrow (sag) border. On a transverse line through the greatest width of glabella the width of median lobe is slightly more than half the width of each composite lobe.

The hooked posterior end of each longitudinal furrow is connected by a short, shallow furrow to the intersection of axial and occipital furrows. Occipital lobes lie entirely outside this intersection; the distance (tr) between inner ends of occipital lobes is a little less than half the width (tr) of the glabella at the occipital ring. The length (exsag) of arcuate palpebral lobe between one-fourth and one-third the length (sag) of glabella. The palpebral furrow is confluent with the axial furrow for a short distance posterior to the anterior pit; as a result each palpebral rim is connected by an eye ridge to the anterior pit.

The single associated hypostoma lacks a posterior border and is incompletely silicified. The maculae serve to divide the subrectangular middle body, which is wider (tr) than long (sag) in a ratio of 5.5:4, into anterior and posterior lobes; the sagittal length of the anterior lobe is three times that of the posterior lobe.

Librigenae, thorax, and pygidium not known.

Illustrated specimens.—USNM 206857–206859.

Occurrence.—USGS collection. 7343 CO (lithology of Millersburg Member of Lexington Limestone). At top of tongue of Clays Ferry Formation, 0.9 mi south of Lair, Ky. Kentucky coordinates, North zone: E.1,983,700 ft; N.302,000 ft, Shawhan quadrangle, Kentucky. USGS collection 4959 CO. Upper

part of Grier Limestone Member of Lexington Limestone, 149–152 ft above Tyrone-Lexington contact. Central Kentucky Parkway. (Blue Grass Parkway), north side at top of bluff. Kentucky coordinates, North zone: E. 1,835,050 ft; N. 173,600 ft, Salvisa quadrangle, Kentucky.

Discussion.—*In Platylichas bottniensis* (Wiman) (Warburg, 1939, pl. 10) the posterior axial and longitudinal furrows intersect in front of the occipital furrow and in this regard differ from those of *P. halli*. The cranidium of *P. laxatus* (McCoy) (Warburg, 1939, pl. 12, figs. 2, 3, 5, 6, 9, 10; Dean, 1963, p. 235–237, pl. 43, figs. 1, 2, 5, 8–12) is much wider (tr) along the posterior border, has larger palpebral lobes, a narrower glabella, and shorter composite glabella lobes than the specimens from Kentucky. Whittington and Williams (1955, p. 424, pl. 40, figs. 113, 114, 117) described an indeterminate species from the Derfel Limestone of the Arenig District Wales, which is very similar in outline of glabella and proportions of frontal lobe but differs in the outline of composite glabellar lobes. Another Welsh species, *P. nodulosus* (McCoy) (Whittington, 1962, pl. VII, figs. 1–8; 1968, p. 100–101, pl. XXXI, figs. 5, 6, 8–11) is very similar to the Kentucky species in cranidial features, differing in having a narrower (tr) middle lobe of the glabella and a wider (sag) anterior border. The median glabellar lobe of *P. glenos* Whittington (1962, p. 28, pl. VII, fig. 15; pl. VIII, figs. 3–5) is even narrower and its convexity in lateral view is greater than in the Kentucky species.

A cranidium designated *P.* cf. *laxatus* (McCoy) by Dean (1962, p. 121, pl. 17, fig. 1) has a narrower glabella than *P. halli*; the composite lobes of the glabella are not terminated posteriorly by as pronouncedly "hooked" longitudinal furrows and the median lobe of the glabella is narrower than in *P. halli*.

Although the type specimen of *Platylichas halli* (Foerste) is not available for comparison, it is more than likely that we are dealing with this or a remarkably similar species. Foerste (1888, p. 120) commented that the type specimen had come from the "Cincinnati Group" in Clermont County, Ohio. Bassler (1915, p. 35) interpreted this to mean "Maysville (Corryville)". The species range may easily include Edenian as well as Maysvillian equivalents.

Ancigin (1973, p. 106–107, pl. XV, figs. 11, 12, 13, 15, 16) has described *Platylichas micus* from the uppermost Arenigian strata from the west side of the southern Urals. The widest part of the glabella is across the compound lobes, and the palpebral furrow is discrete from the axial furrow in this Russian species; in both respects it differs from *P. halli*.

Order ODONTOPLEURIDA Whittington, 1959
Family ODONTOPLEURIDAE Burmeister, 1843
Subfamily ODONTOPLEURINAE Burmeister, 1843
Genus PRIMASPIS Richter and Richter, 1917

Primaspis trentonensis (Hall)

Plate 4, figures 8–14

Acidaspis trentonensis Hall, 1847, p. 240, pl. 64, figs. 4a–f.
Leonaspis trentonensis? (Hall). Whittington, 1941, Jour. Paleontology, v. 15, p. 501–502, pl. 74, figs. 31–34.
Primaspis trentonensis (Hall). Whittington, 1956b, Harvard Coll. Bull. Mus. Comp. Zoology, v. 114, no. 5, p. 203.

The concept of *Primaspis trentonensis* as revised by Whittington (1941, p. 502–503, pl. 74, figs. 31–37; 1956b, p. 203) included three specimens from two different localities. The present examination of specimens from Kentucky suggests that Whittington's hypodigm includes two different species.

The holotype (AMNH 853/2), an enrolled specimen from exposures on the Bay of Quinte, near Belleville, Ontario, is illustrated in plate 4, figures 8–11. The specimen has been somewhat abraded. The posterior margin of the occipital ring has been damaged and may have borne a median tubercle, which is now missing. Behind the occipital furrow a transverse row of five coarse tubercles decorates the axial part of the occipital ring. Each lateral lobe of the occipital ring is low and bounded proximally by a furrow, which may be deep more because of zeolous preparation than from its natural state. The occipital furrow between the lateral occipital lobe and the posterior of the genal region is very shallow.

The pygidium has only two pairs of spines anterior to the major spines and two posterior pairs between the major spines. One of these posterior pairs is rooted in the bases of the major spines.

The two specimens (NYSM 9773, 9774) of *Primaspis* (pl. 4, figs. 12–14) from the Trenton Group at Trenton Falls, N. Y. (Whittington, 1941, pl. 74, figs. 35, 36, 37) have a different ornamentation of the occipital ring. A large median tubercle is present; other tubercles are evenly distributed behind the occipital furrow but increase in size to a transverse row behind the large median tubercle along the margin of the occipital ring. There are two pairs of pygidial border spines in front of the major pair and two posterior pairs, both of which are discrete from the major spines.

Three specimens, to be sure, can hardly be a sufficient sample on which to base two species, but we are faced with the fact that *Primaspis trentonensis*

(Hall) is based on one of them. The other two specimens differ in features that are of species rank. Additional collections should be made and studied.

Primaspis sp. x

Plate 5, figures 1–14; plate 6, figures 1, 2

This species is represented in three collections—USGS collections 6143 CO, 6990 CO, and 7343 CO. An unfortunate amount of variation occurs between specimens, even between those from the same collection, in regard to details of ornament. These differences are caused almost entirely by different degrees of silicification. It is paradoxical that a single partial trilobite. (pl. 5, figs. 1, 2) whose dorsal surface preserves almost no fine ornament is the only known specimen to retain silicified casts of usually evanescent appendages.

In general, cranidial features, including the tuberculate surface ornamentation, are similar to those of *P. evoluta* (Törnquist) as described and illustrated by Bruton (1966), p. 4–7, pl. 1, figs. 3, 5, 6), although slight differences in proportions do exist.

Excluding genal spines the width (tr) of cephalon is approximately 2.5 times its length (sag). Similarly, the width (tr) of the cranidium at the posterior border is 2.0 times the cranidial length (sag). At the palpebral lobes, the width (tr) is about 1.3 times the sagittal length of the cranidium. The anterior width (tr) between antennal notches is almost 1.1 times the cranidial length (sag).

The width (tr) of the glabella at lateral lobe 1*p* is essentially equal to the glabellar length (sag) including occipital ring. At lobe 2*p*, it is almost 0.9 and at lobe 3*p*, almost 0.6 of the glabellar length (sag). Lobe 1*p* semiovoid, pointed anterolaterally; lobe 2*p* about half as long (exsag), semiovoid, but pointed posteroproximally. Lobe 3*p* very small, almost rectangular, narrow, directed anterolaterally. Anterior lobe of glabella slightly expanded. Occipital furrow deepest behind lateral glabellar lobe 1*p*. Occipital ring occupies almost one-third sagittal length of glabella; width (tr) of occipital ring at posterior border equals 0.8 glabellar length including occipital ring. Axial furrows poorly defined anteriorly but become deeply entrenched at distal end of glabellar furrow 3*p*, then run backward and outward around front third of lobes 1*p* and converge sharply to intersect occipital furrow, then diverge markedly around occipital lobes to cross posterior border. Lateral furrows 1*p* and 2*p* are deepest close to the longitudinal furrow. Longitudinal furrows arise faintly from proximal ends of 3*p* running almost straight backward to the occipital furrow, which they join in diverging downward into a deep pit behind lobe 1*p*; they then run almost straight upward and backward halfway across the occipital ring to delimit the proximal sides of occipital lobes.

The occipital ring is divided into an anterior tuberculate half and a raised, smooth, bordering posterior half. A median tubercle is present on the posterior half. Laterally the tuberculate surface extends to the longitudinal furrows; the swollen occipital lobes are a part of the posterior portion of the occipital ring.

On a line through the eye centers, each fixed cheek is a little lower than lateral glabellar lobes 1*p*; the width (tr) on that line is slightly less than the greatest width of lobe 1*p*.

Facial sutures follow raised sutural ridges. Anteriorly the sutures converge slightly in dorsal view and cross the dorsal side of the border above the antennal notch to the outer margin; from there the sutures converge sharply in a curving course downward and backward across the narrowly rolled doublure inside the antennal notch. As a result, the notch is entirely on the free cheek. In ventral view a connective suture runs almost straight between facial sutures and separates an extremely narrow (sag) rostral plate from the remainder of the doublure; in anterior view the connective suture appears somewhat sinuous. The posterior edge of the rostral plate is concave in outline to fit the curved front of the hypostoma. The posterior facial sutures diverge at about 160° to the border furrow, then curve sharply to cross the posterior border immediately within the base of the genal spine.

Each librigena bears a small bulbous eye above a genal platform which slopes approximately 45°. The prominent rolled border, set off by a deep furrow, bears 14 small tubercles along its ventral surface. The length of genal spine is about equal to the distance from axial furrow to facial suture at the posterior border.

The hypostoma is of low convexity; its length about three-fourths its width. Anterior wings flexed dorsally to fit contour of antennal notch on doublure. Lateral notch shallow. Shoulder angular, moderately swollen. Border furrow shallow. Maculae not evident, perhaps because of poor preservation.

Thorax composed of 10 segments, each bearing a strong axial ring, principal pleural ridge, and principal pleural spine. The anterior ridge bears a neat row of tubercles, commonly six, and extends into an anterior pleural spine. Tubercles are also sparsely present on the axial ring.

Exclusive of marginal spines the width (tr) of the pygidium is twice its length (sag). The axis is composed of two rings and terminal piece. The anterior axial ring is confluent with a large pair of diverging, essentially horizontal major spines. From the thickened border four pairs of smaller spines protrude, two pairs ahead of the large pair and two pairs behind. The bases of all spines are discrete.

Appendages.—On the ventral side of a single specimen (pl. 5, fig. 2) crude silicified casts of appendages are preserved. Silicification is too coarse to show the number of segments in each appendage. The specimen does show a pair of slender legs(?) for each segment of the thorax. Although one cannot determine any details of appendages under the cephalon it seems probable that they were different from thoracic appendages. With a modicum of imagination, one can visualize an anterior pair of mitten-shaped appendages (pl. 5, fig. 2, beneath the hypostoma. These modified appendages may have aided in the food-gathering process.

Michael E. Taylor (oral and written commun., 1973) has called my attention to a somewhat similar arrangement of appendages on the modern isopod crustacean *Serolis*.

Illustrated specimens.—USNM 206860–206864 inclusive.

Occurrence.—Clays Ferry Formation, USGS collection 6143 CO, Cynthiana quadrangle; USGS collections 6990 CO, 7343 CO, and 7812 CO Shawhan quadrangle, Kentucky.

Discussion.—I have tentatively assigned to *Primaspis* sp. x the only specimen found in collection 6990 CO; this is a delicate, almost complete trilobite, but silicification of the pygidium is incomplete (pl. 5, figs. 10–14). The major spines of the pygidium are not differentially enlarged and the anterior and posterior spines are little more than tubercles around the margin. Whether the underdevelopment of the pygidial spines is an artifact of poor silicification or an original feature cannot be known until additional specimens are available from the same locality.

Primaspis sp. x bears a strong resemblance to *P. evoluta* Törnquist (Bruton, 1966, p. 4–7, pl. 1, figs. 1–9) from the Boda Limestone of Sweden. The cranidium of the Kentucky species tends to be wider, but this might be related to the smaller size of specimens. The major spines of the pygidium are discrete from minor spines between them; in *P. evoluta* there are three pairs of spines between the major ones and one of these is rooted in the major spines. *P. bestorpensis* Bruton possesses three more pairs of pygidial spines than *P.* sp. x and *P. multispinosa* Bruton has at least five more pairs.

Primaspis primordialis (Barrande) differs in having paired occipital spines on the glabella. In *P. ascitus* Whittington (1956b, p. 199–205, pl. 1, 2) the surface ornamentation is more densely tuberculate, the posterior border of the cranidium including the back of the occipital ring is tuberculate rather than smooth, and the pygidial spines number six pairs of which one is based on the major spines.

All of the species of *Primaspis* described by Whittard (1961, p. 199–204, pl. XXVII) differ from *P.* sp. x either in number of pygidial spines or proportions of the cranidial features. In *P. whitei* there are 17 spines on the ventral border of the free cheeks, wider fixed cheeks, and 2 more pairs of pygidial spines. *Primaspis simulatrix* has more elongate glabellar lobes 1*p*, and a pygidium with many more spines. *P. rorringtonensis* differs in its very densely spaced tubercles on the surface.

Primaspis semievoluta Reed (Dean, 1962, p. 122, pl. 17, figs. 3, 13) has narrower fixed cheeks, but like *P. halli* has a total of five pairs of pygidial spines.

Primaspis harnagensis (Bancroft) (Dean, 1963, p. 237–238, pl. 44, figs. 1, 4, 6, 8) has longer (exsag) glabellar lobes 1*p*, and narrower (tr) fixed cheeks than *P.* sp. x; there are four pairs of pygidial spines in front of the major pair. *P. caractaci* (Salter) possesses one more posterior pair of pygidial spines (Dean, 1963, p. 240).

Bruton (1968a, p. 13–14, pl. 2, fig. 5) noted that *P. peregrina* (Barrande) "has a smooth posterior margin of the occipital ring" and may be the only previously described species to share this feature with the specimens from Kentucky.

Primaspis sp. y

Plate 6, figures 3–16

This species is represented by 3 fragmentary cranidia, 2 librigenae, 10 incomplete pygidia, and 2 fragments of thoracic segments from collection 5015 CO, and 2 fragmentary cranidia, 4 librigenae, 5 incomplete pygidia, and numerous fragments of thoracic segments from collection 6915 CO.

The proportions of the cranidia of this species are almost identical to those of *Primaspis* sp. x, but a few significant differences exist, even though none of the cranidia is fully mature. The surface of the occipital ring in *Primaspis* sp. y is tuberculate over its entire surface; the large median tubercle is positioned high on the posterior part.

On the librigenae, 13 large tubercles or short spines ornament the ventral side of the border.

Six pairs of marginal spines ornament the pygidium. The major spines diverge initially at an angle of 30°; a very short distance behind the pygidial margin they curve inward so that their tips converge at an angle less than 15° without meeting. Three pairs of anterior spines decrease in size forward. Of the two pairs of posterior spines the median pair is the larger; the second smaller pair is rooted in the base of the major pair of spines.

Illustrated specimens.—USNM 206865–206870 inclusive.

Occurrence.—Salvisa Bed of Perryville Limestone Member of Lexington Limestone, USGS collection 6915 CO, USGS collection 5015 CO.

Discussion.—*Primaspis* sp. y differs from *P.* sp. x in lacking a smooth posterior border of the occipital ring. But the most striking difference is in the pygidium. In *P.* sp. y the major spines diverge at 60°, and they maintain that angle throughout their length; there are only two rather than three pairs of anterior border spines and both posterior pairs of spines are discrete from the major spines.

Primaspis sp. y differs significantly from *P. ascitus* Whittington only in the direction of recurving of the major pygidial spines and in the size of the posterior spines that arise from the bases of the major spines. Whittington (1956b, p. 205) noted that the number of anterior border spines in *P. ascitus* is reduced with an increase in pygidial size from a sagittal length of 0.9 to 1.35 mm. In *Primaspis* sp. y a series of pygidia shows no change in number of border spines although the sagittal length, exclusive of the articulating half ring, ranges from 0.75 to 1.5 mm. The close resemblance to *P. ascitus* suggests that the Salvisa Bed may be correlative with the lower part of the Martinsburg Shale north of Harrisonburg, Va.

Primaspis semievoluta has one fewer pair of pygidial spines than does *P.* sp. y and *P. harnagensis;* there are four rather than three pairs in front of the major spines. *P. evoluta* has two pairs of anterior and three pairs of posterior spines.

Associated with the small specimens assigned to *Primaspis* sp. y in collection 5015 CO are a large cranidium and pygidium (pl. 6, figs. 17–19, 21–23), which may be mature specimens of the same species. They are tentatively designated as *Acidaspis* sp. a, however.

Genus ACIDASPIS Murchison, 1839

Acidaspis? sp. a

Plate 6, figures 17–19, 21–23

A large cranidium and part of a large pygidium are associated with *Primaspis* sp. y in USGS collection 5015 CO. Because of the number of border spines it is unlikely that the pygidium could belong to *Primaspis* sp. y; it resembles more closely pygidia of *Acidaspis.* The cranidium lacks the enormous occipital spine of *Acidaspis,* although the obtusely pointed extension of the occipital ring can be interpreted as such a spine. This cranidium may be a large mature specimen belonging to *Primaspis* sp. y. Until additional material is discovered, the correct generic and specific assignment of these two specimens is uncertain.

Sagittal length of cranidium is 6 mm, more than twice that of any cranidium here assigned to *Primaspis* sp. y. Cranidial length (sag) equals 0.6 width (tr) at posterior margin and 0.7 width at palpebral lobes. Length (sag) of glabella including occipital ring is 0.94 sagittal length of cranidium but length of glabella excluding occipital ring only 0.6 cranidial length. Length (sag) of occipital ring about 0.6 length of glabella in front of ring. Longitudinal furrows and occipital furrow shallow and broad, devoid of tuberculation. Middle lobe of glabella narrower (tr) than lateral lobe 1*p* and only slightly wider than greatest width (tr) of fixed cheek. Width (tr) of glabella at lobes 1*p* equals 1.5 sagittal length of glabella excluding occipital ring and 0.7 transverse width of cranidium between palpebral lobes.

Narrow distinct dorsal furrows curve inward around lobes 1*p* to join occipital furrow. A very short, shallow crescentic furrow branches from longitudinal furrow to indent the inner side of lobes 1*p*; this feature previously described only for *Acidaspis aviensis* Bruton (1968b, p. 300, fig. 12). Lateral furrows 1*p* and 2*p* subparallel and deep, clearly defining 2*p*. Furrow 3*p* very faint so that 3*p* is poorly defined and barely separated from frontal lobe. Three pairs of posterior border spines, of which the outer pair is rooted in the inner side of the major spines.

Illustrated specimens.—USNM 206871, 206872.

Occurrence.—Salvisa Bed of Perryville Limestone Member of Lexington Limestone, USGS collection 5015 CO.

Discussion.—The sagittal length of the occipital ring is longer (relative to the width of the ring) than in known species of *Primaspis.* The peculiar indenting of the inner side of glabellar lobe 1*p* is shared by *Acidaspis* sp. b described here. However, in *A.* sp. b, the indenting furrow seems to be a continuation adaxially of furrow 1*p,* whereas in sp. a

it may be a minute indistinct anterolateral branch of the longitudinal furrow. Other species of *Acidaspis* may exhibit this feature, although it seems to have gone unnoticed in previous descriptions; it appears to be present in *A. grayi* Barrande (Bruton, 1968a, pl. 5, figs. 4, 6).

Acidaspis sp. b

Plate 6, figures 20, 24–26

The following description is based on a damaged silicified cranidium and a fragmentary silicified pygidium.

As in other species of *Acidaspis*, the axial lobe of the cranidium is composed of a short wide glabella and an occipital ring dominated by a huge median spine. The occipital furrow is shallow medially; it curves back across the longitudinal furrows and around the posterior ends of lateral glabellar lobes 1*p* to reach the axial furrows. Axial furrows are shallow but distinct in bounding the glabella; from their junction with the occipital furrow behind the lateral lobes 1*p*, they diverge to bound the occipital ring, turning straight back at the border furrow to cross the margin. At the posterior margin the width (tr) of the occipital ring is 1.3 times the sagittal length of the glabella.

The glabella is widest at lateral lobes 1*p*. The sagittal glabellar length is 0.7 width (tr) at lobes 1*p*, 0.9 width (tr) at lobes 2*p*, and 1.22 times width (tr) at lobes 3*p*. Each lateral lobe 1*p* is broadly elliptical and only moderately inflated; length (exsag) is half the sagittal length of glabella. The length (exsag) of lobe 2*p* slightly overlaps lobe 1*p* and is one-third the glabellar length.

Lobe 3*p* is minute; its width (tr) exceeds its length (exsag), which is only 0.13 the sagittal glabellar length. The longitudinal furrow does not alter lobe 3*p*, but originates in the proximal end of furrow 2*p*, from whence it runs back shallowly to meet the occipital furrow; from the junction a short sharply incised furrow curves inward and backward about halfway across the occipital ring. This short furrow might be considered the terminus of the longitudinal furrow. It partially defines a small occipital lobe.

Palpebral lobes are short (exsag), semierect, and positioned opposite the occipital furrow. The palpebral rims and furrows are confluent forward with the eye ridges, which converge to the anterior border furrow, where they terminate against the frontal lobe of the glabella. Anteriorly the facial sutures converge to the border furrow (but not as much as the eye ridges), and cross the border to the front margin where a connective suture parallels the margin. The course on the doublure is not known. Posteriorly the suture runs downward almost to the border furrow, turns laterally parallel to the furrow, and then crosses furrow and border at an angle; the width (tr) of cranidium at the border is 1.6 times the sagittal length of the glabella.

The fragmentary pygidium excluding spines seems to have been about four times as wide as long. The axis must have been composed of two rings and a terminal piece, all crudely defined. The anterior ring is linked by a raised ridge with a pair of coarse marginal spines. Six smaller pairs are arranged three in front of and three between the major spines; the inner pair adjacent to the major spines is based indistinctly on the larger spines.

Illustrated specimens.—USNM 206873, 206874.

Occurrence.—USGS collection 7343 CO. Top of tongue of Clays Ferry Formation 0.9 mi south of Lair; Kentucky coordinates: E. 1,983,700 ft, N. 302,000 ft, Shawhan quadrangle, Kentucky.

Discussion.—The single silicified cranidium described here is almost identical in proportions to that illustrated by Ross (1967, pl. 5, fig. 20); the only difference is the seeming absence of lateral glabellar lobe 3*p* in the previously illustrated specimen. Whether the contrast between limestone and silicified preservation could account for this difference is doubtful, but possible.

The peculiar indenting of glabellar lobe 1*p* adjacent to the longitudinal furrow has been previously discussed, under *Acidaspis* sp. a.

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PLATES 1-6

Contact photographs of the plates in this report are available, at cost from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

PLATE 1

[All illustrations are stereophotographs except figures 14 and 15]

FIGURES 1–13. *Triarthrus eatoni* (Hall) (p. D2).

Kope Formation, Laurel 7½-minute quadrangle, Kentucky, All figures × 5.

1–3. Complete individual, enrolled. Relative to cephalon, dorsal, anterior, and lateral views. UCM 40633a.

4–6. Complete individual, enrolled. Relative to cephalon, dorsal, anterior, and lateral views. UCM 40633b.

7–9. Complete individual, enrolled. Relative to cephalon, dorsal, anterior, and lateral views. UCM 40633d.

10–12. Complete individual, enrolled. Relative to cephalon, dorsal, anterior, and lateral views. UCM 40633e.

13. Partly enrolled individual on pleural tips showing lateral projections that fit snugly against doublure of cephalon. UCM 40633c.

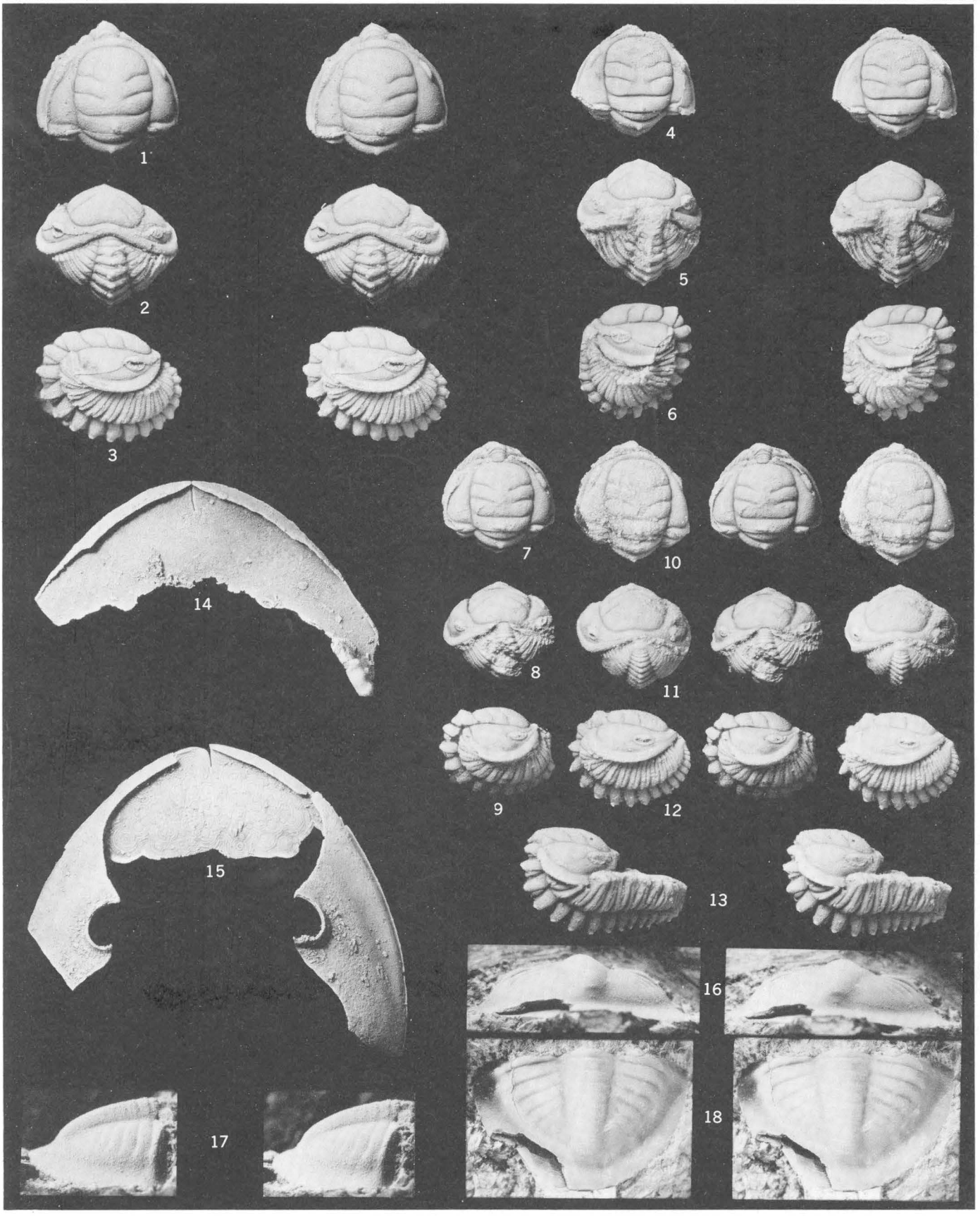
14, 15. *Isotelus gigas* DeKay (p. D5).

USGS colln. 5015 CO, Perryville, Ky. Dorsal views of yoked doublure of free cheeks. Median suture no longer functional. USNM 206844, 206845 (× 1).

16, 17, 18. Megalaspid(?) pygidium (p. D5).

Posterior, lateral, and dorsal views, (× 3).

USNM 206846. Camp Nelson Limestone, USGS colln. 7875 CO.



TRIARTHRUS, *ISOTELUS*, MEGALASPID(?)

PLATE 2

[All figures are stereophotographs]

FIGURES 1–6. *Decoroproetus* sp. x (p. D3).

Two partly enrolled individuals, only partly silicified. USGS colln. 6143 CO, Clays Ferry Formation, Cynthiana quadrangle, Kentucky.

1–3. Specimen preserving preglabellar field anterior border, thoracic and pygidial axis (× 5), USNM 206836.

4–6. Specimen preserving part of genal spine; hypostoma in place (× 4), USNM 206837.

7–16. *Decoroproetus* sp. 2 (p. D4).

USGS colln. 5015, Perryville Limestone Member of Lexington Limestone Perryville quadrangle, Kentucky. All figures (× 4).

7–9. Pygidium, dorsal, posterior, and lateral views, USNM 206838.

10–12. Pygidium, lateral, dorsal, and posterior views, USNM 206839.

13, 14. Librigena, dorsal and ventral views, USNM 206840.

15, 16. Librigena, ventral and dorsal views, USNM 206841.

17. Pygidium undetermined, not described.

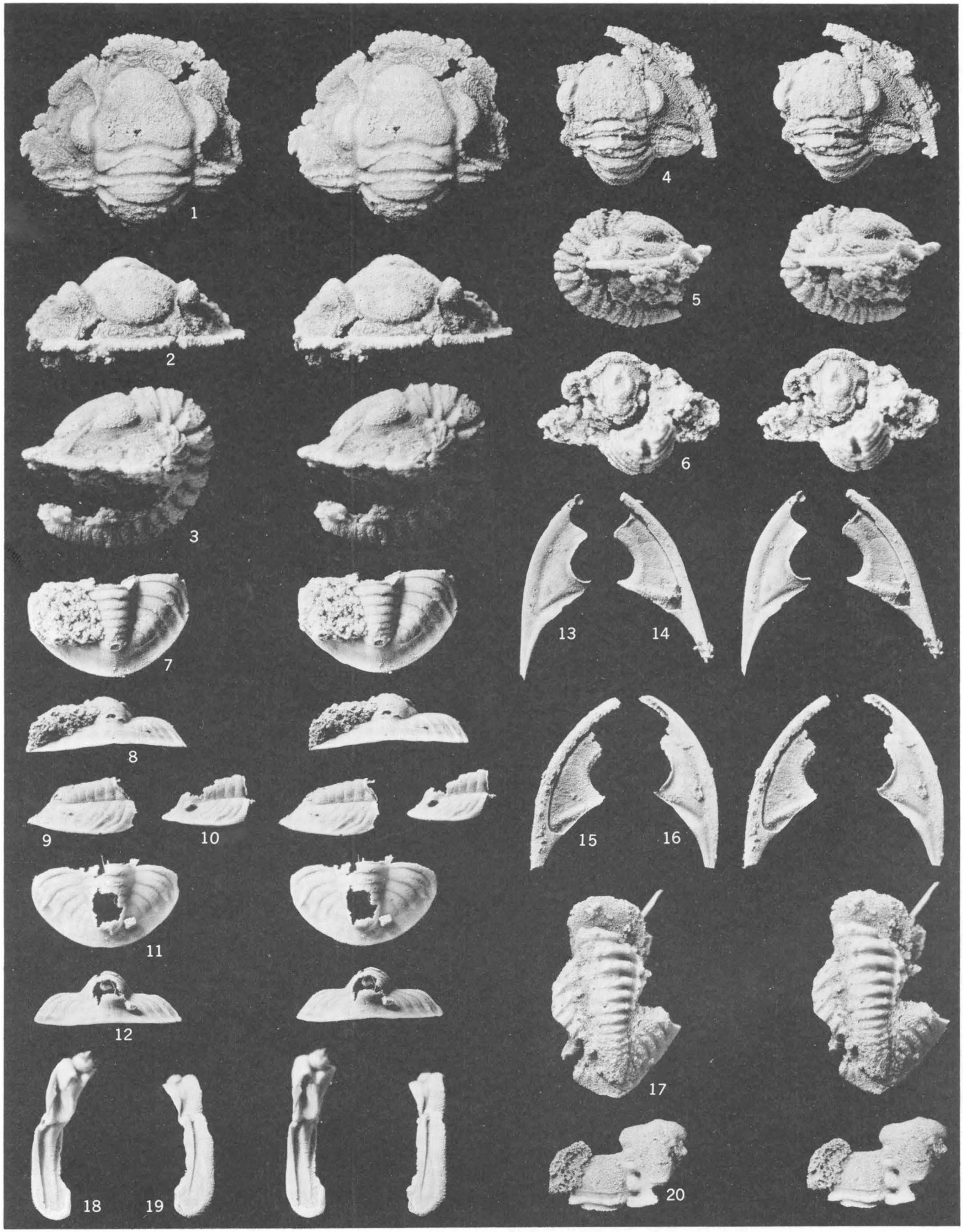
USGS colln. 6419 CO, Logana Member of Lexington Limestone, Wilmore quadrangle, Kentucky. USNM 206843.

18, 19. *Gravicalymene hagani* Ross (p. D5):

Thoracic segment showing construction of pleural tip (× 3), USGS colln. 5015 CO. USNM 206849. Note smooth facet and vincular stop.

20. Cybelinid cranidium (p. D5).

Dorsal view (× 2). USNM 206842. USGS colln. 6419 CO, Logana Member of Lexington Limestone, Wilmore quadrangle, Kentucky.



DECOROPROETUS, GRAVICALYMENE, CYBELINID

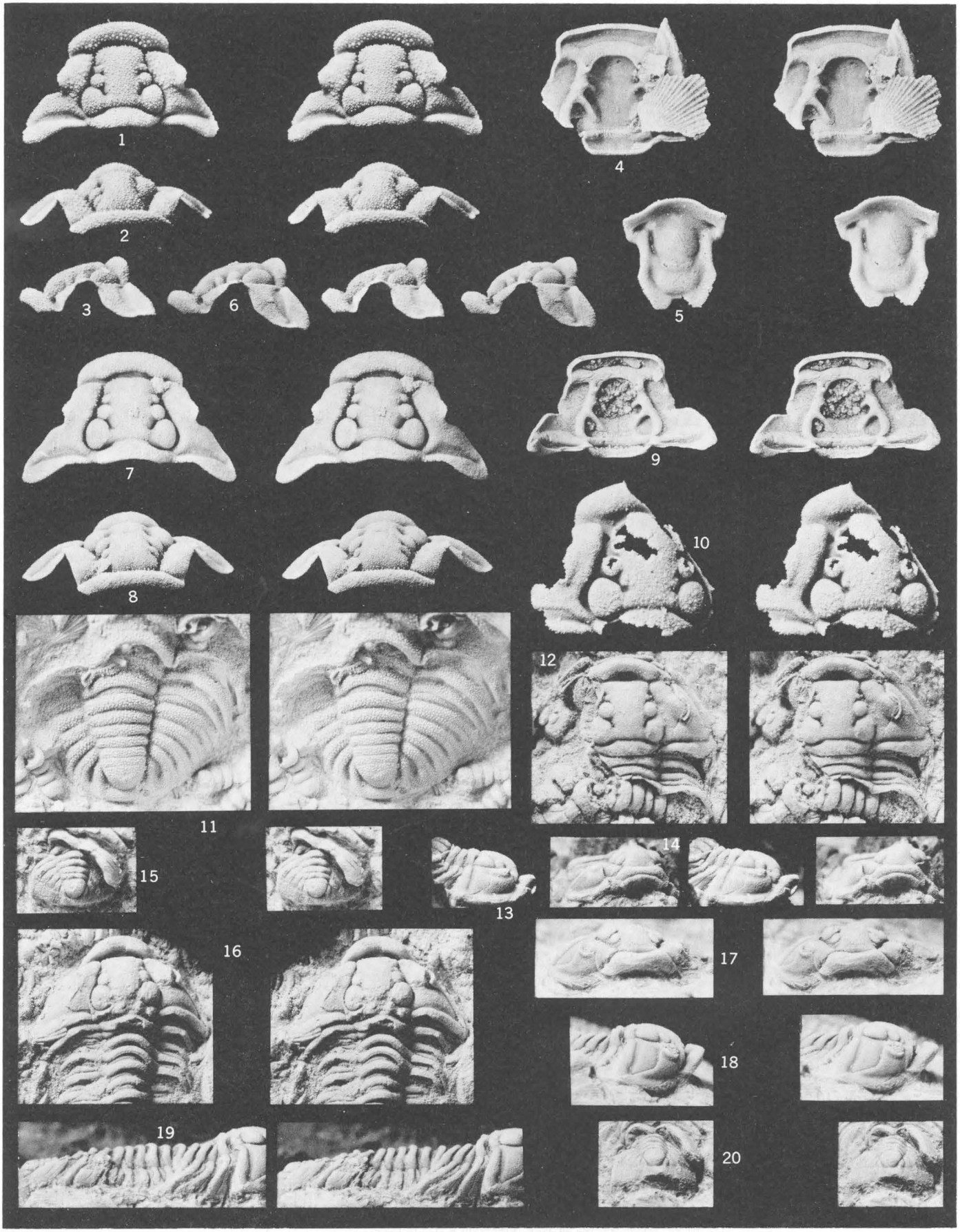
PLATE 3

[All figures are stereophotographs]

FIGURES 1–9. *Gravicalymene hagani* Ross (p. D5).
USGS colln. 5015 CO. Perryville Limestone Member of Lexington Limestone.
1–3. Cranidium, inmature, dorsal, anterior, and lateral views (× 4). USNM 206847.
4. Cranidium, large (possibly gerontic), showing apodemes for attachment of hypostoma. Ventral view (× 2). USNM 206850.
5. Hypostoma, ventral view (× 5). USNM 206852.
6–8. Cranidium, mature, lateral, dorsal, and anterior views (× 2). USNM 206848.
9. Cranidium, ventral view (× 2), showing apodemes for attachment of hypostoma. USNM 206851.

10. *Flexicalymene* sp. (p. D6).
Partial cranidium, dorsal view (× 5). USNM 206856. USGS colln. 6129 CO., Ashlock Formation.

11–20. *Gravicalymene truncatus* n. sp. (p. D6).
USGS colln. 7984 CO, Kope Formation, Moffett Road section, Demossville quadrangle, Kentucky.
11. Large associated pygidium, paratype, dorsal view (× 3). USNM 206853.
12–14. Partial cephalon, paratype, dorsal, lateral, and anterior views (× 4). USNM 206855.
15, 20. Pygidium, dorsal and posterior views (× 3). Same pygidium shown on left in figure 19. USNM 206854 (same no. as figs. 16 and 19).
16–18. Cephalon and anterior part of thorax (same shown in fig. 19), holotype, dorsal, anterior, and lateral views (× 3). USNM 206854.
19. Thorax, lateral view of holotype, same specimen as in figures 15–18, 20. USNM 206854.



GRAVICALYMENE, FLEXICALYMENE

PLATE 4

[All figures are stereophotographs]

FIGURES 1–7. *Platylichas halli* (Foerste) (p. D7).

USGS colln. 7343 CO. Tongue of Clays Ferry Formation, Shawhan quadrangle, Kentucky.

1. Hypostoma, ventral view (× 5), of a partially silicified specimen. USNM 206857.

2–4. Cranidium, dorsal, lateral, and anterior views (× 3). USNM 206858.

5–7. Cranidium, dorsal, anterior, and lateral views (× 2). USNM 206859.

8–11. *Primaspis trentonensis* (Hall) (p. D8).

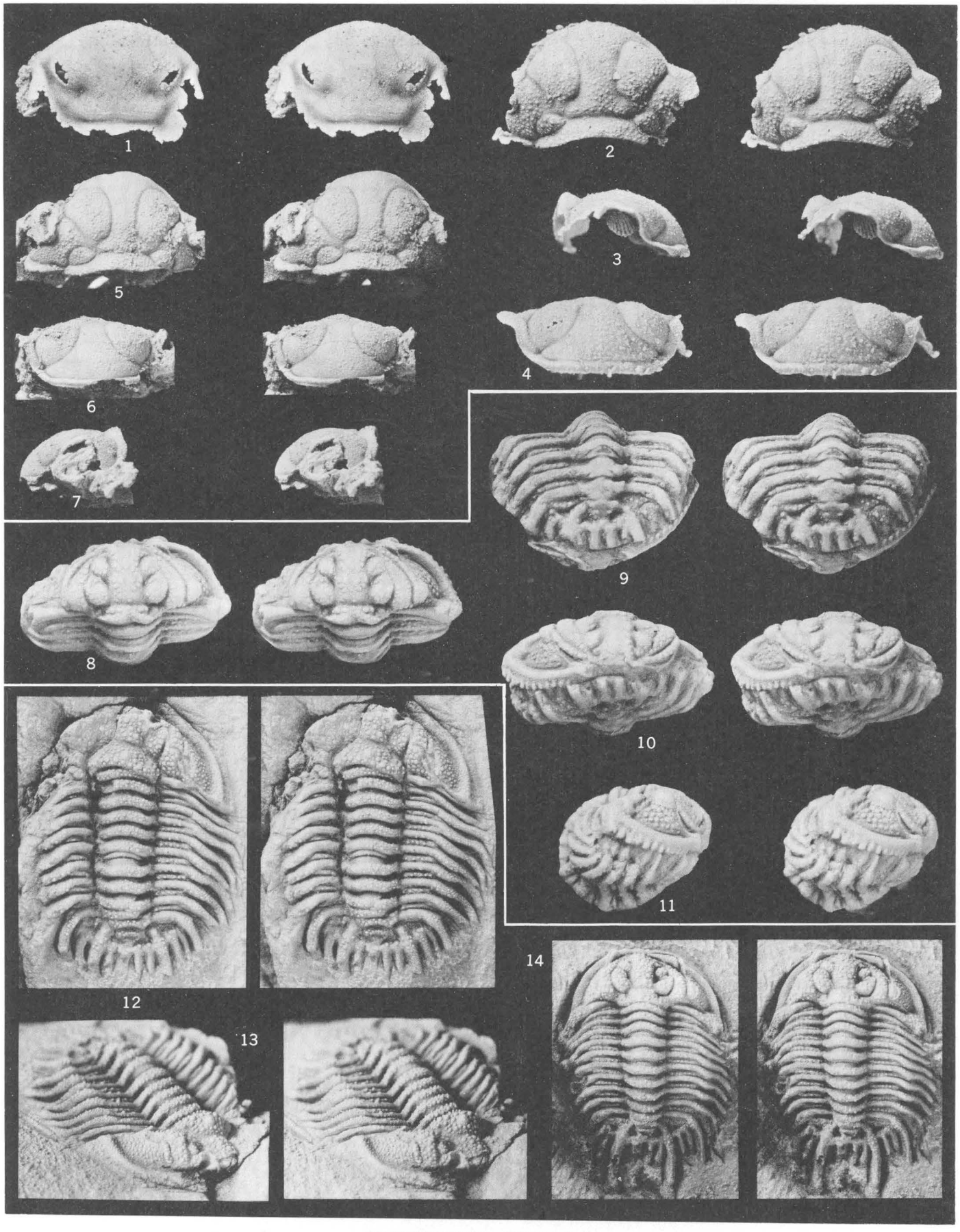
Holotype, illustrated by Hall (1847, pl. 64, fig. 4) and by Whittington (1941, pl. 74, figs. 31–34). Enrolled individual, views relative to cephalon are dorsal, ventral, anterior and lateral (× 6). AMNH 853½. Bay of Quinte, Ontario.

12–14. *Primaspis "trentonensis"* (p. D8).

Trenton Group near Trenton Falls, N.Y., (× 5). Previously illustrated by Whittington (1941, pl. 74, figs. 35–37) but not same species as Hall's holotype.

12, 13. Individual showing ornament of occipital ring and arrangement of pygidial spines. NYSM 9774.

14. Individual demonstrating cephalic features. NYSM 9773.



PLATYLICHAS, PRIMASPIS

PLATE 5

[All figures are stereophotographs]

FIGURES 1–14. *Primaspis* sp. x (p. D9).

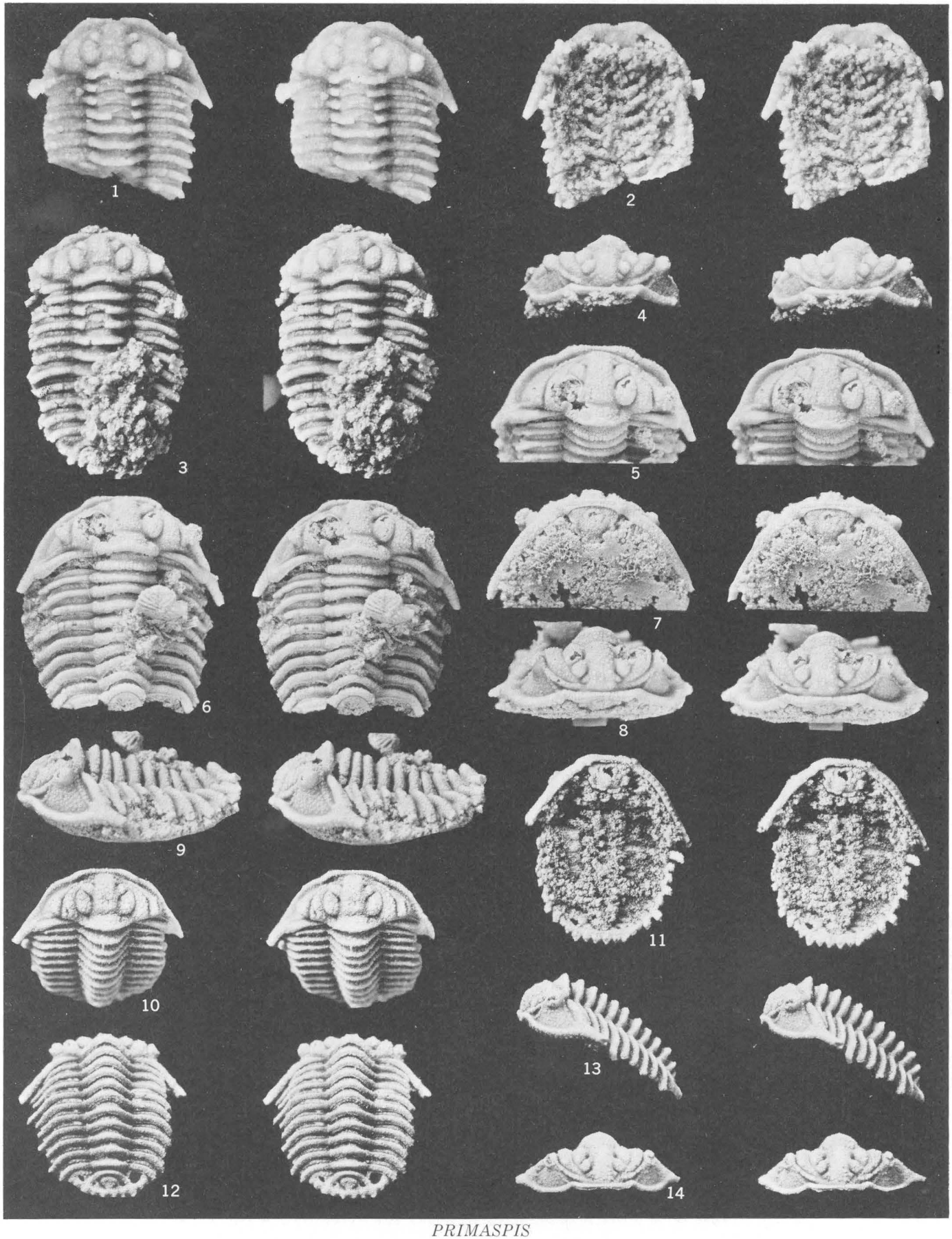
Clays Ferry Formation, Cynthiana and Shawhan quadrangles, Kentucky.

1, 2. Cephalon and partial thorax with silicified casts of appendages crudely preserved on ventral side (× 7). USNM 206860. USGS colln. 6143 CO.

3, 4. Nearly complete individual. Dorsal and anterior views (× 7). USNM 206861. USGS colln. 6143 CO.

5–9. Partial specimen, lacking posterior thorax and pygidium. Views of dorsal cephalon, thorax, ventral cephalon and hypostoma, anterior cephalon, and lateral (× 5). USNM 206863. USGS colln. 7343 CO.

10–14. Complete individual (× 5). USNM 206862. USGS colln. 6990 CO. Stumps of appendages may be partly preserved on ventral side in figure 11. Compare pygidium in figure 12 with that in plate 6, figure 1.



PRIMASPIS

PLATE 6

[All figures are stereophotographs]

FIGURES

1–2. *Primaspis* sp. x (p. D9).
Thorax and pygidium showing fine ornament. Dorsal and lateral views (× 5). USNM 206864. USGS colln. 7343 CO.

3–16. *Primaspis* sp. y (p. D10).
Salvisa Bed of Perryville Limestone Member of Lexington Limestone, USGS colln. 6915 CO, except figs. 13, 14.

3. Posterior part of cranidium, dorsal view showing full width (tr) at posterior border and occipital lobes (× 6). USNM 206865.

4–6. Cranidium lacking posterior part of fixed cheeks. Dorsal, anterior, and lateral views (× 7). USNM 206866.

7–9. Pygidium, dorsal, lateral, and posterior views (× 7). USNM 206868.

10–12. Pygidium, dorsal, lateral, and posterior views (× 7). USNM 206869.

13, 14. Hypostoma, ventral and dorsal views (× 7). USNM 206870. USGS colln. 5015 CO.

15, 16. Librigena, dorsal and lateral views (× 7). USNM 206867.

17–19, 21–23. *Acidaspis*? sp. a (p. D11).
USGS colln. 5015 CO, Salvisa Bed of Perryville Limestone Member of Lexington Limestone.

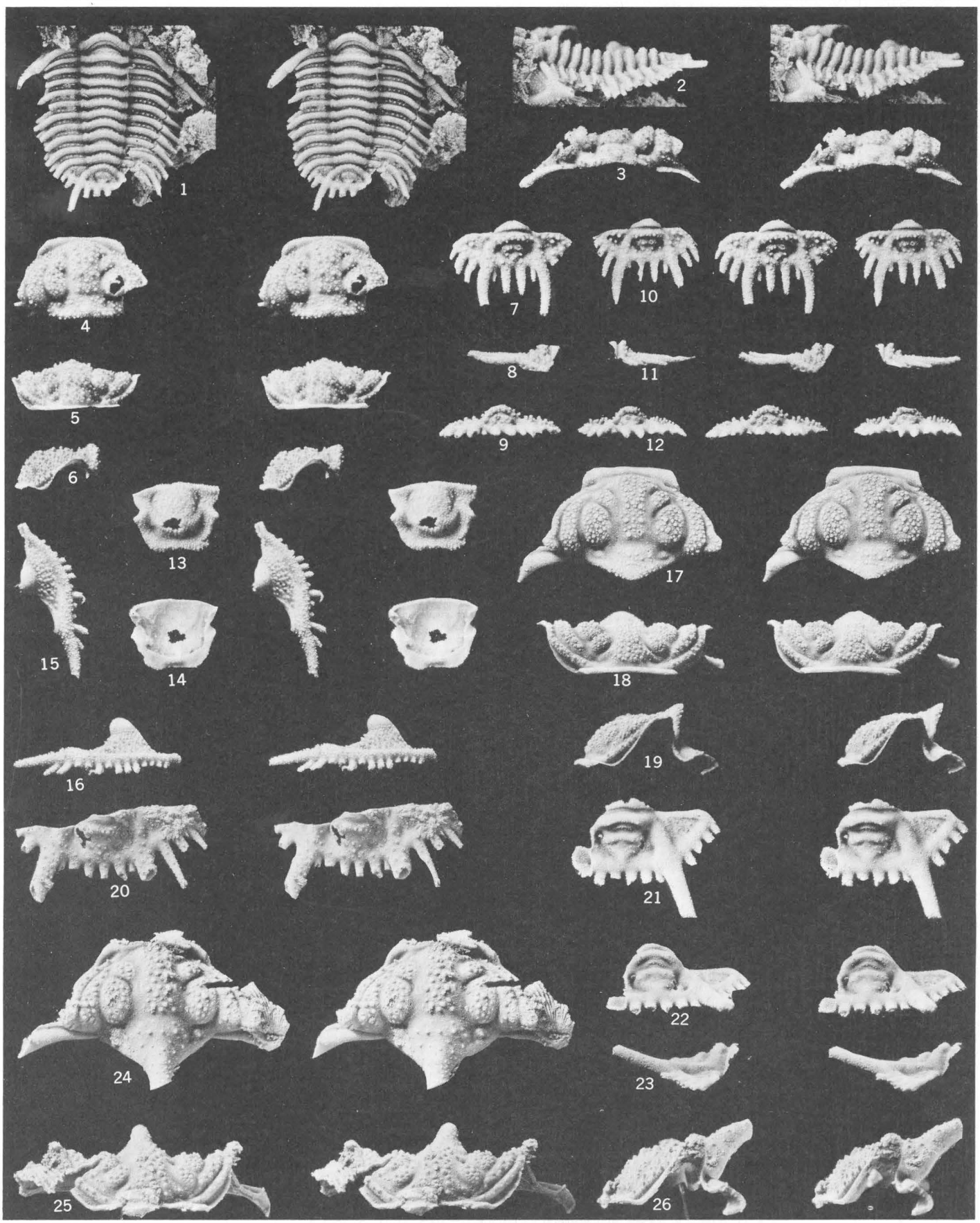
17–19. Cranidium; dorsal, anterior, and lateral views (× 4). USNM 206871.

21–23. Pygidium, lacking left pleural region and tips of all spines. Dorsal, posterior, and lateral views (× 4). USNM 206872.

20, 24–26. *Acidaspis* sp. b. (p. D12).
USGS colln. 7343 CO. Tongue of Clays Ferry Formation.

20. Pygidium, poorly preserved; dorsal view (× 3). USNM 206874.

24–26. Cranidium, dorsal, anterior, and lateral views (× 3). USNM 206873.



PRIMASPIS, ACIDASPIS