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Trilobite Biostratigraphy and Correlation of the Kindblade Formation (Lower Ordovician) of Carter and Kiowa Counties, Oklahoma

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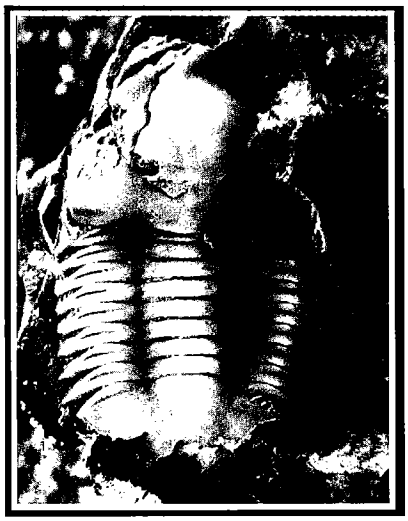

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Cover Illustration

Isoteloides peri Fortey. *1*, Articulated exoskeleton, testate, (UMC 16805), from I-1066; *5*, palpebral view, ×3.4;

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Trilobite Biostratigraphy and Correlation of the Kindblade Formation (Lower Ordovician) of Carter and Kiowa Counties, Oklahoma

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ABSTRACT.—The Kindblade Formation (Ibexian Series, Lower Ordovician) has yielded a diverse suite of trilobite species from measured sections in the Arbuckle Mountains (along Interstate 35) and in the Wichita Mountains (at the type section on the Kindblade Ranch) of Oklahoma. Detailed stratigraphic sampling of up to 1,498 ft (457 m) of the Kindblade Formation yielded 246 trilobite-bearing collections.

Six trilobite interval zones are established for the Kindblade Formation: (in ascending stratigraphic order) the *Ranasasus brevicephalus* Zone, *Jeffersonia granosa* Zone, *Benthamaspis rhochmotis* Zone, *Petigurus cullisoni* Zone, *Bolbocephalus stitti* Zone, and the *Strigigenalis caudata* Zone. Correlative fossiliferous strata from the southern and eastern United States and eastern Canada are typically dolomitized or, if still preserved as limestone, they are abbreviated stratigraphically. The zonal terminology developed for the trilobites of the Kindblade Formation, therefore, stands as a standard for correlation within the Midcontinent (Oklahoma, Texas, and Missouri) and the eastern United States and eastern Canada.

Ross and others (1997) established and named a succession of four stages for the Ibexian Series based upon the trilobite successions in Utah. Unfortunately, the trilobite species used to define the base of these stages and those that characterize the stages are absent in the Oklahoma and Missouri region, especially in the medial Ibexian Series. Formal definition of regionally applicable stage terms through the selection of boundary stratotypes and points is offered for the Jeffersonian and Cassinian Stages originally proposed by Flower (1964). The boundary stratotype and point for the Jeffersonian Stage is the first appearance of *Ranasasus brevicephalus* Cullison or *Chapmania taylori* n. sp. at 62 ft (19 m) above the base of the Kindblade Ranch measured section. The boundary stratotype and point for the Cassinian Stage is defined as the first appearance of *Petigurus cullisoni* at 691 ft (211 m) above the base of the I-35 section.

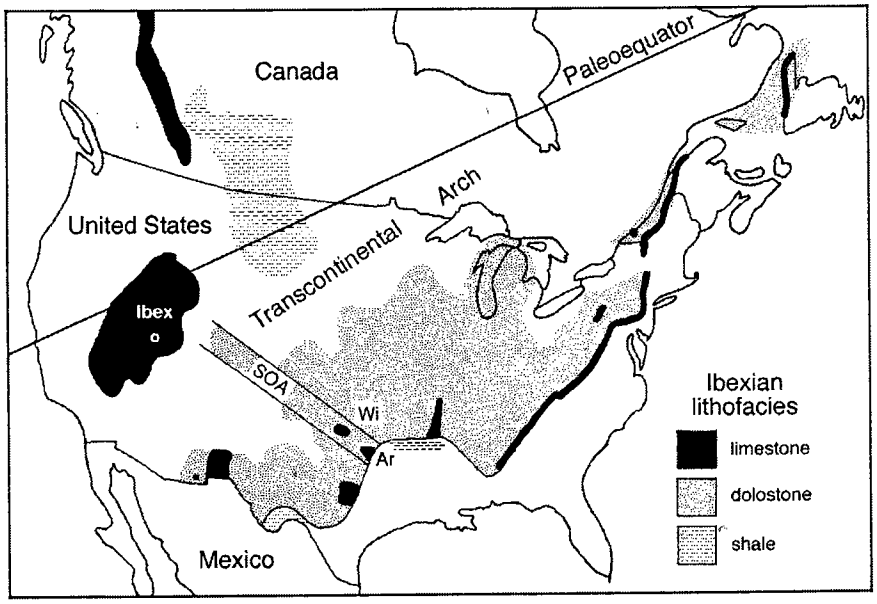
Fifty-two species assigned to 19 genera were recovered from the Kindblade. Four genera are new: *Chapmania* (type species *C. oklahomensis* n. sp.), *Gelasinocephalus* (type species *G. whittingtoni* n. sp.), *Speyeris* (type species *S. hami* n. sp.), and *Cullisonia* (type species *C. producta* [Cullison, 1944]). Twenty-two species are new. Alphabetically, these are: *Bathyurellus arbucklensis, Bathyurellus inflatus, Benthamaspis onomeris, Benthamapsis rhochmotis, Bolbocephalus myktos, Bolbocephalus stitti, Chapmania carterensis, Chapmania oklahomensis, Chapmania taylori, Gelasinocephalus pustulosus, Gelasinocephalus whittingtoni, Ischyrotoma sila, Jeffersonia ulrichi, Petigurus cullisoni, Punka akoura, Punka verecunda, Ranasasus colossus, Randaynia leatherburyi, Speyeris hami, Strigigenalis derbyi, Strigigenalis implexa,* and *Strigigenalis insentis.* Ten species recognized by Cullison (1944) are treated based on material from the Kindblade Formation: *Benthamaspis* cf. *mediacrista, Bolbocephalus jeffersonensis, Cullisonia producta, Jeffersonia granosa, Jeffersonia jenni, Lutesvillia bispinosa, Ranasasus brevicephalus, Ranasasus conicus, Rollia goodwini,* and *Strigigenalis crassimarginata.* An additional 20 taxa are left in open nomenclature.

INTRODUCTION

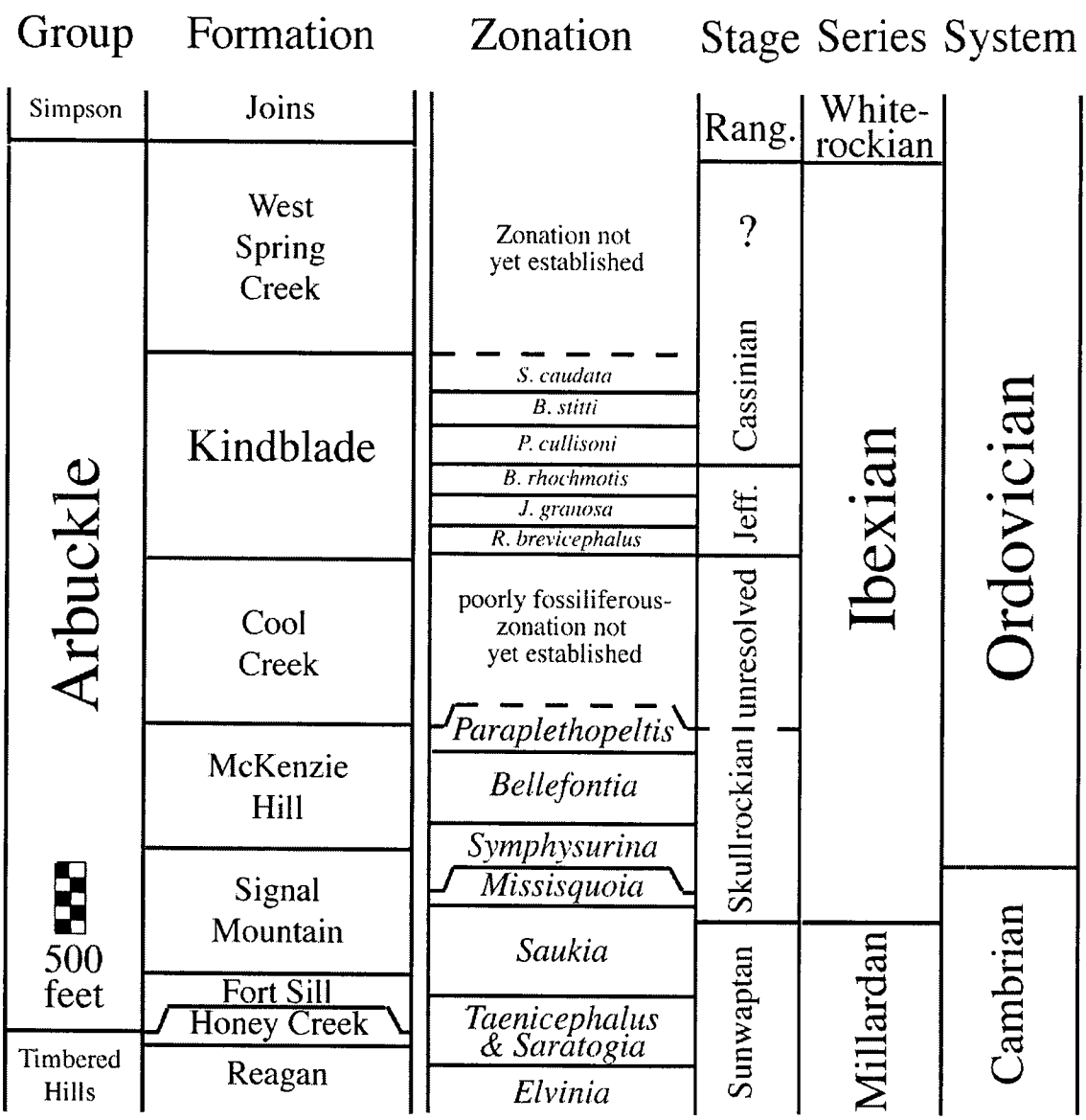
The Lower Ordovician (Ibexian Series) of North America is characterized by thick deposits of marine carbonates that accumulated upon broad, stable platforms (Text-fig. 1). Two facies belts can be outlined east of the Transcontinental Arch. Supratidal and shallow-subtidal carbonates were deposited proximal to the craton, under hypersaline conditions and subjected to penecontemporaneous dolomitization (Ross, 1976). The depauperate faunas recovered from this facies are commonly dominated by gastropods, including *Ceratopea*. Distally, normal marine conditions predominated leading to the preservation of shallow-marine limestones with more abundant and diverse faunas which included trilobites.

The Kindblade Formation is the penultimate formation of the Arbuckle Group, which accumulated in southern Oklahoma from the Late Cambrian to the Middle Ordovician (Text-fig. 2). Across much of the state the Kindblade is present as a dolomite. However, carbonate deposition within the Southern Oklahoma Aulacogen (shown as "SOA" in Text-fig. 1; Wickham and Denison, 1978) is interpreted to have occurred under shallow-subtidal to normal-marine conditions. There, the shallow-subtidal limestones of the Kindblade Formation are the most lithologically uniform within the Arbuckle Group (Ham, 1950, 1955). The Ibexian (Lower Ordovician) limestones of the Kindblade Formation are exposed in the Arbuckle and Wichita Mountains.

Previous studies of the trilobites of the lower part of the Arbuckle Group and the underlying Timbered Hills Group demonstrated the suitability of these Oklahoma outcrops for biostratigraphic study (Stitt, 1971, 1977, 1983). During a reconnaissance of the Kindblade Formation for the Amoco Oil Company in the 1970s, Derby and others (1977; 1991, fig. 8) recovered a limited fauna consisting of three trilobite species. J. R. Derby (personal communication, 1970) suggested, however, that detailed sampling would result in the recovery of a more diverse trilobite fauna. The current study of the Kindblade Formation continued the investigations of Stitt into a younger portion of the Arbuckle Group, documenting the succession of 56 trilobite species within the next fossiliferous formation (Table 1). Reexamination of the Amoco collections confirmed Derby's identification of *Peltabellia missouriensis* (Cullison), although the specimens that he identified as *Bolbocephalus sancticlairi* (= *B. st. clairi*) Cullison are reassigned to *Bolbo-*



Text-figure 1. Map of Ibexian Series (Lower Ordovician) lithofacies distributions for limestone (black), dolomite (stippled), and shale (dashed). Note scarcity of limestone facies east and south of the Transcontinental Arch. Abbreviations: Ar–Arbuckle Mountains, SOA–Southern Oklahoma Aulacogen, Wi–Wichita Mountains. After Bally and Cook (1975); Ross (1976).



Text-figure 2. Diagram summarizing Arbuckle Group formation names and trilobite zones as exposed in Arbuckle and Wichita Mountains of southern Oklahoma. After Stitt (1971, 1977, 1983); Derby and others (1977, 1991); original data.

cephalus stitti. Further, *Ischyrotoma abrupta* (Cullison) is revised with the specimen assigned to *Ischyrotoma sila* n. sp. An unidentified and previously uncited, fragmentary pygidium from the Amoco collections has been identified as *Punka akoura* n. sp.

The Kindblade Formation was sampled intensively at measured sections at the type section on the Kindblade Ranch (Wichita Mountains, Kiowa County) and on the Chapman Ranch, located east of I-35, (Arbuckle Mountains, Carter County) in southern Oklahoma (Text-fig. 3). The measured sections were selected to avoid major structural complications and local to regional dolomitization documented during field mapping in the Wichita Mountains by Brookby (1969) and in the Arbuckle Mountains by Ham (1950) and Fay (1989). Sections were measured using a Brunton compass and a Jacob's staff. The section was painted at 5-ft (1.5-m) intervals, and the cumulative footage was noted on the rock approximately every fifth paint stripe. Paleontologic

TABLE 1.—Previous Paleontological Studies Including the Kindblade Formation of Southern Oklahoma

Taxonomic Group	Author(s)
Algae and Porifera:	Toomey (1964); Riding and Toomey (1972); J. R. Derby *in* Rigby and Toomey (1978); Derby and others (1977, 1991); Toomey and Nitecki (1979)
Arthropoda–Trilobita:	Cloud and Barnes, 1948; J. R. Derby *in* Derby and others (1977, 1991)
Brachiopoda:	Ulrich and Cooper (1938); Cooper (1952, 1956); J. R. Derby *in* Derby and others (1977, 1991)
Bryozoa:	Ross (1966)
Conodonta:	Brand (1976); R. L. Ethington *in* Toomey and Nitecki (1979); Ethington and Dresbach, 1990; Dresbach and Ethington (1991); Dresbach (1998)
Mollusca:	Yochelson and Bridge (1957); Smith and Toomey (1964); Yochelson (1973); J. R. Derby *in* Derby and others (1977, 1991); Toomey (1980)

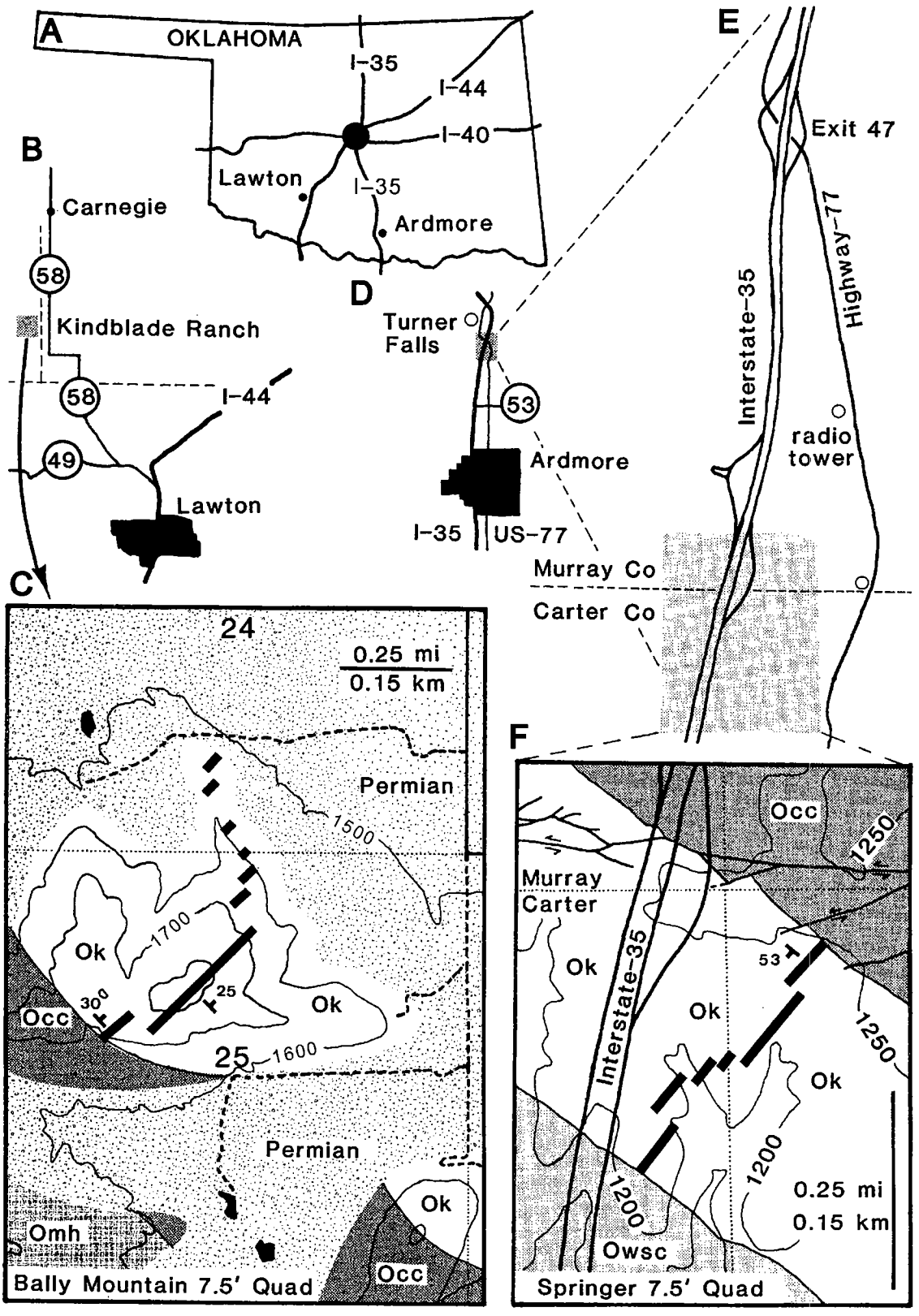
sampling was conducted on a bed-by-bed basis for approximately 50 ft (15 m) along strike. Additional samples resulted from the comminution of 50–75-lb (23–34-kg) boulders removed occasionally from thick-bedded limestones. Identifiable trilobite material was labeled by stratigraphic position and wrapped for transportation. Lithologic descriptions of the sections were recorded on a bed-by-bed basis and included notation of any associated non-trilobite macrofossils. An average of 25 ft (8 m) of stratigraphic section, excluding covered intervals, could be sampled and described each day. Trilobite samples were prepared in the Advanced Paleontology Laboratory of the Department of Geological Sciences, University of Missouri–Columbia.

Acknowledgments

I would like to thank the late James H. Stitt, (University of Missouri–Columbia) who toiled selflessly in his role as my dissertation advisor. R. L. Ethington kindly discussed problems of large-scale correlation in Lower and Middle Ordovician strata and fundamental concepts of biostratigraphy. J. F. Taylor (Indiana University of Pennsylvania) sparked my interest in trilobites, introduced me to the University of Missouri–Columbia, and provided the stimulus to complete the revision of the dissertation. R. A. Fortey, S. R. Westrop, and J. R. Derby provided critical reviews.

Doyle Leatherbury (Apache, Oklahoma), and A. C. and Curtis Pletcher (Springer, Oklahoma) graciously provided access to the measured sections. A. C. Spreng (University of Missouri–Rolla) and R. D. White (Yale Peabody Museum) provided access to some of Cullison's collections. J. R. Derby facilitated examination of the Amoco collections before their transfer to the University of Oklahoma. G. P. Chludzinski collected the topotype specimen of *Bolbocephalus jeffersonensis*; W. D. Boyce provided latex molds of his specimens of *Strigigenalis crassimarginata*; and

Text-figure 3 *(facing page)*. Index maps for measured sections of the Kindblade Formation. (A) Map of Oklahoma showing interstate highways and locations of Ardmore and Lawton. (B) Location of Kindblade Ranch and communities of Lawton and Carnegie. (C) Geologic map for portion of the Bally Mountain 7.5′ Quadrangle, Kiowa County (after Brookby, 1969), showing line of section for the Kindblade Ranch section (bold black line). Topographic contour interval = 100 ft (30 m). Abbreviations: Occ–Cool Creek Formation, Ok–Kindblade Formation, Omh–McKenzie Hill Formation. (D, E) Location of the Interstate-35 section and community of Ardmore and Turner Falls. (F) Geologic map for portion of the Springer 7.5′ Quadrangle, Carter County (after Ham, 1950; Fay, 1989), showing position of the I-35 section (bold black line), east of the southern scenic turnout on the Chapman Ranch. Topographic contour interval = 50 ft (15 m). The section was located in the adjacent pasture to avoid the major fault that truncates an estimated 90 ft (27 m) of section from the base of the Kindblade Formation at the highway road cut. Abbreviations: Occ–Cool Creek Formation, Ok–Kindblade Formation, Owsc–West Spring Creek Formation.



Text-figure 3.

D. Short and A. Gresham printed some of the photographs assembled in the plates.

The Department of Geological Sciences, University of Missouri–Columbia supported study of the Kindblade Formation in the form of graduate assistantships, supplies, equipment, and field support (through a gift from Chevron). Field support also was provided through a research grant from the Geological Society of America (4260-89).

LITHOSTRATIGRAPHY

The stratigraphic nomenclature of the Arbuckle Group was stabilized following the work of Decker (1939a,b) and Ham (1950, 1955). The Kindblade Formation was designated to include the "main" range zone of the gastropod operculum *Ceratopea* (Decker, 1939b, p. 26). Ham (1950, p. 58; 1955) defined the base of the Kindblade Formation in the Arbuckle Mountains at the top of a thin-bedded limestone interval that yields chert nodules of up to 1.0 ft (0.3 m) in diameter. The base of the formation was recognized on the I-35 section on this basis. This horizon lies between the oolitic cherts typical of the underlying Cool Creek Formation and slightly below an interval containing abundant specimens of the lithistid sponge *Archaeoscyphia* (Ham, 1950, 1955). The large chert nodules are not present at the Kindblade Ranch measured section in the Wichita Mountains. Thus, in this measured section, the base of the Kindblade Formation was placed where a marked increase in bedding thickness occurs above the uppermost oolitic chert of the Cool Creek Formation (3 ft [1 m] above the base of the measured section), and at a position below the first occurrence of *Archaeoscyphia* or *Ceratopea.*

The underlying Cool Creek Formation exhibits ample evidence of deposition under shallow, hypersaline conditions, including (1) reduced macrofossil diversity, (2) abundant laterally linked stromatolitic boundstone, (3) abundant oolitic limestone, (4) abundant dolomite and chert, and (5) pseudomorphs after evaporite minerals (St. John and Eby, 1978; Ragland and Donovan, 1986; Gao and Land, 1991; J. R. Derby *in* Derby and others, 1991). The base of the Kindblade Formation is marked by decreases in content of chert, oolite, and dolomite, by increase in stacked-hemispherical stromatolitic boundstone, by absence of evaporite pseudomorphs, by increase in average bedding thickness, and by a marked increase in faunal diversity with the establishment of the *Ranasasus brevicephalus* Zone fauna. This diversity increase indicates a return to normal-marine conditions not experienced in the Arbuckle Group since the deposition of the lower lime-mudstone member of the McKenzie Hill Formation (Stitt, 1983). This event can be correlated with the base of the Honeycut Formation of Texas and the Jefferson City Formation of Missouri (Derby and others, 1991, figs. 2, 3; see section on correlation below) and probably represents a eustatic rise in sea-level. This horizon is marked by a sharp decrease in oolitic chert both in Missouri (Thompson, 1991, p. 39) and in Oklahoma. Trilobites of the *Ranasasus brevicephalus* Zone are present within 35 ft (11 m) of this horizon in Oklahoma, within 70 ft (21 m) in Texas (Cloud and Barnes, 1948), and within 20 ft (6 m) in Missouri (Cullison, 1944; Thompson, 1991; Loch and others, 1993).

Subtle lithologic variations are evident in the Kindblade Formation, although Ham (1950, 1955) believed that the Kindblade was the most uniform of the Ordovician formations within the Arbuckle Group. Fay (1989) delineated three informal members of the Kindblade Formation on road cuts along Interstate 35 (I-35) in the Arbuckle Mountains. These members record the gradual shallowing of water depth during deposition of the Kindblade Formation.

In Fay's (1989) lower member of the Kindblade Formation, cyclic deposition of thick-bedded, bioturbated lime mudstones alternating with thin- to medium-bedded lime mudstones and grainstones is well established (Lindsay and Koskelin, 1991, p. 79–80). Preferential weathering of the thin- to medium-bedded limestones leaves the thick-bedded strata standing in positive relief, reminiscent of aligned tombstones ("tombstone topography"). Thick-bedded, stacked-hemispherical stromatolitic boundstones are common. Biostromes composed of *Archaeoscyphia* with or without *Calathium* are restricted to the lower member (Toomey and Nitecki, 1979) and functioned as baffles for lime-mud deposition. The mudstones and sponge-algal biostromes are interpreted to have been deposited below fair-weather–wave base, in a deep-subtidal setting. The packstones and grainstones are thought to represent a shallowing-upward accumulation of sediment to a position above fair-weather wave base, allowing for winnowing of the fine-sized sediment fraction and concentration of the coarse fraction. Common, thin skeletal lime grainstones that commonly exhibit scoured bases are thought to represent tempestites (storm-generated beds; Tenney, 1984). These interpretations are consistent with the lithofacies

associations and interpretations outlined by Osleger and Read (1991, p. 1230–1231) for Late Cambrian carbonate-ramp sediments in the Appalachian fold belt of Virginia and Tennessee.

The base of the middle member of Fay (1989) is marked by the lowest occurrence of oolitic limestones (Fay's bed 82), interbedded with thick-bedded lime mudstone and thin-bedded wackestone to grainstone. The basal oolite bed was correlated physically from exposures along the interstate to a position 660 ft (201 m) above the base of the I-35 section. The ooids seen in hand sample were most commonly present in a matrix of lime mud and were classified as oolitic lime mudstones to packstones; oolitic lime grainstones are scarce. The mixture of oolites and lime mud is interpreted to result from the washing of oolites formed in shoal water, higher-energy settings into quiet water, subtidal settings under the influence of storms. The presence of a proximal source for oolites indicates a general shallowing in the Kindblade Formation between the lower and middle members of Fay.

The upper member of the Kindblade Formation of Fay (1989) has relatively fewer oolitic limestones than the middle member. Thick-bedded, locally bioturbated lime mudstones with thin argillaceous to dolomitic partings predominate, with smaller amounts of thin skeletal grainstones and scarce, laterally linked hemispherical stromatolitic boundstones. Read (1980, p. 1593) interpreted a similar lithofacies association in the Lenoir and Lincolnshire Formations of Virginia as a shallow-subtidal deposit. Severe reduction in the number of trilobites and associated macrofauna may indicate conditions of restricted circulation in a lagoonal setting, as suggested by Lindsay and Koskelin (1991).

Although Lindsay and Koskelin (1991) interpreted all of the Arbuckle Group as an iterative repetition of complete and incomplete shallowing-upward cycles (parasequences), these cyclic features are not as obvious in the middle and upper members of Fay (1989) as in the lower member. Absence of cryptalgal laminites, ribbon carbonates, oncolites, mud-cracked laminites, solution breccias, microkarst features, and silica-replaced evaporite minerals (Read, 1980, p. 1581, 1590; Osleger and Read, 1991, p. 1228–1229) indicate that the shallowing-upward cycles in the Kindblade failed to aggrade to intertidal or supratidal conditions. Interpretation of cyclic sedimentation in the Arbuckle Group, including the Kindblade, was used by Goldhammer and others (1993, fig. 13) to correlate from western Texas to central Pennsylvania.

Intraclastic lime wackestone to packstone is common to abundant throughout the Kindblade Formation. Sepkoski (1982) and Osleger and Read (1991) interpreted this type of lithology in other areas to result from storm scour and redeposition of clasts within rimmed-lagoonal to intrashelf-basin settings. Sediments accumulating within the Southern Oklahoma Aulacogen probably were deposited in this type of setting at slightly greater water depths than those intertidal- to supratidal-dolomitic sediments on the adjacent portions of the platform. For example, mud cracks and oolitic lime grainstones are absent in the lower part of the Kindblade Formation but are present in contemporaneous deposits of the Jefferson City Formation of Missouri (Cullison, 1944). Fortey (1979) noted a close association of storm-generated intraformational conglomerates and the trilobite *Isoteloides peri*. Both intraformational conglomerate (intraclastic wackestones to intraclastic rudstones) and *I. peri* are less common in the Wichita Mountains than in the Arbuckle Mountains.

Oolitic limestones were not observed in the Kindblade Formation at the type section in the Wichita Mountains. This prevented application of Fay's (1989) informal member terminology (see, however, Donovan and others, 1986). At the type section, lime mudstones in the lower portions of the Kindblade Formation are conspicuously darker than those from the Arbuckle Mountains, suggesting deposition at somewhat greater depths or under quieter conditions. Recovery of limonitic trilobite molds, after pyrite, from collection KR-437 suggests at least occasional reducing conditions below the sediment-water interface following deposition. This would contribute to the preservation of dispersed organic matter and could result in a darker-gray rock color. Stromatolitic boundstones are nearly absent and sponge-algal buildups are more commonly biohermal than biostromal in their geometry on the Kindblade Ranch.

The Kindblade Formation was deposited in an intrashelf basin influenced by the presence of the Southern Oklahoma Aulacogen. Deposition of carbonate sediment in the position of the Wichita Mountains occurred under slightly deeper, quieter water conditions than for that of the Arbuckle Mountains. Shallowing-upward cycles, most evident low in the formation along the I-35 section, were the dominant mode of sedimentation in the Kindblade Formation. Following resumption of normal-marine conditions at the top of the underlying Cool Creek Formation, the Kindblade Formation, as a whole, was a

shallowing-upward lithologic package from deep-subtidal at the base to near-intertidal conditions at the top of the section. Terrigenous clastic lithologies (shales and sandy dolomites, Fay, 1989) within the overlying West Spring Creek indicate continued shallowing within the basin.

TRILOBITE BIOFACIES

Most trilobites are interpreted to have lived as part of benthic marine communities. Fortey (1975) described four benthic trilobite communities, now referred to as biofacies, which were identified through the recurrent association of trilobite genera during the Early Ordovician. Each of these biofacies was associated with a different lithology from shelf-margin build-ups to basinal sediments across a bathymetric gradient. A fifth group of pelagic species was independent of substrate type.

Fortey (1980) described an additional nearshore, bathyurid biofacies, based upon his revision of the trilobites of the Catoche Formation of western Newfoundland (Fortey, 1979). The Kindblade, as previously discussed, was deposited under moderate- to shallow-subtidal depth. The trilobite fauna of the Kindblade Formation is a classic example of such a bathyurid biofacies. Among the 18 genera recovered from the Kindblade, 14 are assigned to the Bathyuridae, including 31 of 34 named species. Importantly, the relatively shallow-water character of the Kindblade and the dominance of the bathyurid trilobites within the fauna are consistent throughout the formation. The implication of this observation is that any faunal boundaries established within the Kindblade will be based upon origination and extinction events rather than faunal replacement as a function of changing biofacies.

TRILOBITE BIOSTRATIGRAPHY

Ross and others (1997) summarized the biostratigraphic data and zonal terminology applicable to the Ibexian (Lower Ordovician) rocks of the western United States and Canada. Unfortunately, the trilobite zones developed from the Ibex region of western Utah (Text-fig. 1) cannot be directly applied to southern Oklahoma because there are no species common to both areas. To illustrate the dissimilarity of the faunas of these two regions, Jaccard coefficients were calculated (Text-fig. 4; Table 2) and indicate a strong dichotomy between the species of the Great Basin and those documented from the Kindblade Formation (see also Loch, 1995). In the absence of trilobite species that characterize the Ibexian trilobite zones, it is appropriate to develop a separate zonal terminology applicable to the southern and eastern United States and eastern Canada.

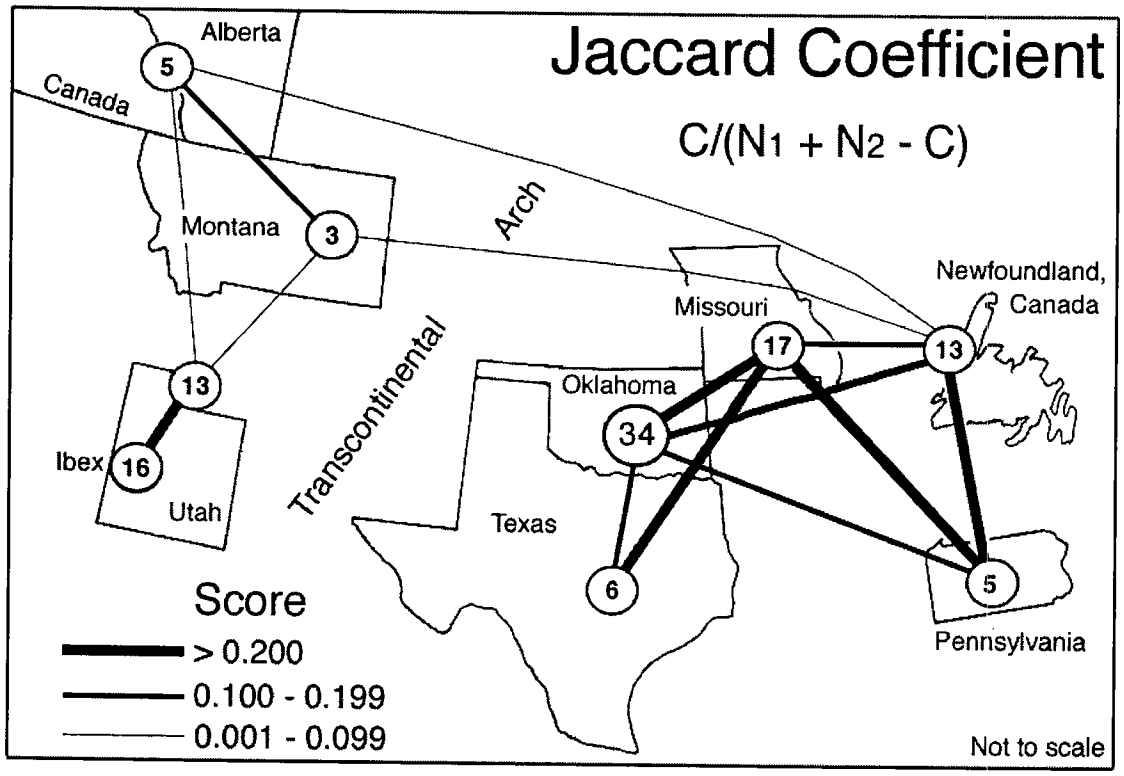
The zones, or biozones, described below, are defined as biostratigraphic-interval zones (Salvador, 1994, p. 59–61). In the current study, a zone extends from its base at the lowest stratigraphic occurrence of one or more trilobite species (a bioevent) upward through an interval of rock until the base of the overlying zone (bioevent) is encountered. Although defined by the lowest occurrence of one or more species, a zone is characterized by all those species present within its limits (Murphy, 1977). Correlation of the zone may be based upon either the bioevent at the base or upon the shared presence of any of the component species.

A pragmatic approach was employed in the design of this zonal terminology to facilitate the regional correlation of the Kindblade Formation. Preference was given to those taxa with at least one locality established in the literature beyond the study region for the definition of zones and their bases. This preference guarantees the utility of the zonal terminology for immediate correlation of the Kindblade Formation. Common species, those with greater than 10 specimens, are preferred to assure the recognition of the defined zones. Morphologically distinctive and relatively large species were chosen as the eponymous species for each zone to promote field identification and facilitate preliminary correlations for later studies. Based upon these criteria the following zonal terminology was developed (Text-fig. 2):

Strigigenalis caudata Zone (youngest)
Bolbocephalus stitti Zone
Petigurus cullisoni Zone
Benthamaspis rhochmotis Zone
Jeffersonia granosa Zone
Ranasasus brevicephalus Zone (oldest).

Ranasasus brevicephalus Zone

The base of this zone is placed at the lowest occurrence of *Ranasasus brevicephalus, Bolbocephalus jeffersonensis,* or *Chapmania taylori.* The *R. brevicephalus* Zone extends stratigraphically upward to the base of the overlying *Jeffersonia granosa* Zone. Six collections from 35 to 254 ft (11–77 m) above the base of the I-35 section are assigned to the *R. brevicephalus* Zone (Pl. 1, in pocket). This fauna, however, is better represented at the Kindblade Ranch measured section by 23 collections that extend from 66 to 253 ft (20–77 m; Pl. 2, in pocket) above the base of



Text-figure 4. Graphic illustration of Jaccard similarity coefficients for Kindblade Formation and equivalent strata in the United States and Canada. Note the weak linkage between two endemic trilobite faunas. A western fauna is present in the Rocky Mountains (Alberta, Montana, Utah; data from Dean, 1989; Lochman, 1966; Ross, 1951; Hintze, 1953). The trilobite fauna of the Kindblade Formation is most closely associated with faunas east of the Transcontinental Arch from Newfoundland, Pennsylvania, Missouri, and Texas (data from Boyce, 1989; Lees, 1967; Cullison, 1944; Cloud and Barnes, 1948). The formula for the Jaccard coefficient is presented in the upper left, where C is the number of species found to be common between two localities under consideration. The number of species (N) for each locality is within the circle. The number of species for the Kindblade Formation excludes species in open nomenclature.

the section. The following is a list[1] of the nine species that occur in the *R. brevicephalus* Zone:

Benthamaspis cf. *mediacrista* (Cullison, 1944)
Bolbocephalus jeffersonensis Cullison, 1944
\+ *Bolbocephalus myktos* n. sp.
Bolbocephalus sp. 3
Chapmania taylori n. sp.
\+ *Cullisonia producta* (Cullison, 1944)
Jeffersonia sp. 1
Ranasasus brevicephalus Cullison, 1944
Ranasasus conicus Cullison, 1944

[1]On this and subsequent species lists, those taxa that continue upward from an underlying zone are indicated by "–"; those that extend into overlying strata are marked with "+"; and those that have ranges extending above and below the zone are marked with "±".

The fauna of the *Ranasasus brevicephalus* Zone is characterized by *R. brevicephalus, Bolbocephalus jeffersonensis,* and *Chapmania taylori.* These three species are restricted to the lower 80 ft (24 m) of the Kindblade Ranch section. *Cullisonia producta* joins this assemblage 9 ft (3 m) above the base of the zone in this measured section and extends upward until 1 ft (0.3 m) above the base of the *Jeffersonia granosa* Zone (Pl. 2). *Benthamaspis* cf. *B. mediacrista* appears restricted to an interval near the top of the *R. brevicephalus* Zone.

Jeffersonia granosa Zone

The base of this zone is drawn at the lowest occurrence of *Jeffersonia granosa.* The lowest occurrence of *Benthamaspis rhochmotis* marks the base of the overlying zone. The *J. granosa* Zone spans 31 collections and ranges from 255 to

TABLE 2.—Jaccard Coefficients of Faunal Similarity for Lower Ordovician Trilobite Assemblages Correlative with the Kindblade Formation

Locality	OK	MO	TX	PA	NF	MT	UT-N	UT-I	AB
N[a]	38	17	6	5	13	3	13	16	5
Oklahoma (OK)	xxxx								
Missouri (MO)	0.244	xxxx							
Texas (TX)	0.142	0.353	xxxx						
Pennsylvania (PA)	0.147	0.222	0.000	xxxx					
Newfoundland (NF)	0.146	0.154	0.000	0.286	xxxx				
Montana (MT)	0.000	0.000	0.000	0.000	0.067	xxxx			
Utah, North (UT-N)	0.000	0.000	0.000	0.000	0.040	0.067	xxxx		
Utah, Ibex (UT-I)	0.000	0.000	0.000	0.000	0.000	0.056	0.050	xxxx	
Alberta (AB)	0.000	0.000	0.000	0.000	0.059	0.143	0.059	0.000	xxxx
References:[b]	9	3	2	6	1	7	8	5	4

[a]N indicates number of binomial species used in calculations for each locality.

[b]References: 1—Boyce (1989); 2—Cloud and Barnes (1948); 3—Cullison (1944); 4—Dean (1989); 5—Hintze (1953); 6—Lees (1967); 7—Lochman (1966); 8—Ross (1951); 9—this study.

475 ft (78–145 m; Pl. 1) in the I-35 section and 16 collections between 254 and 436 ft (77–133 m; Pl. 2) in the Kindblade Ranch section. The following 12 species occur in the *J. granosa* Zone:

– *Bolbocephalus myktos* n. sp.
Chapmania carterensis n. sp.
Chapmania oklahomensis n. sp.
Chapmania sp. 1
– *Cullisonia producta* (Cullison, 1944)
\+ *Gelasinocephalus whittingtoni* n. sp.
\+ *Ischyrotoma sila* n. sp.
\+ *Jeffersonia granosa* Cullison, 1944
\+ *Lutesvillia bispinosa* Cullison, 1944
\+ *Punka akoura* n. sp.
Punka sp. 1
Rollia goodwini Cullison, 1944

Chapmania oklahomensis and *Punka* sp. 1 have restricted stratigraphic ranges within the *Jeffersonia granosa* Zone. Recovery of these species elsewhere would allow for precise correlation with the middle and upper portions, respectively, of this zone.

Benthamaspis rhochmotis Zone

The base of this zone is placed at the lowest occurrence of the eponymous species. The *Benthamaspis rhochmotis* Zone extends upward to the base of the overlying *Petigurus cullisoni* Zone. In the I-35 section, 37 collections from 476 to 690 ft (145–210 m; Pl. 1) above the base of the formation are assigned to the *B. rhochmotis* Zone. In the Kindblade Ranch section, the 15 collections recovered between 437 and 622 ft (133–190 m; Pl. 2) are assigned to the *B. rhochmotis* Zone. The following assemblage of 19 species occurs in this zone:

Bathyurellus arbucklensis n. sp.
\+ *Bathyurellus inflatus* n. sp.
Benthamaspis rhochmotis n. sp.
\+ *Bolbocephalus* sp. 1
\+ *Gelasinocephalus pustulosus* n. sp.
– *Gelasinocephalus whittingtoni* n. sp.
± *Ischyrotoma sila* n. sp.
Isoteloides? sp. 1
– *Jeffersonia granosa* Cullison, 1944
\+ *Jeffersonia ulrichi* n. sp.
– *Lutesvillia bispinosa* Cullison, 1944
\+ *Petigurus* sp. 1
± *Punka akoura* n. sp.
\+ *Punka verecunda* n. sp.
Ranasasus colossus n. sp.
\+ *Speyeris hami* n. sp.

Strigigenalis derbyi n. sp.
\+ *Strigigenalis implexa* n. sp.
\+ *Strigigenalis* sp. 1

Benthamaspis rhochmotis, Gelasinocephalus pustulosus, Jeffersonia ulrichi, and *Punka akoura* all appear within 10 ft (3 m) of the base of the *Benthamaspis rhochmotis* Zone and highlight this horizon in the I-35 section (Pl. 1). The stratigraphic range of *G. pustulosus* is restricted to just above the base of the *B. rhochmotis* Zone and will serve to refine correlation of the zone if recovered elsewhere. *Jeffersonia ulrichi* is known only from the I-35 section.

Petigurus cullisoni Zone

The base of this zone is placed at the lowest occurrence of *Petigurus cullisoni.* The zone continues upward to the base of the overlying *Bolbocephalus stitti* Zone. The *P. cullisoni* Zone in the I-35 section ranges across 45 collections from 691 to 993 ft (211–303 m; Pl. 1) and includes 24 collections from 623 to 901 ft (190–275 m; Pl. 2) in the Kindblade Ranch section. The following assemblage of 19 species occurs in the *P. cullisoni* Zone:

Bathyurellus? sp. 1
\- *Bathyurellus inflatus* n. sp.
Bolbocephalus cf. *B. convexus* (Billings, 1865)
\- *Bolbocephalus* sp. 1
Ischyrotoma sp. 1
\- *Ischyrotoma sila* n. sp.
\+ *Isoteloides peri* Fortey, 1979
\+ *Jeffersonia* sp. 2
\- *Jeffersonia ulrichi* n. sp.
Lutesvillia sp. 1
\- *Petigurus* sp. 1
\+ *Petigurus cullisoni* n. sp.
Punka akoura n. sp.
± *Punka verecunda* n. sp.
\- *Speyeris hami* n. sp.
Strigigenalis crassimarginata (Cullison, 1944)
\- *Strigigenalis implexa* n. sp.
Strigigenalis insentis n. sp.
\- *Strigigenalis* sp. 1

Few of the common taxa have mutually exclusive stratigraphic ranges above the base of the *Petigurus cullisoni* Zone. It has been necessary, therefore, to select subsequent biotic events based upon the appearance of distinctive or abundant species (*Strigigenalis caudata, Benthamaspis onomeris,* and *Bolbocephalus stitti*). Significantly, *Petigurus cullisoni* exhibits a long stratigraphic range, and on both sections continues into the overlying *Bolbocephalus stitti* Zone. Recovery of one of these long-ranging species cannot yield a unique solution to the zonal assignment of the sample if a short-ranging, diagnostic species like *Ischyrotoma* sp. 1 or *Speyeris hami* is absent.

Bolbocephalus stitti Zone

The base of the *Bolbocephalus stitti* Zone is placed at the lowest occurrence of *Bolbocephalus stitti* or *Benthamaspis onomeris.* The top of the zone is drawn at the base of the *Strigigenalis caudata* Zone. Thirty-six collections from 994 to 1226 ft (303–374 m) in the I-35 section are assigned to the *B. stitti* Zone (Pl. 1). Three collections from 901 ft (277 m) to the top of the Kindblade Ranch section are assigned to the *Bolbocephalus stitti* Zone (Pl. 2). Post-Ordovician erosion and Permian sedimentation have obscured an estimated 380 ft (116 m) of the upper Kindblade Formation in the type section. The following trilobite fauna of 12 species occurs in the *B. stitti* Zone:

\+ *Benthamaspis onomeris* n. sp.
\+ *Bolbocephalus stitti* n. sp.
Bolbocephalus sp. 2
\+ *Dimeropygiella* sp. 1
± *Isoteloides peri* Fortey, 1979
\- *Jeffersonia* sp. 2.
± *Petigurus cullisoni* n. sp.
\- *Punka verecunda* n. sp.
Ranasasus sp. 1
Randaynia leatherburyi n. sp.
± *Strigigenalis crassimarginata* (Cullison, 1944)
\+ *Strigigenalis insentis* n. sp.

Bolbocephalus stitti was selected as the eponymous species for this zone because it is large, morphologically distinctive, and the most abundant trilobite recovered from this zone. The stratigraphic range of *B. stitti,* it is noted, does extend throughout much of the overlying *Strigigenalis caudata* Zone.

Strigigenalis caudata Zone

The base of this zone is marked by the lowest occurrence of the eponymous species at 1,227 ft (374 m) above the base of the Kindblade Formation in the I-35 section (Pl. 1). The uppermost 13 collections from this section are assigned to the *S. caudata* Zone. The top of the zone is undefined until a detailed study of the overlying West Spring Creek Formation can be undertaken. The *S. caudata* Zone is missing in the Kindblade Ranch section due to subsequent erosion or burial. The following 14 species occur within the *S. caudata* Zone:

- *Benthamaspis onomeris* n. sp.
- *Bolbocephalus stitti* n. sp.
- *Dimeropygiella* sp. 1
- *Isoteloides peri* Fortey, 1979
  Jeffersonia jenni Cullison, 1944
- *Petigurus cullisoni* n. sp.
  Randaynia sp. 1
  Strigigenalis caudata (Billings, 1865)
- *Strigigenalis crassimarginata* (Cullison, 1944)
- *Strigigenalis insentis* n. sp.
  Strigigenalis cf. *S. knighti* Boyce, 1989
  Strigigenalis sp. 2
  Strigigenalis? sp. 3

The fauna of the *Strigigenalis caudata* Zone includes two distinct components: (1) those species with long stratigraphic ranges that continue from the underlying zone, and (2) those species restricted to 1 to 3 collections within the zone (Pls. 1, 3, in pocket). The ranges of most of the continuing species seem be truncated abruptly near the base of the zone. This truncation is not thought to reflect an extinction event, but rather is believed to be an artifact of the low number of collections from the upper 300 ft (91 m) of the section (Text-fig. 5). *Isoteloides peri*, in particular, may be expected to range throughout the *S. caudata* Zone and possibly into the overlying West Spring Creek Formation. *Isoteloides peri* occurs with *S. caudata* in collections from Vermont (Desbiens and others, 1996) and Newfoundland (Fortey, 1979; Boyce, 1989) although this co-occurrence is not a feature of the Kindblade collections. The low number of collections through this interval is also believed to govern the rarity and short stratigraphic ranges of the six species with their lowest occurrences within the *Strigigenalis caudata* Zone.

GRAPHIC CORRELATION

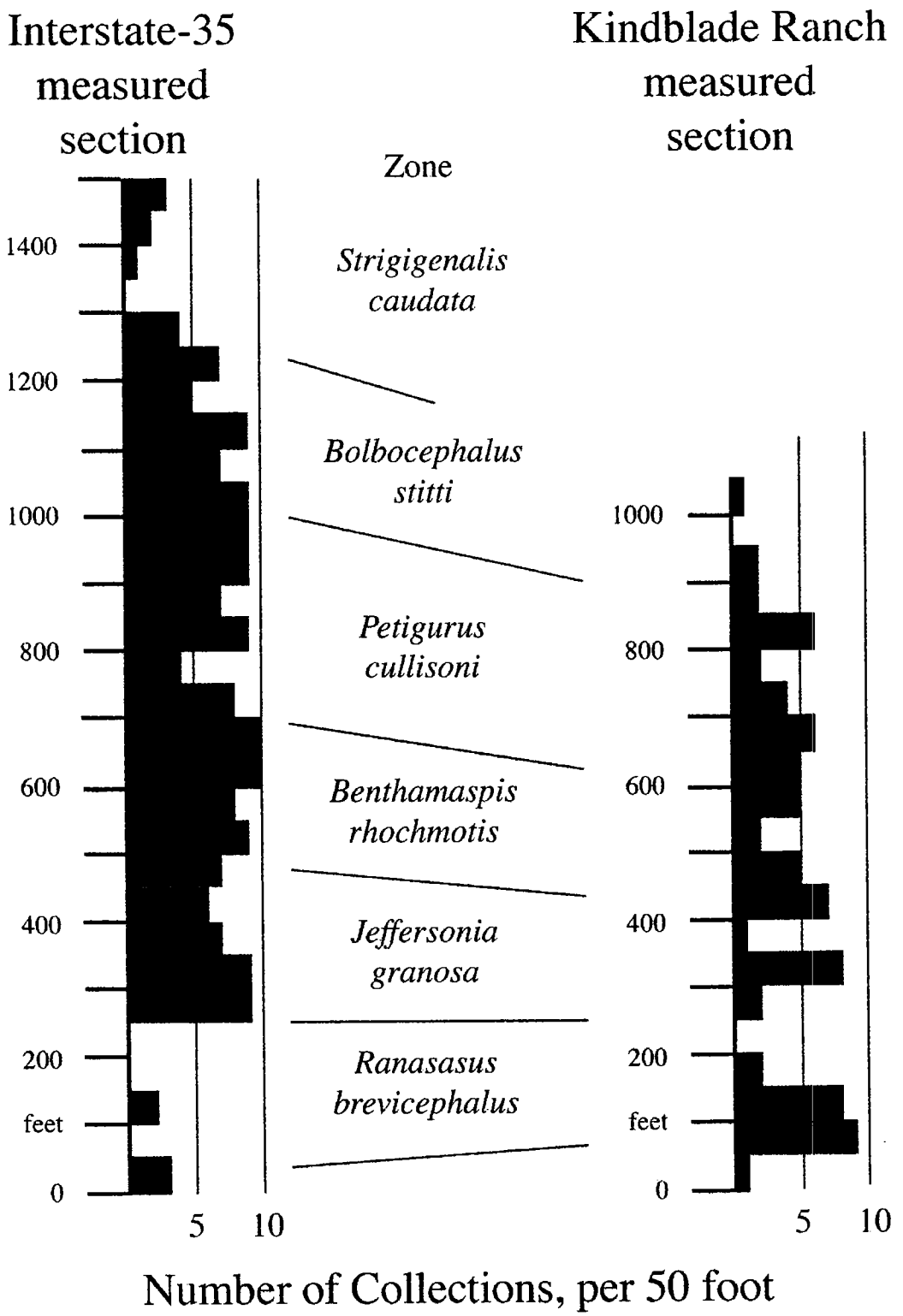
For the purpose of chronocorrelation, biostratigraphic units are ideally bounded by isochronous horizons. Scott (1985) noted that it is not possible to directly test whether a biotic event is isochronous throughout its geographic range. He suggested, however, that species which maintain a relatively constant stratigraphic position (homotaxy) are less likely to be diachronous than those that fail to maintain their position. A graphic correlation diagram (Text-fig. 5) was prepared to test the homotaxial sequence of first (lowest) and last (highest) appearances of the species within the Kindblade Formation. Those species that appear close to a line of correlation plotted onto the graph are judged to have maintained their homotaxial position and to be more nearly isochronous.

A graphic correlation diagram (Shaw, 1964; Miller, 1977; Edwards, 1984, 1991) displays the lowest and highest occurrences of a species on a bivariate graph. The axes of the graph can be two measured sections (scaled in feet or meters) or a measured section and a composite standard section (scaled in composite standard units). The lowest and highest appearances of those species at both localities under consideration are plotted as (x, y) points between the axes. In the absence of unconformities or other complications, the data points should appear as a linear trend with a positive slope. A line of correlation (LOC) is fitted to the trend, either mathematically or by eye.

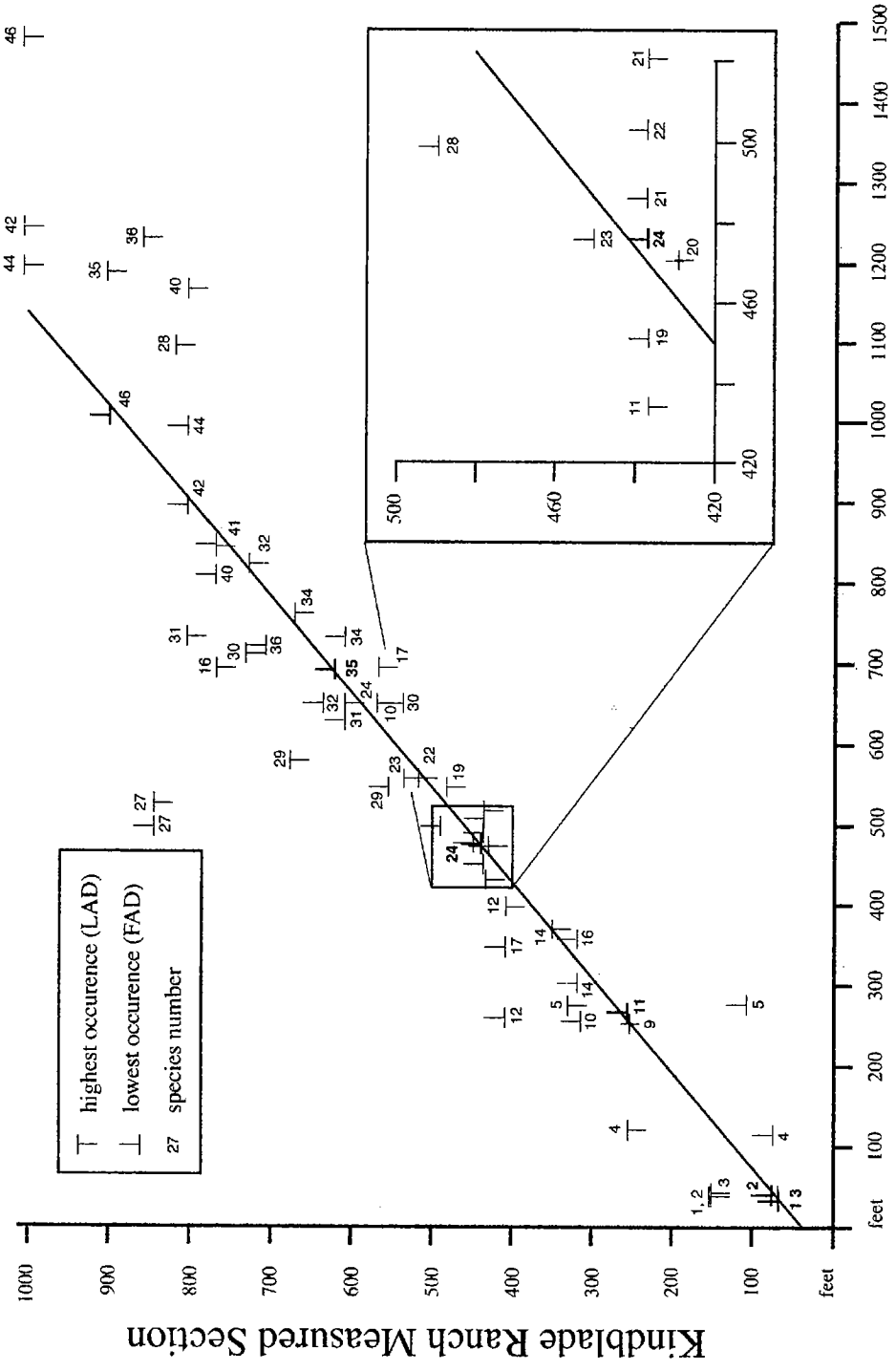
The graphic correlation diagram for the Kindblade Formation (Text-fig. 6) was constructed with the Kindblade Ranch section as the ordinate (y-axis) and the more complete, more fossiliferous I-35 section as the abscissa (x-axis). Data points (Table 3) representing the first (FAD) and last (LAD) appearances of the 31 species present from both sections form a continuous linear trend without obvious evidence of an unconformity until influenced by the erosional truncation of the Kindblade Ranch section (upper right on Text-fig. 6). Above 1,000 ft (305 m) at the Kindblade Ranch section, a horizontal plateau is apparent and results from the foreshortening of the last appearances (LAD) of trilobite taxa in the upper part of the Kindblade.

Most of the data points plotted upon the graphic correlation diagram (Text-fig. 6) fit into a relatively tight field. A single line of correlation was fit by eye to these data points for the lowest 1,000 ft (305 m) of the formation. The first occurrences of all species used to define the base of a zone (in bold on Text-fig. 6) occur relatively close to the line of correlation. This suggests that, within the limits of resolution, their lowest occurrence is not notably diachronous. Correlations based upon these species with localities outside Oklahoma can be made with greater confidence than for possible alternatives which are demonstrably diachronous between the Oklahoma measured sections.

Several data points fall well off of the line of correlation when the I-35 and Kindblade Ranch sections are compared (e.g., *Lutesvillia bispinosa*, species 10 of Text-fig. 6). This may represent either an immigration event that occurred over a resolvable time scale or foreshortening of the species range as a result of incomplete sampling. It is possible to estimate a total stratigraphic extent of a species by mapping each first and last



Text-figure 5. Frequency histograms of trilobite-bearing collections per 50-ft (15-m) intervals for the Interstate-35 and Kindblade Ranch sections of the Kindblade Formation. Note sharp decline in number of collections within the upper 200 ft (61 m) of the I-35 section. This decline mirrors continued shallowing of the basin at the transition from the middle to upper members of Fay (1989).



Text-figure 6. Graphic correlation diagram for Interstate-35 and Kindblade Ranch sections of the Kindblade Formation. Measured section footages for the Interstate-35 (x-axis) and the Kindblade Ranch (y-axis) sections form the coordinate system for plotting lowest occurrence and highest occurrence data (FAD and LAD, respectively) for each trilobite species. For example, the base of *Lutesvillia bispinosa* in the Kindblade Ranch section (y = 313 ft [95 m]) is plotted as a function of its position on the I-35 section (x = 255 ft [78 m]). A line of correlation was fitted intuitively. Bold symbols represent the lowest occurrence of species of zonal significance. The species names associated with the numbers shown on the diagram are in Table 3.

TABLE 3.—Stratigraphic Range Data for Trilobites from Kindblade Formation Used in Preparation of Graphic Correlation Diagram (Text-fig. 6)

Species no.[a]	Species name	I-35 FAD[b]	I-35 LAD[c]	Kindblade Ranch FAD	Kindblade Ranch LAD	KR to I-35 FAD	KR to I-35 LAD	Composite Standard FAD[d]	Composite Standard LAD[d]
1	*Bolbocephalus jeffersonensis*	40	40	66	151	34.5	135.7	34	136
2	*Chapmania taylori*	35	40	66	152	34.5	136.9	34	137
3	*Ranasasus brevicephalus*	40	44	75	151	45.2	135.7	45	136
4	*Cullisonia producta*	115	119	75	254	45.2	258.3	45	258
5	*Bolbocephalus myktos*	275	275	109	331	85.7	350.0	86	350
6	*Ranasasus conicus*	119	119					119	119
7	*Jeffersonia* sp. 1			143	143	126.2	126.2	126	126
8	*Bolbocephalus* sp. 1			151	151	135.7	135.7	136	136
9	*Benthamaspis* cf. *B. mediacrista*	254	254	253	253	257.1	257.1	254	257
10	*Lutesvillia bispinosa*	255	650	313	571	328.6	635.7	255	650
11	*Jeffersonia granosa*	266	434	254	437	258.3	476.2	258	476
12	*Chapmania carterensis*	260	398	409	409	442.9	442.9	260	443
13	*Rollia goodwini*	268	305					268	305
14	*Chapmania oklahomensis*	302	371	319	349	335.7	371.4	302	371
15	*Chapmania* sp. 1			305	305	319.0	319.0	319	319
16	*Ischyrotoma sila*	368	691	319	770	335.7	872.6	336	873
17	*Punka akoura*	346	696	411	564	445.2	627.4	346	696
18	*Ranasasus colossus*			437	437	476.2	476.2	427	476
19	*Gelasinocephalus whittingtoni*	451	546	437	481	476.2	528.6	451	546
20	*Punka* sp. 1	471	471	429	429	466.7	466.7	467	471
21	*Gelasinocephalus pustulosus*	486	521	437	437	476.2	476.2	476	521
22	*Bathyurellus arbucklensis*	503	556	437	520	476.2	575.0	476	575
23	*Strigigenalis derbyi*	476	556	451	538	492.9	596.4	476	596
24	*Benthamaspis rhochmotis*	476	650	437	610	476.2	682.1	476	682
25	*Jeffersonia ulrichi*	482	579					482	579
26	*Isoteloides* sp. 1	486	486					486	486
28	*Punka verecunda*	499	1093	489	823	538.1	935.7	499	1093
27	*Bolbocephalus* sp. 2	499	525	846	846	963.1	963.1	525	963
29	*Petigurus* sp. 1	546	580	556	677	617.9	761.9	546	762
30	*Strigigenalis implexa*	650	711	538	735	596.4	831.0	596	831
31	*Bathyurellus inflatus*	630	732	610	805	682.1	914.3	630	914
32	*Strigigenalis* sp. 1	650	821	636	741	713.1	838.1	650	838
33	*Bathyurellus*? sp. 1			671	671	754.8	754.8	671	755
34	*Speyeris hami*	732	762	610	671	682.1	754.8	682	762
35	*Petigurus cullisoni*	691	1185	623	907	697.6	1035.7	691	1185
36	*Isoteloides peri*	721	1227	708	861	798.8	981.0	708	1227
37	*Bolbocephalus* cf. *B. convexus*	762	841	741	741	838.1	838.1	741	841
39	*Lutesvillia* sp. 1			805	805	914.3	914.3	805	914
40	*Jeffersonia* sp. 2	809	1064	770	805	872.6	914.3	809	1064
41	*Ischyrotoma* sp. 1	846	849	770	770	872.6	872.6	846	873
42	*Strigigenalis crassimarginata*	893	1241	805	1010	914.3	1158.3	893	1241
43	*Randaynia leatherburyi*			901	901	1028.6	1028.6	901	1028
44	*Strigigenalis insentis*	994	1195	805	1010	914.3	1158.3	914	1195
45	*Benthamaspis onomeris*	994	1234					994	1234
46	*Bolbocephalus stitti*	1009	1474	901	1010	1028.6	1158.3	1009	1474
47	*Ranasasus* sp. 1	1127	1210					1127	1210
48	*Dimeropygiella* sp. 1	1212	1227					1212	1227
49	*Strigigenalis caudata*	1227	1227					1227	1227
50	*Strigigenalis* cf. *S. knighti*	1272	1272					1272	1272
51	*Randaynia* sp. 1	1369	1369					1369	1369
52	*Bolbocephalus* sp. 3	1440	1440					1440	1440
53	*Strigigenalis* sp. 2	1444	1444					1444	1444
54	*Strigigenalis*? sp. 3	1468	1468					1468	1468
55	*Jeffersonia jenni*	1468	1475					1468	1475

[a]Species numbers assigned in stratigraphic occurrence based on composite standard footage.
[b]FAD stands for First Appearance Datum (lowest stratigraphic occurrence) of each species.
[c]LAD stands for Last Appearance Datum (highest stratigraphic occurrence) of each species.
[d]The line of correlation for the Graphic Correlation Diagram (Text-fig. 6) was used to extend species ranges that were foreshortened through preservational or collection problems. The composite standard FADs and LADs were selected to maximize the teilzone represented in the two measured sections.

appearance point onto the line of correlation (Shaw, 1964; Miller, 1977; Edwards, 1984, 1991). A composite standard range chart (Pl. 3; Table 2) for all trilobite species was prepared to compensate for foreshortened stratigraphic ranges.

CORRELATION

Previous reconnaissance studies of the Kindblade Formation (Cloud and Barnes, 1948, p. 63–65, 372–376, pl. 15) established an approximate correlation for this interval between Oklahoma and Texas. Additional correlations have been drawn (Twenhofel, 1954) based upon reconnaissance collections of gastropods, cephalopods, brachiopods, and the lithistid sponge *Archaeoscyphia*. The field mapping of the Arbuckle Mountains by Ham provided stratigraphically located collections of brachiopods (Cooper, 1952) and the gastropod operculum *Ceratopea* (Yochelson and Bridge, 1957; Toomey, 1980). Similar stratigraphic collections were obtained for *Archaeoscyphia* by Toomey (1964; Toomey and Nitecki, 1979) and by J. R. Derby (*in* Derby and others, 1977; 1991, fig. 8) for brachiopods, gastropods, and three species of trilobites. The accurate stratigraphic data developed in these later studies, supplemented by microfossil data (Brand, 1976; Ethington and Repetski, 1984) and preliminary data from this study (Loch, 1991; J. D. Loch *in* Derby and others, 1991; Loch and others, 1993) refined the correlation of the Kindblade Formation (Derby and others, 1991, fig. 2). Consequently, correlations of the Kindblade Formation to contemporaneous strata in the eastern and southern United States are more precise than previously possible.

Southern Missouri and Northern Arkansas

Exposed along the flanks of the Ozark Dome are Lower Ordovician dolomitic carbonates of the Jefferson City and Cotter Formations (Text-fig. 7; see Thompson, 1991, p. 38–54 for nomenclatorial history). Chert nodules collected from these dolomites yielded scarce trilobites and an associated fauna of sponges, brachiopods, gastropods, and cephalopods (Cullison, 1944). The nodules were most commonly collected as float blocks in the soil and commonly lack a well-defined stratigraphic context (Cullison, 1944, p. 86–91, pl. 2). Interpretations of Cullison's species range charts and stratigraphic associations, therefore, must be made cautiously (Text-fig. 7).

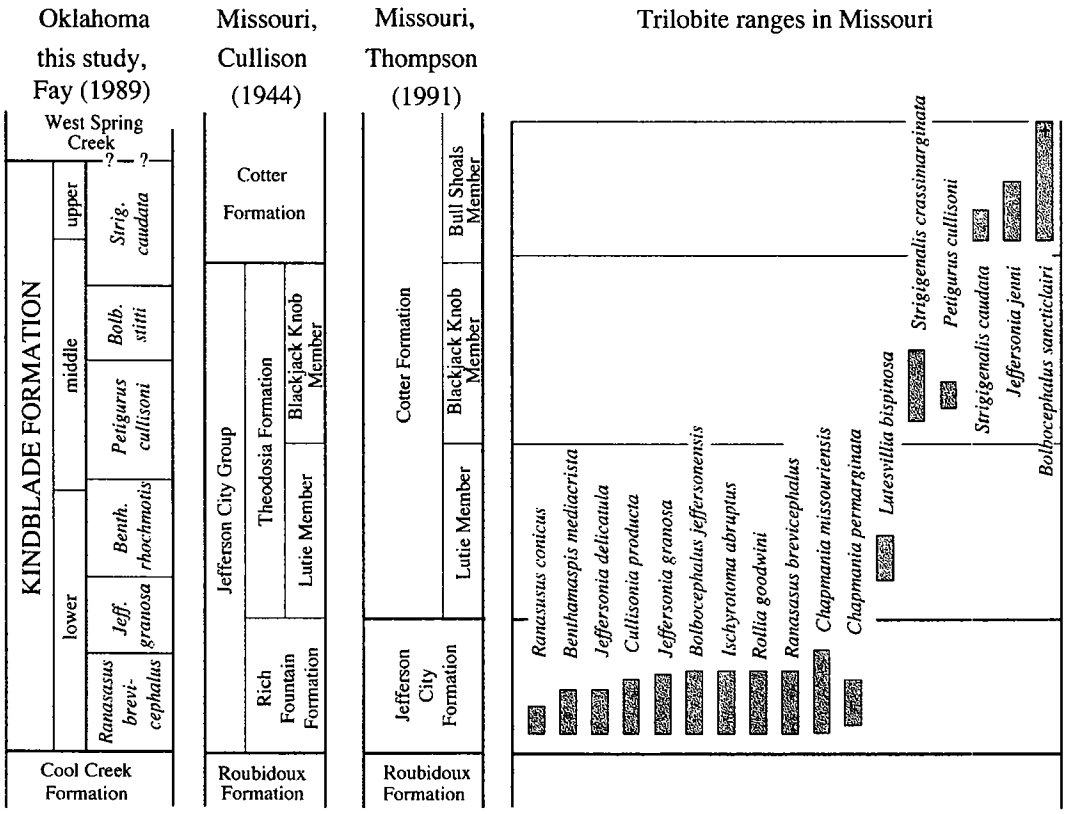
The Jefferson City Formation (= Rich Fountain Formation of Cullison, 1944) yielded a trilobite fauna of 11 species. The following four species from the Jefferson City Formation are restricted to the *Ranasasus brevicephalus* Zone in Oklahoma: *Benthamaspis mediacrista, Bolbocephalus jeffersonensis, Ranasasus brevicephalus,* and *Ranasasus conicus.* The Jefferson City Formation also yielded *Jeffersonia granosa* and *Rollia goodwini* that are restricted to the *Jeffersonia granosa* Zone in Oklahoma. Although the stratigraphic ranges of these two groups of species fail to overlap in Oklahoma, Cullison (1944, pl. 2; Text-fig. 7) depicted the ranges as concurrent within the Jefferson City. Allowing for faunal mixing between chert nodules, the Jefferson City Formation of southern Missouri correlates with roughly the lower 300 ft (91 m) of the Kindblade Formation. Loch and others (1993) documented the occurrence of a chert moldic trilobite fauna from the top of the informal "Quarry Ledge" member of the Jefferson City that yielded *R. brevicephalus* in association with *"Peltabellia" missouriensis* and *Ischyrotoma abrupta.* That portion of the Jefferson City Formation known to occur at or below the "Quarry Ledge" member correlates most precisely with the *Ranasasus brevicephalus* Zone in Oklahoma. Additionally, *Bolbocephalus* sp. 3 (Pl. 6) is known from a cranidium recovered from the *R. brevicephalus* Zone in Oklahoma. An additional specimen recovered from the Jefferson City Formation was found among collections held at the University of Missouri–Rolla.

The Lutie Member of the Cotter Formation (= Lutie Member of the Theodosia Formation of Cullison, 1944) is correlated with lower half of the Kindblade Formation based upon the shared occurrence of *Lutesvillia bispinosa* (Cullison, 1944). Assignment of the Lutie Member to either the *Jeffersonia granosa* or the *Benthamaspis rhochmotis* Zones, however, is not possible in the absence of additional material.

A single pygidium of *Petigurus cullisoni* in association with *Strigigenalis crassimarginata* was recovered by Cullison from the Blackjack Knob Member of the Cotter Formation (= Blackjack Knob Member of Theodosia of Cullison, 1944). In Oklahoma, these species occur together in the upper *Petigurus cullisoni,* the *Bolbocephalus stitti,* and lower *Strigigenalis caudata* Zones within the upper third of the Kindblade Formation.

The Bull Shoals Member of the Cotter Formation (= Cotter Formation of Cullison, 1944) yielded *Jeffersonia jenni.* This species occurs in the *Strigigenalis caudata* Zone in Oklahoma.

Stratigraphic data for the Kindblade Formation trilobites largely confirm previous correla-



Text-figure 7. Stratigraphic nomenclature for the Jefferson City and Cotter Formations of southern Missouri (after Thompson, 1991, fig. 29). Trilobite stratigraphic ranges are redrawn from Cullison (1944, pl. 2) and are estimated positions of chert nodules recovered loose from soil. The 50-ft (15-m) range for *Petigurus cullisoni* from the Blackjack Knob Member, for example, represents only one pygidium. Kindblade Formation zonal terminology is present for comparison. Abbreviations (left column): *Benth.*, *Benthamaspis*; *Bolb.*, *Bolbocephalus*; *Jeff.*, *Jeffersonia*; *Strig.*, *Strigigenalis*.

tions between Oklahoma, Missouri, and Arkansas made by J. S. Cullison, Josiah Bridge, P. E. Cloud, and V. E. Barnes (fig. F *in* Twenhofel, 1954, chart 2, cols. 51–55), Toomey (1964, text-fig. 2), and J. E. Repetski and J. R. Derby (*in* Derby and others, 1991, fig. 2). In contrast, Ross and others (1982, sheet 2, cols. 39, 40, 44, 45) placed the base of the Cotter Formation above the Kindblade Formation within the West Spring Creek Formation. Available trilobite data from Oklahoma and Missouri suggest, however, this contact is slightly older and more appropriately correlated with a position within the upper Kindblade Formation.

Central Texas

The Honeycut Formation (Ellenburger Group) of Texas is composed of alternating beds of dolomite and limestone (Cloud and Barnes, 1948). Megafossils have been recovered from the limestones and uncommon chert nodules of the Honeycut Formation. Unfortunately, few of the trilobites collected were identified to species level. Cloud and Barnes (1948, pl. 42) and J. R. Derby (*in* Toomey, 1964; *in* Derby and others, 1991, fig. 3) identified *Bolbocephalus jeffersonensis*, *Ranasasus brevicephalus*, and *Ranasasus conicus* in the lowermost Honeycut Formation. These species are restricted to the *Ranasasus brevicephalus* Zone in Oklahoma. The lowest occurrence of *Jeffersonia granosa*, at roughly 130 ft (40 m; Cloud and Barnes, 1948, p. 456, 197, pl. 42) above the base of the Honeycut Formation, is correlated with the base of the *Jeffersonia granosa* Zone in Oklahoma.

The nearly contemporaneous nature of the bases of the Honeycut and Kindblade Formations has been noted by numerous authors

(Ulrich and Cooper, 1938, p. 23, 25, pl. 58; Twenhofel, 1954, chart 2, cols. 54–56; Toomey, 1964, text-fig. 2; Derby and others, 1991, fig. 2). In contrast, Ross and others (1982, sheet 2, cols. 38–40) suggested that the base of the Honeycut Formation correlates with a position near the middle of the Kindblade Formation. The trilobite data, however, is consistent with the close temporal correlation of the base of these formations.

Central Pennsylvania

The Axemann Limestone punctuates a thick dolomitic interval consisting of the Bellefonte and Nittany Dolomites in the region around State College, Pennsylvania (Butts and Moore, 1936; Butts, 1945; Wagner, 1966). The lowest occurrence of *Strigigenalis caudata* at approximately 150 ft (46 m) above the base of the Rockview Member (Lees, 1967, pl. 13, 18) correlates with the base of the *Strigigenalis caudata* Zone, at 1,227 ft (37 4 m) above the base of the Kindblade Formation. *Isoteloides peri* and *Petigurus cullisoni* are present below this horizon in the Axemann Formation (Lees, 1967, pl. 13). These two species occur together in the *Petigurus cullisoni* and *Bolbocephalus stitti* Zones in Oklahoma (Pls. 1, 3).

Sando (1958, p. 842, pl. 2) collected a trilobite fauna from limestones of the Rockdale Run Formation near Chambersburg, Pennsylvania, which he termed the *Isoteloides* faunule. This fauna includes *Goniotelina* sp., *Isoteloides peri* (as *Isoteloides* cf. *I. flexus*), and *Dimeropygiella* sp. 1. In Oklahoma, *I. peri* and *Dimeropygiella* sp. 1 have concurrent stratigraphic ranges from the middle of the *Bolbocephalus stitti* Zone to low in the *Strigigenalis caudata* Zone. This confirms the correlation by Sando (1957, p. 27, pl. 3) of that portion of the Rockdale Run Formation that yielded the *Isoteloides* faunule with the upper Kindblade Formation in Oklahoma. Significantly, this also confirms correlations of the Axemann Limestone and the Rockdale Run Formation within Pennsylvania (Sando, 1957, pl. 3; Wagner, 1966, p. 20, fig. 6; Lees, 1967, p. 29, fig. 2).

Goldhammer and others (1992; 1993, figs. 4, 13) used carbonate cyclostratigraphy and the distribution of detrital quartz to correlate from the Arbuckle Mountains into central Pennsylvania. Their correlations, made independent of biostratigraphic data, equate the Axemann Limestone of Pennsylvania with the lower West Spring Creek Formation in Oklahoma. This correlation is not supported by the trilobite data presented here or by available microfossil distributions.

Newfoundland, Canada

Boyce (1989) described a fauna of 15 trilobite species from the interbedded limestones and dolomites of the Barbace Cove Member of the Boat Harbour Formation. Boyce (1989, p. 9–11, fig. 4) divided the member into an underlying *Strigigenalis brevicaudata* Zone and an upper *Strigigenalis caudata* Zone, with the base of the latter zone defined by the lowest occurrence of *S. caudata*. The *Strigigenalis brevicaudata* Zone is correlated with the upper *Bolbocephalus stitti* Zone in Oklahoma based upon its stratigraphic position and the shared species (Table 4). The base of Boyce's (1989) *Strigigenalis caudata* Zone correlates with the base of the *Strigigenalis caudata* Zone at 1,227 ft (374 m) above the base of the Kindblade in Oklahoma.

Strigigenalis caudata first occurs near the top of the Barbace Cove Member and continues into the overlying Catoche Formation (Fortey, 1979; Boyce, 1989, fig. 4). None of the species that originate higher in the Catoche Formation, however, are known at present from the Kindblade Formation. Recovery of some of these species may be expected from the overlying West Spring Creek Formation.

Western United States

The classic silicified trilobite faunas recovered from the Ibex region of Utah (Text-fig. 1; Hintze, 1953) and northeastern Utah and southern Idaho (Ross, 1951) are presently considered the standard of comparison for the Lower Ordovician (= Ibexian Series) rocks of North America (Ross and others, 1997). Ross (1951) designated a sequence of trilobite assemblage zones, labeled Zone A through Zone O, to subdivide these faunas. Subsequently, Hintze (1953) substituted binomial species names for these alphabetical designations, but the alphabetical designations have remained in popular usage. Ross and others (1997) defined the Ibexian Series to replace the traditional concept of the Canadian Series for the Lower Ordovician of North America. This included an attempt to standardize the usage of these trilobite assemblage zones and integrate them with conodont interval zones (Ethington and Clark, 1981).

Application of the Ross (1951) and Hintze (1953) zonal terminology to the Kindblade Formation, however, has been problematic in the absence of trilobite species shared between the two regions. Previously, the Kindblade has been correlated to the Ibex Zone G, the *Hintzeia celsaora* Zone, based largely upon stratigraphic position (Ross and others, 1997; Derby and oth-

TABLE 4.—Trilobites from Barbace Cove Member of Boat Harbour Formation, Newfoundland, Canada (Boyce, 1989)

Zone*		Usage (this paper)	Boyce (1989)
		Bolbocephalus convexus	
B	S	*Dimeropygiella* sp. 1	*Hystricurus crassilimbatus*
		Grinnellaspis newfoundlandensis	
B	S	*Isoteloides peri*	*Jeffersonia angustimarginata*
	S	*Jeffersonia jenni*	
		Peltabellia implexa	*Peltabellia* cf. *P. peltabella*
B	S	*Petigurus cullisoni*	*Petigurus* sp. nov. A
		Petigurus nero	
		Randaynia langdoni	
		Strigigenalis brevicaudata	
	S	*Strigigenalis caudata*	
B	S	*Strigigenalis crassimarginata*	*Peltabellia crassimarginata*
	S	*Strigigenalis* cf. *S. knighti*	*Peltabellia knighti*

*Those species that occur in the *Bolbocephalus stitti* Zone and in the *Strigigenalis caudata* Zone in Oklahoma are indicated by B and S, respectively.

ers, 1977, 1991). In the Ibex standard, the base of the *Acodus deltatus–Oneotodus costatus* conodont Zone lies approximately 98 ft (30 m) below the base of Zone G (Ross and others, 1997). In Oklahoma, the lowest occurrence of *O. costatus* lies at approximately 100 ft (30 m) above the base of the Kindblade, indicating that the lowermost portions of the Kindblade correlate with the latest portions of Ross–Hintze Zone F (Ethington and Dresbach, 1990).

STADIAL TERMINOLOGY

The Kindblade Formation was recognized as Lower Ordovician when it was defined by Decker (1939a, p. 1320; 1939b). Concentrated effort to establish a stadial succession for the (Lower Ordovician) Canadian Series had not yet been successful (Twenhofel, 1954). As an alternative, the formational succession in the Ozark region of Missouri and Arkansas was accepted as a standard for comparison (Gasconade, Roubidoux, Jefferson City, Cotter, and Black Rock Formations; Twenhofel, 1954, chart 2).

Flower (1957, 1964) proposed a set of stadial terms for the Canadian System of North America, although this interval had more commonly been interpreted as the Canadian Series (Lower Ordovician). These stages were the Gasconadian (the oldest), Demingian, Jeffersonian, and Cassinian. The Gasconadian and Jeffersonian Stages were based upon exposures and faunas recovered from the Ozarks of Missouri and northern Arkansas. The Demingian Stage was based upon outcrops near Deming, New Mexico. The Cassinian Stage was based upon the outcrops near Fort Cassin, New York. Unfortunately, none of these stages was well defined using modern stratigraphic practices (see Salvador, 1994); neither were they well-studied faunally.

Ross and others (1997) proposed the Ibexian Series as the first series for the Ordovician of North America based upon the silicified trilobite faunas of the Ibex region of western Utah. Within the Ibexian they proposed a four-fold subdivision of the Ibexian Series based upon the faunas described by Ross (1951) and Hintze (1953):

Blackhillsian Stage
(= Ross–Hintze Zones H, I, J, and K)
Tulean Stage
(= Ross–Hintze Zones G-1 and G-2)
Stairsian Stage
(= Ross–Hintze Zones D, E, and F)
Skullrockian Stage
(= Ross–Hintze Zones B and C).

Ross and others (1997) formally established each of these stages, including the selection of a stratotype and the definition of a boundary horizon. The base of the Skullrockian Stage was defined by the lowest occurrence of conodonts

characteristic of the *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* conodont Zone. This conodont boundary lies less than 1 ft (0.1 m) below the base of the *Eurekia apopsis* trilobite Zone. This trilobite horizon, and by implication, the base of the Skullrockian can be recognized across broad regions of western and southern North America, including Oklahoma (see Stitt, 1971, 1977; Derby, and others, 1972). *Paraplethopeltis genacurva,* characteristic of the upper Skullrockian Stage (= Zone C) at Ibex (Hintze, 1953) was recovered from the uppermost part of the McKenzie Hill Formation in Oklahoma (Stitt, 1983). This suggests that the base of the overlying Stairsian Stage—defined as the lowest occurrence of the trilobites characteristic of *Leiostegium–Kainella* Zone (= Zone D)—should occur very high within the McKenzie Hill or low within the Cool Creek Formation. Although the Skullrockian–Stairsian Stage boundary can be recognized throughout much of western North America (Ross and others, 1997), it has not yet been identified in Oklahoma as a result of preservation problems in the upper part of the McKenzie Hill Formation (Stitt, 1983) and lack of systematic collecting in the overlying Cool Creek Formation. The base of the Tulean Stage, the base of Zone G, is at the lowest occurrence of the *Menoparia genalunata* at Ibex (as previously discussed). Although the lowermost Kindblade can be correlated broadly with uppermost portions of Zone F, the absence of shared trilobite species makes the recognition of the base of the Tulean Stage imprecise in Oklahoma. The base of the Blackhillsian Stage, the first occurrence of *Trigonocera typica,* cannot be resolved on the basis of trilobites in Oklahoma. Derby and others (1991) reported *Isoteloides flexus* (Zone H) and other Blackhillsian species from the West Spring Creek Formation in Oklahoma. Therefore, of the four stages erected by Ross and others (1997), only the base of the oldest, the Skullrockian Stage, can be well resolved in Oklahoma. It is apparent that, based upon the dissimilarity in trilobite faunas and the difficulty in applying the stage terms developed in Ibex, that a need exists to develop an independent stadial terminology applicable to the southern and eastern United States and eastern Canada.

Two alternatives exist for the development of a stadial terminology for the southern and eastern United States and eastern Canada. The first would be the development of a new and independent suite of terms based upon the Oklahoma succession. The second possibility would be to evaluate Flower's (1957, 1964) stadial terminology and, if the concepts are geologically appropriate, to upgrade their use to modern standards. Although his stadial terms were not well defined, it is possible to find Flower's stadial terms in the recent literature (Derby and others, 1991; Fortey and others, 1991; Boyce and Stouge, 1997; Repetski and others, 2000). Therefore, it seems prudent to evaluate the faunal basis of Flower's stadial terms. Study of the trilobite faunas of the Kindblade Formation and the faunas of the Fort Cassin Formation (Brett and Westrop, 1996) form the basis for evaluating the Jeffersonian and Cassinian Stages.

Jeffersonian Stage

Flower's (1957, 1964) Jeffersonian Stage was based upon the faunas illustrated from the Jefferson City Formation of southern Missouri. Cullison (1944) documented the faunas of the Jefferson City including the description of 12 trilobite species. The Jefferson City Formation is largely dolomite, and its fossils are preserved in its associated cherts. As a result, biostratigraphic data are governed by the diagenetic development of cherts and is relatively imprecise. No clear or desirable measured section with sufficient biostratigraphic data exists to base a stadial boundary stratotype in the type region of the Jefferson City. Among the trilobites identified from the lower Kindblade are seven species, however, named by Cullison (1944) from the Jefferson City Formation. These form the basis for correlations between Oklahoma and Missouri and the strong ties between Oklahoma and Missouri for the computed Jaccard Coefficients (Text-fig. 4).

Loch (1995) previously proposed that the Jeffersonian Stage be retained and suggested the boundary stratotype and horizon required under contemporary stratigraphic practice (see Salvador, 1994). Loch (1995) chose the Kindblade Ranch measured section as the lectostratotype section on the basis of its higher collection density and faunal abundances near the base of the formation. The boundary horizon for the base of the Jeffersonian Stage was taken as the first occurrence of *Ranasasus brevicephalus* and *Chapmania taylori* (as *"Peltabellia" permarginata*) at 62 ft (18.9 m) above the base of the measured section.

Cassinian Stage

Early in the study of the Kindblade trilobites, it became apparent that a turnover in the trilobite faunas (Pl. 1, 2; see also Derby and others, 1991, fig. 9) at approximately 700 ft (213 m)

above the base of the I-35 section. The significance of this turnover was not readily apparent before the restudy of the trilobites of the Fort Cassin Formation (Brett and Westrop, 1996). Above the 700-ft (213-m) level, trilobites characteristic of the Jeffersonian Stage are replaced by species known from the Fort Cassin Formation, the basis of Flower's (1957, 1964) Cassinian Stage.

Brett and Westrop (1996) documented faunas from the Fort Cassin Formation of New York State. The Fort Cassin yielded a low diversity fauna of 11 species, of which only one (*Isoteloides peri*) is known from the Kindblade. Brett and Westrop (1996), however, used *I. peri* along with several other species to correlate the Fort Cassin with the Catoche Formation of Newfoundland, Canada. The trilobites of the Catoche and uppermost Boat Harbour Formations (Fortey, 1975; Boyce, 1989) appear somewhat older than the Fort Cassin and share more species in common with the Kindblade Formation (see Correlation). Unfortunately, a significant unconformity is present at the base of the Fort Cassin (Brett and Westrop, 1996) and within the uppermost Boat Harbour Formation (the pebble bed at the base of the Barbace Cove Member of the Boat Harbour Formation; Boyce, 1989). Contemporary stratigraphic practice (Salvador, 1994) advises against the selection of a boundary stratotype in a measured section with significant unconformities. In Oklahoma, there is no physical evidence of unconformity or indication on the graphic correlation diagram (Text-fig. 6) of an unconformity at the Jeffersonian–Cassinian turnover.

The lectostratotype for the Cassinian Stage is selected as the I-35 section on the basis of its high collection density, faunal abundance, and continuity of section through the boundary interval (Loch, 1998). The boundary horizon is selected as the first occurrence of *Petigurus cullisoni* at 691 ft (211 m) above the base of the measured section. *Isoteloides peri* has its first appearance 30 ft (9 m) higher at 721 ft (220 m). These two species are known to occur together in the Cassinian rocks of the Barbace Cove Member of the Boat Harbour Formation in Newfoundland, Canada (Boyce, 1989; see, however, Boyce and Stouge, 1997). The rocks of the middle and upper Kindblade along with those of the Barbace Cove Member of the Boat Harbour Formation could, then, be considered as lower Cassinian. The fauna of the Fort Cassin Formation in conjunction with the faunas of the Catoche Formation, with taxa not known from the Kindblade, might be considered as an upper Cassinian. The upper limits on the Cassinian in Oklahoma would be defined by the lowest occurrence of Middle Ordovician (Whiterockian Series) taxa 90 ft (27 m) below the top of the West Spring Creek Formation in Oklahoma (Derby, 1969, 1973; Ethington and Dresbach, 1990). This transition was interpreted by T. R. McHargue (*in* Derby and others, 1993, figs. 13, 14) to occur at a minor hiatus.

SYSTEMATIC PALEONTOLOGY

Trilobites assigned to 18 genera and 34 species are described and illustrated from the Kindblade Formation. Those species treated in the modern literature (Boyce, 1989; Brett and Westrop, 1996; Fortey, 1979) were not redescribed. Second and subsequent species descriptions were abridged to conserve space by omitting mention of shared features or characters. Twenty species were left in open nomenclature, typically when fewer than five specimens were recovered.

Cullison (1944) named many of the species recovered from the Kindblade Formation from the Lower Ordovician of southern Missouri. His illustrated type material was distributed to the Yale Peabody Museum, the United States National Museum (Smithsonian), and the Missouri School of Mines. Attempts to examine that portion of Cullison's type material stored at the Missouri School of Mines, now the University of Missouri–Rolla, were largely unsuccessful. Only the paratype librigena of *Ischyrotoma abrupta* (Cullison; MSM 7256) could be located among the collections. Type material was borrowed from the Yale Peabody Museum and examined. Comparisons with Cullison's type material are difficult, however, due to differences in preservation. Cullison's specimens are internal molds recovered from chert nodules, whereas the Kindblade trilobites are preserved (testate or exfoliated) in limestone.

Morphological terms applied in the following descriptions are largely consistent with those outlined in Part O, Arthropoda I, Trilobita (Revised) of the Treatise on Invertebrate Paleontology (Whittington, 1997). Measurements of the glabella are exclusive of the occipital ring, unless otherwise noted or the ring is absent. Bathyurids from the Kindblade Formation commonly lack definite pygidial border furrows. For these taxa, the border is considered to include the unfurrowed portions of the pleural region (Whittington, 1997).

Disarticulated trilobite sclerites have been associated based upon similarity in prosopon, con-

vexity, and facial suture, as well as congruent stratigraphic distribution.

Specimens from Oklahoma were prepared for photography through the application of an opaque black ink and a coating of magnesium oxide. Exposures were made on Kodak Technical Pan film using an ASA of 100 and a 4–48 second exposure time. The film was processed in Kodak D-76 developer for 10 minutes.

Specimens are housed at the Department of Geological Sciences at the University of Missouri–Columbia (UMC). Detailed abundance data are assembled in Appendix I (Interstate-35 measured section) and Appendix II (Kindblade Ranch measured section).

Phylum ARTHROPODA Siebold and Stannius, 1845
Class TRILOBITA Walsh, 1771
Order PTUCHOPARIIDA Swinnerton, 1915
Family ASAPHIDAE Burmeister, 1843
Subfamily ISOTELINAE Angelin, 1854
Genus *ISOTELOIDES* Raymond, 1910

Type species.—*Asaphus canalis* Whitfield, 1886, p. 336–339; from the Fort Cassin Formation of Vermont; by original designation (Raymond, 1910, p. 35), see Brett and Westrop (1996, p. 412, 413, 418) for discussion.

ISOTELOIDES PERI Fortey, 1979
Plate 4, Figures 1–9

Isoteloides peri Fortey, 1979, p. 69–72, pl. 23, figs. 1, 2, 4, 7, 8 [only; figs. 3, 5, 6 = *I. canalis* following Brett and Westrop, 1996]; Stouge and Boyce, 1983, pl. 14, fig. 8, pl. 15, figs. 2–5; Boyce, 1989, p. 33, pl. 3, figs. 1–8; Brett and Westrop, 1996, p. 418, figs. 13.1–13.11; Desbiens and others, 1996, p. 1143, pl. 2, figs. 1–3, 25, pl. 3, fig. 16, pl. 4, figs. 7–19.

Isoteloides cf. *I. flexus* Hintze. Sando, 1958, pl. 2, figs. 33–35.

Isoteloides sp. of Lees, 1967, pl. 12, figs. 1–3, 9.

Isoteloides latimarginatus Fortey, 1979, p. 72, pl. 24, fig. 9 [only].

Diagnosis.—The diagnosis of Brett and Westrop (1996, p. 418) is accepted.

Supplemental description.—The following observations supplement the specific description of Fortey (1979, p. 69–70). Thorax of 8 slightly convex (tr.) segments of equal length (sag.) with broad axial ring. Pleurae with marked fulcrum; pleural furrows weakly impressed across fulcrum, obsolete laterally. Distal part of anterior four pleurae (opposite librigenal spine of librigenae) slopes evenly downward to rounded termination; distal part of posterior four pleurae slightly concave (tr.), widen (tr.) distally, becoming successively wider toward pygidium. Smooth except for terrace lines on articulating facets.

Remarks.—Specimens of *Isoteloides* from the Kindblade Formation are assigned to *I. peri* because (1) the cranidia possesses relatively small palpebral lobes; (2) the anterior facial sutures diverge at a low angle; (3) the relatively short anterior border, approximately 0.2 times the total cranidial length; (4) a relatively narrow (tr.) frontal area; and (5) the long pygidial axis. The proportional width of the frontal area and length of the pygidial axis for Oklahoma specimens fall within the fields illustrated for *I. peri* by Brett and Westrop (1996, figs. 11.2, 12.2). Librigenae of *I. peri* n. sp. from Oklahoma (Pl. 4, Fig. 8) have a somewhat narrower (tr.) post-ocular librigenal field than those illustrated by Fortey (1979, pl. 23, fig. 1). In this respect, the Kindblade Formation librigenae are similar to those illustrated by Boyce (1989, pl. 3, figs. 4, 5). Hypostomes recovered from the Kindblade conform to that illustrated by Fortey (1979, pl. 23, fig. 4), differing only in the degree of truncation to the anterior margin of the fork.

Isoteloides peri is also known from the Catoche and Boat Harbour Formations of Newfoundland, Canada (Fortey, 1979; Boyce, 1989); the Beauharnois Formation of Ontario, Canada (Desbiens and others, 1996); the Fort Cassin Formation of Vermont (Brett and Westrop, 1996); the Axemann Limestone of Pennsylvania (Lees, 1967); and the Rockdale Run Formation of Maryland (Sando, 1958). Dean (1989, p. 39) suggested the presence of *Isoteloides* in correlative portions of the Outram Formation of Alberta, Canada. This material, after further study, may be referred to *I. peri*. Specimens identified by E. O. Ulrich (*in* Weller and St. Clair, 1928, p. 90) as *Isoteloides whitfieldi* Raymond, 1910, from the Powell Formation of Missouri may be assigned to *I. peri* upon reexamination.

Material.—Total 24 cranidia, 44 pygidia, 25 librigenae, 8 hypostoma, 1 articulated exoskeleton.

Occurrence.—Interstate-35 measured section: 35 collections from 721 to 1,227 ft (220–374 m) above the base of the section. Recovered from the *Petigurus cullisoni* Zone at I-721, I-738, I-739, I-757, I-765, I-771, I-805, I-809, I-841, I-846, I-851, I-883, I-917, I-918, I-926, I-940, I-943, I-944, I-945, I-950, I-951, I-952, I-954, I-955, I-976. Recovered from the *Bolbocephalus stitti* Zone at

I-994, I-1036, I-1038, I-1041, I-1044, I-1045, I-1066, I-1098, I-1106, I-1227. Kindblade Ranch measured section: 4 collections from 708 to 861 ft (216–263 m) above the base. Recovered from the *Petigurus cullisoni* Zone at KR-708, KR-816, KR-860, KR-861.

ISOTELOIDES? SP. 1

Plate 4, Figure 10

Remarks.—A single fragmentary hypostome with a deeply bifurcated posterior margin from low in the Kindblade Formation is assigned to the Family Asaphidae. Morphologically this hypostome is similar to that of *Isoteloides peri* (Pl. 4, Fig. 9) and is considered congeneric. The lateral border is broad, widest slightly posterior to the maculae, with distinctly angular lateral and posterior margins. The maculae are long (tr.) and lie at right angles to the axis.

Although *Isoteloides*? sp. 1, *I. peri* (Pl. 4, Fig. 9; Fortey, 1979, pl. 23, fig. 4; Boyce, 1989, pl. 3, figs. 4, 5), and *I. canalis* (Whitfield; see Brett and Westrop, 1996, figs. 9.5, 9.6) all feature hypostomes with broad lateral borders, only the lateral margin of the hypostome of *I.*? sp. 1 is distinctly angular. Hypostomes of the younger species *I. flexus* and *I. polaris* (Hintze, 1953, pl. 17, figs. 6, 10, respectively) have relatively narrow lateral borders with their maximum widths opposite the maculae.

Occurrence.—One hypostoma recovered from the *Benthamaspis rhochmotis* Zone from 486 ft (148 m) above the base of the I-35 section.

Family BATHYURIDAE Walcott, 1886
Subfamily BATHYURINAE Hupé, 1955
Genus *BOLBOCEPHALUS* Whitfield, 1890

Type species.—*Bathyurus seelyi* Whitfield, 1886, p. 339, by original designation (Whitfield, 1890, p. 36, 37).

Diagnosis.—Genus of Bathyurinae with glabella constricted (tr.) opposite posterior margin of palpebral lobes, expanded anteriorly to equal or exceed width of occipital ring (tr.); strongly convex (sag.), inflated anteriorly to extend beyond preglabellar furrow and overturned frontal area. Librigenae strongly convex (tr.), lateral border furrow well impressed, lateral border subvertical anteriorly. Pygidium semicircular in outline, moderately convex; axis roughly 0.7 times pygidial length; border furrow absent, pleural ribs flush with or inflated to rise slightly above border, in posterior view pleural region curves evenly from axial furrow to margin.

Discussion.—The diagnosis conforms to that of H. B. Whittington (*in* Moore, 1959, p. O376, O377) with additional emphasis on pygidial characters. Revision of the pygidial diagnosis of *Bolbocephalus* was possible after Fortey (1979, p. 78–79) correctly associated the cranidium and pygidium of *Bolbocephalus convexus* (Billings, 1865).

Cullison (1944) illustrated two species of *Bolbocephalus* from Missouri that will be involved in later discussions. Of these, *Bolbocephalus st. clairi* was published originally in a faunal list provided by E. O. Ulrich (*in* Weller and St. Clair, 1928, p. 90) for the Powell Formation of southeastern Missouri. Cullison (1944, p. 78–79) noted that the name was a *nomen nudum*, but he retained the name and formally described the species based upon new material from Missouri and the specimens studied by Ulrich. The trivial name is corrected, as directed by Article 32.5.2.4.1 of the International Code of Zoological Nomenclature (Ride, 1999, p. 40), to *B. sancticlairi*.

The holotype pygidium of *Bolbocephalus stevensi* Boyce (1989, p. 47, 48, pl. 23, figs. 5–8) exhibits several features distinct from *Bolbocephalus*, as diagnosed above. The pygidial axis is markedly longer than in other species assigned to the genus; the border is narrower; and the pleural ribs are strongly inflated to stand above the border. These characteristics lead me to exclude the holotype pygidium, *B. stevensi*, and one of the illustrated paratype pygidia (Boyce, 1989, pl. 24, figs. 1–3) from *Bolbocephalus*, assigning them questionably to *Strigigenalis*. The generic assignment of the paratype cranidium and at least two paratype pygidia (Boyce, 1989, pl. 23, figs. 1–4, pl. 24, figs. 4–10) to *Bolbocephalus* appears correct but will require the erection of a new trivial name.

Four named species, two of which are new, are assigned to *Bolbocephalus* from the Kindblade Formation. At least six additional new species-level taxa are left in open nomenclature suggesting that the species diversity of *Bolbocephalus* is under-represented.

BOLBOCEPHALUS JEFFERSONENSIS Cullison, 1944

Plate 5, Figures 1–8

Bolbocephalus jeffersonensis Cullison, 1944, p. 77–8, pl. 34, figs. 28–29.

Bolbocephalus aff. *B. jeffersonensis* Cullison. Cloud and Barnes, 1948, pl. 42, fig. 24.

[Not] *Bolbocephalus* cf. *B. jeffersonensis* Cullison. Cloud and Barnes, 1948, pl. 42, fig. 25.

Diagnosis.—Large *Bolbocephalus* with elongate glabella which is only slightly constricted poste-

riorly, evenly rounded in anterior view, glabella not inflated sufficiently to overhang preglabellar furrow; frontal area slightly convex, overturned, preglabellar field long, narrow anterior border; anterior facial sutures slightly curved, slightly convergent. Pygidium moderately convex; axis tapered, bluntly rounded, moderately convex (tr.); pleural ribs slightly inflated, stand slightly above border; moderately impressed pleural furrows; 1–3 faint pairs of interpleural furrows; border slightly convex, moderately declined.

Supplemental description.—Cranidium large, up to 1.8 cm long (sag.); pentagonal in outline; slightly convex (sag.). Glabella large, broadly rounded anteriorly; rectangular to clavate in outline, slightly constricted at posterior corner of palpebral lobes; moderately convex (tr.), in sagittal profile slightly convex posterior to palpebral lobes, strongly convex anteriorly with anterior edge oriented vertically. Glabellar length 0.8 times cranidial length; palpebral glabellar width (tr.) 0.8 times glabellar length. Glabellar furrows absent. Axial furrows moderately impressed, slightly sinuous. Preglabellar furrow broad, evenly curved; moderately impressed laterally, weakly impressed axially. Occipital ring long, 0.2 times cranidial length; rectangular in outline. Occipital furrow slightly sinuous, broadest axially; moderately impressed. Anterior border short, slightly raised, tubular, of constant length laterally with slight anterior arch. Anterior border furrow evenly curved, faintly impressed. Preglabellar field hidden in dorsal view by glabella, overturned, slightly convex in sagittal profile; in lateral view 0.33 times cranidial height. Preocular field narrow, slightly convex (exsag.), slightly overturned at border furrow. Palpebral lobes semicircular in outline; large, 0.33–0.4 times glabellar length; with narrow rim defined by moderately impressed palpebral furrow; set posteriorly, entirely behind glabellar mid-length. Palpebral fields slightly convex slightly declined (tr.). Posterior areas, posterior facial sutures unknown. Anterior branch of facial sutures slightly convergent, slightly curved adaxially to intersect anterior margin in line with axial furrows.

Librigenal fragment large, up to 1.6 cm long (exsag.), slightly convex, with broad, short genal spine. Genal field large, slightly convex, steeply declined; low eye socle present. Lateral border furrow broad, moderately impressed anteriorly. Posterior border furrow weakly impressed. Lateral border narrow anteriorly, strongly convex; steeply declined to overturned marginally.

Pygidium large, up to 2.0 cm long (sag.); semicircular in outline with estimated pygidial width 1.7 times pygidial length (sag.), moderately convex (sag., tr.). Axis narrow, slightly tapered, bluntly truncated posteriorly, moderately convex (tr.); composed of short articulating half-ring, 2–4 poorly defined axial rings, hexagonal terminal axial piece. Terminal axial piece inflated to stand above posterior border, 2 inflated nodes present at posterior corners. Anterior axial width (tr.) estimated at 0.7 times axial length, greater than width of pleural fields; axial length (sag.) 0.7 times pygidial length (sag.). Ring furrows shallowest axially, weakly impressed anteriorly, posterior furrows successively shallower. Axial furrows straight, well impressed, weaken posteriorly. Pleural fields small, triangular, with 4 pairs of pleural ribs; slightly convex (tr.), rise slightly above adjacent border; extend posteriorly beyond axis. Four pairs of well-to faintly impressed pleural furrows; 1–3 pairs of interpleural furrows restricted to pleural fields, best impressed on distal ends of pleural ribs. Border furrow absent. Border wide, nearly constant in width, slightly longer post-axially; slightly convex, moderately declined. Articulating facet short (exsag.).

Testate material smooth, pits on exfoliated surfaces.

Remarks.—Examination of the collections at the University of Missouri–Rolla failed to produce the illustrated type material of *Bolbocephalus jeffersonensis* (MSM 7181, MSM 7182). A single pygidium identified as *B. jeffersonensis* Cullison (illustrated as Pl. 5, Fig. 7) was stored among an unsorted lot of specimens removed from open display. Unfortunately, this pygidium was not associated with a valid collection label and lacked collection number or locality number. The display tag, however, did record the specimen as coming from a locality 6 mi (9.6 km) north of Rolla, Missouri. The pygidia from Oklahoma assigned to *B. jeffersonensis* conform to the morphology of this pygidium from southern Missouri.

Cullison (1944, p. 78) differentiated *Bolbocephalus jeffersonensis* and *Bolbocephalus sancticlairi* based upon the absence of a posterior fixigenal node in the former and the presence of a flat, declined pygidial border in the latter. Additionally, in anterior view the glabella of *B. sancticlairi* is pointed and overturned, rather than evenly rounded and oriented vertically as in *B. jeffersonensis.* The pleural ribs on the pygidia of *B. sancticlairi* are nearly flush with the border, whereas those of *B. jeffersonensis* are slightly inflated to stand in low relief over the border.

The glabella of *Bolbocephalus jeffersonensis* is less inflated (sag., tr.) than those of others spe-

cies in this genus and is apparently unique in the vertical orientation of the anterior end of the glabella. Other, younger species, including *Bolbocephalus stitti*, *Bolbocephalus myktos*, and *Bolbocephalus* sp. 3, have glabellas which are inflated and overhang beyond the preglabellar furrow.

Bolbocephalus jeffersonensis is known from the Jefferson City Formation of Missouri (the Rich Fountain Formation of Cullison, 1944) and the Honeycut Formation of Texas (Cloud and Barnes, 1948; Toomey, 1964, p. 102).

Material.—Total 5 cranidia, 8 pygidia, 2 librigenae.

Occurrence.—Interstate-35 section: 1 collection from the *Ranasasus brevicephalus* Zone at 40 ft (12 m) above the base of the section. Kindblade Ranch measured section: 4 collections from 66 to 151 ft (20–46 m) above the base. Recovered from the *R. brevicephalus* Zone at KR-66, KR-75, KR-132, KR-151.

BOLBOCEPHALUS cf. *B. CONVEXUS* (Billings, 1865)

Plate 7, Figures 1, 2

Dolichometopus? convexus Billings, 1865, p. 269, fig. 253.

Bolbocephalus convexus (Billings, 1865). Boyce, 1989, p. 46–47, pl. 22, figs. 1–8 (synonymy to date).

Diagnosis and description.—See Fortey (1979, p. 78).

Remarks.—Fortey (1979, p. 78–80, pl. 26, figs. 1–8) diagnosed and redescribed *Bolbocephalus convexus*. Cranidia illustrated by Fortey (1979, pl. 26, figs. 1, 3, 4, 6) exhibit moderately impressed axial furrows including a straight segment that extended from the occipital furrow to the midlength of the palpebral lobe. This feature is especially evident on the small cranidium figured by Boyce (1989, pl. 22, figs. 1–4). Three large cranidia from Oklahoma possess moderately impressed axial furrows with such a straight segment in conjunction with a slightly convex (tr.) glabella, slightly convex (tr.) posterior areas, a moderately impressed occipital furrow, and a short occipital ring (Pl. 7, Fig. 1). The Oklahoma cranidia differ from the majority of those of *B. convexus* in having a glabella which appears more elongate than quadrate and posterior areas which seem relatively broader (tr.). These differences are less striking, however, when the Oklahoma specimens are compared to a similarly large specimen (Fortey, 1979, pl. 26, figs. 3, 6).

One fragmentary pygidium conforms to previously illustrated specimens of *Bolbocephalus convexus*. The pygidial axis is long, broad, and only slightly tapered. The preserved left pleural region has 3 pleural furrows and 2–3 interpleural furrows (Pl. 7, Fig. 2). The axial and ring furrows are moderately to faintly impressed, contributing to an effaced appearance for the pygidium. Although many of the illustrated pygidia of *B. convexus* lack the third pleural furrow, this furrow is developed on the holotype pygidium (see Fortey, 1979, pl. 26, fig. 8), as well as specimens figured by Ludvigsen (1978, pl. 1, figs. 5, 6).

Bolbocephalus convexus is a stratigraphically long-ranging species in Newfoundland (Boyce, 1989, fig. 4) which occurs with *Strigigenalis caudata* in the upper part of its range. In contrast, in Oklahoma, *Bolbocephalus* cf. *B. convexus* is restricted to an interval below the range of *S. caudata*. *Bolbocephalus convexus* is known from the Oxford Formation of Ontario (Ludvigsen, 1978), the Catoche Formation and Barbace Cove Member of the Boat Harbour Formation of Newfoundland (Fortey, 1979; Boyce, 1989).

Material.—Total 3 fragmentary cranidia, 1 fragmentary pygidium.

Occurrence.—Interstate-35 section: 2 collections from the *Petigurus cullisoni* Zone at 762 and 841 ft (232, 256 m) above the base of the section. Kindblade Ranch section: 1 collection from the *P. cullisoni* Zone at 741 ft (226 m) above the base.

BOLBOCEPHALUS STITTI n. sp.

Plate 6, Figures 1–9

Bolbocephalus st. clairi Cullison, 1944. Identified by J. D. Loch, *in* Derby and others, 1991, fig. 10D; identified by J. R. Derby, *in* Derby and others, 1991, fig. 8.

Diagnosis.—Large *Bolbocephalus* with elongate glabella which is severely constricted posteriorly, slightly nasute in anterior view bounded by angular preglabellar furrow, inflated to extend beyond preglabellar furrow; frontal area flat, overturned, with short frontal area; anterior facial sutures slightly curved and convergent to produce preocular area; flat palpebral fields separated by broad trough from distinct baccula on posterior areas. Pygidium moderately convex; axis distinctly tapered, bluntly truncated, moderately convex (tr.); pleural ribs not inflated, flush with border; moderately impressed pleural furrows; 2 pairs of faint interpleural furrows; border steeply declined, nearly flat. Deep pits on exfoliated surfaces.

Description.—Cranidium large, up to 1.5 cm long (sag.); subtriangular in outline; strongly convex

(sag.). Glabella elongate; severely constricted anterior to occipital furrow, expanded anteriorly; anterior margin appears rounded in dorsal view, with slight nasute appearance in anterior view. Glabella moderately to strongly convex (tr.); strongly inflated (sag.) to extend beyond preglabellar furrow and to overhang frontal area, sagittal profile with faint flexure at palpebral lobes. Glabellar length 0.8 times cranidial length; width at constriction 0.7 times glabellar length, maximum glabellar width 0.8 times glabellar length. Axial furrows well impressed, deepest opposite glabellar constriction; sinuous, strongly convergent from posterior margin to posterior of palpebral lobes, curve abaxially to diverge anteriorly. Preglabellar furrow moderately impressed, shallowed and constricted at axis, recurved to accentuate nasute appearance of glabella in anterior view. Occipital ring trapezoidal, 0.2 times cranidial length (sag.). Occipital furrow straight, well impressed, shallowest abaxially. Anterior border furrow and anterior border absent. Frontal area flat, short (sag.), overturned; distinct flange extends downward near axis. Preocular areas descend from axial furrow, steepen anteriorly. Palpebral lobes semielliptical, 0.33 times glabellar length; broad, well-impressed palpebral furrow present; centered slightly posterior to glabellar mid-length. Palpebral fields narrow, slightly convex (tr.), rise above axial furrows. Posterior areas triangular, long (exsag.), broad (tr.); pronounced baccula opposite glabellar constriction; separated from palpebral fields by broad trough that runs from posterior of palpebral lobe anteriorly to meet axial furrow at palpebral mid-length. Well-impressed posterior border furrow. Anterior branch of facial sutures initially parallel then gently curve to converge axially. Posterior branch of facial sutures diverge at roughly 55°, curve posteriorly, intersect posterior margin at acute angle.

Librigenae up to 2.0 cm long, trapezoidal in outline, moderately convex (tr.). Genal field large, sharply declined, broadest posteriorly. Simple eye socle present. Lateral border furrow moderately impressed; widened, deepened posteriorly; continuous with broad, moderately impressed posterior border furrow. Lateral border narrow, overturned anteriorly; widened, becomes declined posteriorly. Genal spine short, stout, flattened.

Pygidium up to 1.5 cm long (sag.); pygidial width 1.3–1.6 times pygidial length. Axis broad, long, slightly tapered; composed of articulating half-ring, 4 axial rings, rectangular terminal axial piece. Anterior axial width 0.33 times maximum pygidial width (tr.). Anterior ring furrow moderately impressed, shallowest axially, other ring furrows successively fainter posteriorly. Axial furrows well impressed, shallower posteriorly, continuous post-axially. Pleural fields large, moderately convex (tr.), with 4 pair of pleural ribs; ribs not inflated, lie flush with border; distally flat. Anterior pleural furrows moderately impressed, remaining 3 pair shorter, fainter. Two faintly impressed interpleural furrows present on anterior pleural ribs. Border moderately wide, nearly flat. Articulating facet concave, 0.66 times width of pleural region, posterior corner opposite posterior-most ring furrow.

Prosopon of fine, elongate granules to ridges on uncommon testate specimens. Widely spaced, faint pits on abundant exfoliated material; frontal area, librigenal border with oblique terrace lines or aligned, closely spaced pits oblique to margin.

Remarks.—Bolbocephalus stitti is easily separated from those *Bolbocephalus* species described from Missouri. *Bolbocephalus jeffersonensis* Cullison (1944, p. 77–78, pl. 34, figs. 28, 29; Pl. 5, Figs. 1–8) exhibits a glabella outlined by axial furrows which are straight and moderately divergent. This results in a glabella that expands anteriorly in a uniform manner. *Bolbocephalus stitti*, in contrast, has sinuous axial furrows that cause the glabella to exhibit a clavate form. Further, the frontal area of *B. stitti* is overturned, whereas in *B. jeffersonensis* it is oriented subvertically. Similarly, the cranidium of *B. sancticlairi* Cullison (1944, p. 78–79, pl. 35, figs. 27–31) is evenly expanded anteriorly and is not as convex (sag., tr.) as for *B. stitti*.

The cranidium of *Bolbocephalus stitti* compares closely with the paratype cranidium of *B. stevensi* Boyce (1989, p. 47–48, pl. 23, figs. 1–4). Each cranidium is describes as having a finely granulose prosopon, is nasute in anterior view, exhibits a pronounced baccula, and in each the glabella is severely constricted posteriorly. The overall convexity of *B. stitti*, however, is strikingly greater than in *B. stevensi* in both anterior and lateral views. The pygidium of *B. stitti* differs from some paratype pygidia of *B. stevensi* (Boyce, 1989, pl. 24, figs. 6–10) in having an axis that is narrower (tr.) and less inflated, with a better impressed axial furrow around the terminal axial piece.

The pygidium of *Bolbocephalus stitti* is most similar to those species which also exhibit faintly impressed interpleural furrows: *Bolbocephalus convexus* and *B. glaber*. *Bolbocephalus convexus*

(Billings, 1865; see Fortey, 1979, p. 78–80, pl. 26, figs. 1–10; Boyce, 1989, p. 46, 47, pl. 22, figs. 1–8, pl. 24, figs. 6–10) differs from *B. stitti* in possessing a pygidial axis that is relatively broader, longer and more effaced, a glabella that is nearly equidimensional, and in lacking a genal spine. The pygidium of *B. glaber* Poulsen (1927, p. 304, pl. 20, figs. 10, 27) entirely lacks ring, pleural, and interpleural furrows.

The lectotype cranidium of *Bolbocephalus seelyi* (Whitfield, 1886, p. 339, pl. 33, figs. 14–18; 1890, pl. 3, figs. 3–4; Whittington, 1953, p. 655–656, fig. 2A,B, pl. 66, figs. 1, 4, 5) is similar to that of *Bolbocephalus stitti.* Shared features include an angular preglabellar furrow, strongly constricted glabella, and inflated fixigenal node. The pygidium of *B. seelyi,* however, features interpleural furrows that are well impressed (Whittington, 1953, fig. 2C, pl. 66, figs. 9, 13, 14, 17, 22).

Etymology.—Named in honor of my late doctoral advisor, James H. Stitt, in recognition of his critical contributions to high-resolution biostratigraphy in the Timbered Hills and Arbuckle Groups of Oklahoma (Stitt, 1971, 1977, 1983).

Material.—Total of 39 cranidia, 42 pygidia, 11 librigenae. Holotype: UMC 16923 (Pl. 6, Figs. 1, 2). Paratypes: UMC 16924–16929.

Occurrence.—Interstate-35 section: 15 collections from 1,009 to 1,474 ft (308–449 m) above the base of the section. Recovered from the *Bolbocephalus stitti* Zone at I-1009, I-1064, I-1079, I-1080, I-1135, I-1178 and from the *Strigigenalis caudata* Zone at I-1212, I-1222, I-1227, I-1255, I-1269, I-1270, I-1444, I-1468, I-1474. Kindblade Ranch measured section: 2 collections from the *B. stitti* Zone at 901 and 1,010 ft (275, 308 m) above the base.

BOLBOCEPHALUS MYKTOS n. sp.
Plate 6, Figures 10–15

Diagnosis.—Large *Bolbocephalus* with elongate glabella slightly constricted posteriorly, strongly nasute in anterior view due to angular preglabellar furrow; frontal area slightly convex, overturned with preglabellar field of moderate length and narrow anterior border; anterior facial sutures slightly divergent, nearly straight, resulting in broad preocular areas; palpebral and posterior areas slightly convex (tr.). Pygidium moderately convex; axis slightly tapered, truncate, strongly convex (tr.); well-impressed pleural furrows; interpleural furrows very faint; pleural ribs lie flush with border; border steeply declined, flat anteriorly, slightly convex post-axially. Deep pits on exfoliated surfaces.

Description.—Cranidium up to 1.8 cm long (sag.); pentagonal in outline; equant in dorsal view. Glabella slightly constricted posterior to palpebral lobes, expanded anteriorly; nasute, sharply rounded in anterior view. Glabella strongly convex anteriorly (sag.), inflated to extend anteriorly beyond preglabellar furrow and overhang frontal area; moderately convex (tr.). Glabellar width at constriction 0.8 times glabellar length (sag.), maximum glabellar width equal to glabellar length. Axial furrows slightly convergent from posterior margin to posterior corner of palpebral lobes, then slightly divergent anteriorly. Preglabellar furrow sinuous. Occipital ring slopes anteriorly toward occipital furrow. Occipital furrow nearly straight, curved anteriorly laterally. Anterior border thread-like; anterior border furrow weakly impressed. Preglabellar field overturned, slightly convex, narrowest at axis. Preocular areas wide (tr.), descend steeply away from glabella, slightly convex. Palpebral lobes approximately 0.4 times glabellar length (exsag.); nearly centered on glabellar mid-length, posterior end opposite glabellar constriction. Palpebral fields broad; mildly inflated adjacent to glabella; nearly flat (exsag.). Anterior branch of facial sutures straight initially; slightly divergent, curving adaxially near margin, intersect margin outside anterior projection of axial furrows. Posterior branch of facial sutures sharply divergent.

Librigenae with wide, slightly convex (tr.), steeply declined librigenal fields. Lateral border furrow separate from broad posterior border furrow. Border steeply inclined, narrowed anteriorly. Genal spine directed slightly outward.

Pygidium up to 1.3 cm long (sag.), with pygidial width (tr.) 1.5 times pygidial length (sag.). Axis tapered, bluntly rounded posteriorly, strongly convex (tr.); with, trapezoidal terminal axial piece. Ring furrows sinuous. Axial furrows broader post-axially; appear sinuous as result of depressions at intersections with pleural furrows. Pleural regions with 3–4 low (tr.) pleural ribs which lie flush with border, in posterior view produce smooth curve from axial furrow to lateral margin. Faintly impressed interpleural furrows. Border furrow absent; border defined by distal ends of pleural furrows. Articulating facet long, broad, concave; posterior corner opposite second ring furrow.

Prosopon smooth on testate surfaces except for terrace lines on cranidial border, thick terrace lines on libriginal border, oriented obliquely

across genal spine; deep, widely spaces pits on exfoliated surfaces, most dense along pygidial margin, absent from articulating facet.

Remarks.—The posteriorly constricted, anteriorly expanded and inflated (sag.) glabella of *Bolbocephalus myktos* is diagnostic for the genus.

The broad preocular areas of *Bolbocephalus myktos* are similar to those of *B. jeffersonensis.* The glabella of *B. jeffersonensis*, however, is rounded anteriorly and fails to overhang the frontal area. In the remaining well-illustrated species of *Bolbocephalus* the anterior facial sutures converge to parallel the course of the axial and preglabellar furrows. This results in a narrow band of uniform width, composed of the narrow anterior fixiginae and short frontal area, which encircles the anterior of the glabella (see Pl. 6, Fig. 6, for *Bolbocephalus stitti*; Pl. 5, Fig. 3 for *B. jeffersonensis*; Boyce, 1989, pl. 22, fig. 2 for *B. convexus*; Whittington, 1953, pl. 66, figs. 4, 7 for *B. seelyi*). Seen in anterior view, the preglabellar furrow of *B. myktos* is angled, rather than broadly curved (Pl. 6, Fig. 12). The preglabellar furrows of *B. stitti* (Pl. 6, Fig. 5) and the lectotype of *B. seelyi* (Whittington, 1953, Pl. 66, fig. 4) are similarly angled. The posterior areas of *B. myktos* lack the baccula seen on *B. stitti.* The preglabellar field of *B. myktos* is significantly longer than that of *B. seelyi.*

The illustrated pygidium (Pl. 6, Figs. 13, 14) is assigned to *Bolbocephalus myktos* based upon the degree of pitting on the exfoliated surfaces, relative convexity (tr.), and impression of axial furrows. The pygidium, however, was recovered from below the associated cranidia and librigenae. The faint interpleural furrows on the pygidium of *Bolbocephalus myktos* distinguishes this new species from *B. seelyi* (Whitfield, 1886; Whittington, 1953, p. 655–657, fig. 2, pl. 66, figs. 1–10, 12–14, 17, 21, 22) and *B. kindlei* Boyce (1989, p. 48, pl. 25, figs. 1–8, pl. 26, figs. 1–4). The pygidium of *Bolbocephalus glaber* Poulsen (1927, p. 304, pl. 20, figs. 10, 27) is highly effaced, lacking interpleural, pleural, and ring furrows from the pygidium. The pygidium of *Bolbocephalus convexus* (Billings, 1865; Fortey, 1979; Boyce, 1989) is more globular in form with a long, low axis which is blunt posteriorly, rather than rounded as in *B. myktos.*

Etymology.—Derived from *myktos*, Greek m.; nose; referring to the nasute anterior margin of the glabella.

Material.—Total 2 cranidia, 4 pygidia, 3 librigenae. Holotype: UMC 16930 (Pl. 6, Figs. 10–12). Paratypes: UMC 16931, 16932.

Occurrence.—Interstate-35 section: 1 collection from the *Jeffersonia granosa* Zone at 275 ft (84 m) above the base of the section. Kindblade Ranch measured section: 5 collections from 109–331 ft (33–101m) above the base. Recovered from the *Ranasasus brevicephalus* Zone at KR-109, KR-143, KR-151, KR-243; and from the *Jeffersonia granosa* Zone at KR-312, KR-331.

BOLBOCEPHALUS SP. 1

Plate 5, Figures 9–13

Remarks.—The two cranidia identified as *Bolbocephalus* sp. 1 exhibit a posteriorly constricted glabella which is inflated anteriorly (sag.) to extend beyond the preglabellar furrow and to overhang the frontal area, a morphology typical of *Bolbocephalus.* The anterior lobe of the glabella is evenly rounded, rather than nasute, distinguishing it from *Bolbocephalus stitti* n. sp. (Pl. 6, Fig. 5) *B. myktos* n. sp. (Pl. 6, Fig. 12), and *B. sancticlairi* (Cullison, 1944, p. 78, 79, pl. 35, figs. 27–29). A narrow anterior border is visible in *Bolbocephalus* sp. 1 as in *Bolbocephalus jeffersonensis* n. sp. (Pl. 5, Fig. 3). *Bolbocephalus* sp. 1, however, differs in having a markedly shorter preglabellar field and a glabella that is more strongly constricted posteriorly.

The more complete specimen (UMC 16941; Pl. 5, Figs. 9–11) was collected by Cullison but was not described. The associated collection label indicated that it was from the Missouri School of Mines (MSM) locality 75.27, "at top of section measured 10/4/40, center N. line . . . Ele 760'" in the Jefferson City Formation of Missouri. Cullison (1944), however, does not list the locality. The description of MSM 75.27 places it immediately adjacent to MSM locality 75.26 (see Cullison, 1944, p. 87, for additional details), a locality that has also yielded *Peltabellia missouriensis* and *Ranasasus conicus.*

Occurrence.—One collection from the *Ranasasus brevicephalus* Zone at 151 ft (46 m) above the base of the Kindblade Ranch measured section.

BOLBOCEPHALUS SP. 2

Plate 7, Figures 3, 4

Remarks.—One complete and 3 fragmentary pygidia of this species are assigned to *Bolbocephalus* based upon the overall convexity, the prominent axis, and the moderately declined border. These specimens are distinguished by their granulose prosopon, paired tubercles on the axial rings and terminal axial piece, 4 pairs of interpleural furrows that are best impressed medially, and the concave border that is narrowest post-axially from the *Bolbocephalus* species il-

lustrated from the Kindblade. *Bolbocephalus* sp. 2 compares most closely with the younger species *B. kindlei* Boyce (1989, p. 48, pl. 25, figs. 1–8, pl. 26, figs. 1–4) based upon the similar granulose prosopon and the interpleural furrows that extend to the lateral margins. The interpleural furrows of *B. kindlei* are most distinct adaxially and marginally, rather than being shallowed. The pygidial axis of *B. kindlei* ends in a terminal axial piece that stands in only low relief over the pleural region and that lacks the paired tubercles seen on *Bolbocephalus* sp. 2. *Bolbocephalus seelyi* (Whitfield, 1886; Whittington, 1953, p. 655–657, fig. 2, pl. 66, figs. 1–10, 12–14, 17, 21, 22) is the only other species of the genus to possess moderately impressed interpleural furrows, which reach the lateral margins. *Bolbocephalus seelyi* also exhibits a terminal axial piece that stands in low relief and is poorly defined posteriorly, has pleural furrows that are curved distally, and lacks the paired tubercles on the axial rings and terminal axial piece.

Occurrence.—Interstate-35 section: 2 collections from the *Benthamaspis rhochmotis* Zone at 499 and 525 ft (152, 160 m) and 1 collection from the *Petigurus cullisoni* Zone at 846 ft (258 m) above the base of the section.

BOLBOCEPHALUS SP. 3

Plate 7, Figures 5, 6, 9

Remarks.—A single cranidium is assigned to *Bolbocephalus* on the basis of the moderately convex (sag.) glabella that is constricted posterior to the palpebral lobes. The glabella of *Bolbocephalus* sp. 3 is rounded anteriorly rather than nasute. This character separates it from *Bolbocephalus stitti* n. sp. (Pl. 6, Fig. 5), *B. myktos* n. sp. (Pl. 6, Fig. 12), *B. sancticlairi* (Cullison, 1944, p. 78–79, pl. 35, figs. 27–29), and *B. seelyi* (Whitfield, 1886; Whittington, 1953, pl. 66, fig. 4). The degree of constriction behind the palpebral lobes and the moderately inflated bacculae separate *Bolbocephalus* sp. 3 from *B. jeffersonensis* n. sp. (Pl. 5, Figs. 1, 4).

Occurrence.—Interstate-35 section: 1 cranidium from the *Strigigenalis caudata* Zone at 1,440 ft (439 m) above the base of the section, with 1 cranidium from 1,215 ft (370 m) assigned questionably.

BOLBOCEPHALUS spp.

Plate 7, Figures 7, 8, 10–17

Remarks.—Three fragmentary cranidia are assigned to *Bolbocephalus* based upon the presence of a posteriorly constricted glabella which extends anteriorly to overhang the frontal area. The stratigraphically lowest of these (Pl. 7, Fig. 7) differs from *Bolbocephalus myktos* in having a weakly impressed occipital furrow, a moderately developed posterior fixigenal node, and a glabella which is rounded anteriorly in dorsal view. A fragmentary unassigned pygidium (Pl. 7, Fig. 10) was recovered from this horizon and bears moderately impressed pleural and interpleural furrows. The second unassigned *Bolbocephalus* cranidium occurred within the stratigraphic range of *B. stitti*. This cranidium (Pl. 7, Fig. 8) exhibits a glabella which is slightly convex (tr.) and only slightly constricted posteriorly, slightly inflated posterior areas, and a moderately impressed occipital furrow. A third cranidium (Pl. 7, Figs. 11, 12) collected near the top of the stratigraphic range of *B. stitti* differs from that species in having a moderately impressed occipital furrow and a strongly convex (exsag.) palpebral furrow.

Three pygidia are assigned to *Bolbocephalus* based upon their globular shape and broad, slightly convex axis. Two of the pygidia exhibit a dorsally arched posterior margin, analogous to the anterior arch on a cephalon. The first specimen (Pl. 7, Figs. 14, 15) has pleural regions and a border which curves evenly to the lateral margin in posterior view; the second is flat to slightly concave near the margin (Pl. 7, Figs. 16, 17). The third pygidium (Pl. 7, Fig. 13) is highly effaced and lacks the flattened pleural region seen in the pygidium of the *Ranasasus colossus*, also known from that collection. It may be significant that these pygidia are large, each more than 2.0 cm long (sag.), although they do not appear conspecific with any other described species from the Kindblade Formation.

Genus *CULLISONIA* n. gen.

Type species.—*Jeffersonia producta* Cullison, 1944, p. 73, 74, by monotypy and original designation herein.

Diagnosis.—Genus of large Bathyurinae with triangular anterior border; rectangular glabella with faintly impressed 1s lateral glabellar furrow; palpebral lobes steeply inclined (tr.). Pygidium triangular in outline; border broad longest postaxially, oriented subhorizontally.

Remarks.—*Cullisonia* is a monospecific genus erected to accommodate *"Jeffersonia" producta* Cullison (1944). The pygidial morphology of this species is significantly different from that of the type species of *Jeffersonia* in its triangular outline and subhorizontally oriented border to merit a

unique generic designation. The geometry of the pleural ribs, the rectangular glabellar outline, and well-impressed palpebral furrow, however, suggest a close affinity with the genus *Jeffersonia*.

Etymology.—Named in honor of James S. Cullison, deceased, of the University of Missouri–Rolla, for his work on the Lower Ordovician stratigraphy and trilobites of Missouri.

CULLISONIA PRODUCTA (Cullison, 1944)
Plate 8, Figures 1–5

Jeffersonia producta Cullison, 1944, p. 73–74, pl. 34, figs. 1–9.
Jeffersonia cf. *J. producta* Cullison. Cloud and Barnes, 1948, pl. 42, figs. 22, 23.

Diagnosis.—Same as for the genus.

Supplemental description.—Cranidium large, up to 1.6 cm long (sag.), moderately convex (sag.), roughly trapezoidal in outline. Glabella large, rectangular in outline, broadly rounded anteriorly, moderately convex (sag., tr.) with faint keel. Glabellar length 0.6–0.7 times cranidial length (sag.); palpebral glabellar width (tr.) 0.8 times glabellar length (sag.). One faint pair of 1s lateral glabellar furrows, as broad depressions on exfoliated glabella. Axial furrows narrow, well impressed, moderately convergent from posterior margin to 1s lateral glabellar furrows, slightly convergent anteriorly. Preglabellar furrow well impressed. Occipital ring long, greater than 0.1 times cranidial length (sag.), posteriorly declined near axial furrows, medial occipital node set anteriorly on ring. Occipital furrow generally well impressed but shallowing to weakly impressed at axial furrows, broadest axially, anterior side steeply declined. Anterior border less than 0.1 times cranidial length (sag.), triangular in outline, anteriorly produced at axial line; flat, inclined upward from border furrow; in anterior view edge appears thick with rounded margin, dorsally peaked with slight anterior arch. Anterior border furrow evenly curved. Preglabellar field slightly declined (sag.), length variable, equal to or less than that of border. Anterior fixigenae slightly convex, declined anterolaterally, moderately wide (tr.). Palpebral lobes short, 0.3 times glabellar length (exsag.), semicircular in outline, inclined (tr.) with distal edge at height of glabella; centered slightly posterior to glabellar mid-length, posterior corner opposite 1s lateral glabellar furrow. Narrow palpebral rim defined by broad, well-impressed palpebral furrow. Posterior areas triangular, short (exsag.), broad, less than width of occipital ring; well-impressed posterior border furrow present. Anterior branch of facial sutures straight, moderately divergent. Posterior branch of facial sutures strongly divergent at 70° to axial line, sinuous, curved distally to intersect posterior margin at nearly right angle.

Librigenae large, up to 1.6 cm long. Librigenal field broad (tr.), widened posteriorly, moderately convex, moderately declined distally. Lateral border furrow moderately impressed anteriorly as decline in slope, shallowed posteriorly. Low ridge drawn from posterolateral corner of librigenal field separates lateral and posterior border furrows. Lateral border thick, horizontal, broadest anteriorly, tapered posteriorly. Librigenal spine long, narrow, undivided. Eye socle present, unornamented.

Pygidium large, up to 1.7 cm long (sag.), strongly convex (sag., tr.), triangular in outline with maximum pygidial width (tr.) 1.2 times pygidial length (sag.). Axis broad, slightly tapered, evenly rounded posteriorly, strongly convex (tr.); 4 axial rings with axial spines, elongate terminal axial piece. Ring furrows straight, well impressed anteriorly, successively shallower posteriorly; each furrow shallowed axially and distally. Anterior axial width approximately 0.33 times maximum pygidial width (tr.); axial length 0.8–0.9 times pygidial length (sag.). Axial furrows straight, well impressed, slightly convergent anterior to terminal axial piece, curved abaxially to intersect border furrow posteriorly. Pleural fields strongly convex (tr.); short (exsag.), fail to extent to mid-length of terminal axial piece; with 4 strong pleural ribs defined by 4 moderately to well-impressed, steep-sided pleural furrows. Interpleural furrows faintly impressed for length of pleural rib. Border furrow as moderately to well-defined flexure in pleural region. Border narrow, slightly concave, slightly declined anteriorly, up to 4 faint ridges extend from edges of anterior pleural ribs onto border; border widened posteriorly, broadest post-axially where moderately concave with inclined margin.

Prosopon on testate specimens as fine granules, uncommon. Exfoliated material smooth with fine pits; pits absent from furrows.

Remarks.—The upturned anterior cranidial border, inclined palpebral areas, strongly convex pygidial axis, axial pygidial spines, and post-axially concave pygidial border on the Oklahoma specimens are consistent with illustrated specimens of *Jeffersonia producta*. Some degree of variability is evident, however, in the shape and inclination of the anterior border, as well as the length of the post-axial pygidial border.

Cullisonia producta is known from the Jefferson City Formation of southern Missouri and northern Arkansas (the Rich Fountain Formation of Cullison, 1944) and the Honeycut Formation of the Ellenburger Group of Texas (Cloud and Barnes, 1948; Toomey, 1964, p. 102).

Material.—Total 6 cranidia, 4 pygidia, 7 librigenae.

Occurrence.—Interstate-35 section: 2 collections recovered from the *Ranasasus brevicephalus* Zone at 115 and 119 ft (35, 36 m) above the base of the section. Kindblade Ranch measured section: 6 collections from 75 to 254 ft (23–77 m) above the base. Recovered from the *R. brevicephalus* Zone at KR-75, KR-75A, KR-84, KR-108, KR-109, KR-119, KR-128, KR-132, KR-143, and the *Jeffersonia granosa* Zone at KR-254.

Genus *GELASINOCEPHALUS* n. gen.

Type species.—*Gelasinocephalus whittingtoni* n. sp.

Diagnosis.—Genus of Bathyurinae with large, subrectangular, strongly convex (sag.) glabella which fails to overhang the frontal area; frontal area slightly convex (sag.) with pronounced anterior arch (tr.), the anterior margin turned under on exfoliated surfaces; testate frontal area with coarsely ridged anterior border separated from preglabellar field by faint anterior border furrow; anterior facial sutures intersect anterior margin on line with or between extension of axial furrows; anterior fields narrow (tr.).

Remarks.—Two species, *Gelasinocephalus whittingtoni* n. sp. and *G. pustulosus* n. sp., are assigned to this genus based upon the anteriorly arched and overturned frontal area. The complete association of the cranidium, librigena, and pygidium of *G. whittingtoni* dictated its selection as type species over *G. pustulosus.*

The anteriorly inflated glabella of *Gelasinocephalus* is also present in the bathyurid genera *Bolbocephalus, Ranasasus,* and *Petigurus.* As the construction of the name implies, *Gelasinocephalus* appears closest to *Bolbocephalus* Whitfield. However, the glabella of *Bolbocephalus* extends beyond the anterior margin in most species and is constricted (tr.) at the occipital furrow. The frontal area of *Bolbocephalus* is typically shorter (sag.), flat, and oriented vertically with no trace either the anterior arch or convexity seen in *Gelasinocephalus.* The axial furrows of *Ranasasus* Cullison are faintly impressed and outline a glabella that is only slightly convex transversely and that overhangs the anterior margin. The pygidial axis of *Ranasasus* is only slightly convex (tr.) anteriorly. The prosopon of *Petigurus* Raymond is uniformly pustulose, the glabella overhangs the frontal area, and the pygidial axis is long and well defined posteriorly.

Some species of *Ischyrotoma* Raymond exhibit a dorsally arched and strongly ridged anterior cranidial border, as seen in *Gelasinocephalus.* On exfoliated specimens the ventral margin of the cranidium fails to turn back and under the remainder of the frontal area. Further, the pygidium of *Ischyrotoma* is strikingly different, being strongly convex with a thickened marginal rim which is confluent with well-defined pleural ribs.

Etymology.—Compounded from *gelasinos,* Greek, m., for dimple, and *kephale,* Greek, f., for head; referring to the anterior cranidial border which is turned back and under the remainder of the exfoliated frontal area. Latin m. suffix "*-us*" applied to maintain parallelism with other related genera.

GELASINOCEPHALUS WHITTINGTONI n. sp.

Plate 9, Figures 1–13

Diagnosis.—Large, smooth *Gelasinocephalus* with equidimensional glabella, lateral glabellar furrows faint or absent on exfoliated specimens, palpebral lobes set posteriorly, anterior course of facial sutures intersect anterior margin in line with extension of axial furrows, posterior areas moderately long, posterior branch of facial suture recurved distally. Librigena with broad, steeply declined (tr.), ridged lateral border; librigenal spine short, posteriorly rounded. Pygidium with low axis; posterior margin extended posteroventrally; deep, concave doublure.

Description.—Cranidium up to 1.4 cm long (sag.), trapezoidal in outline, strongly convex (sag.). Glabella large, subrectangular in outline, broadly rounded anteriorly, very slightly constricted at the occipital furrow, slightly tapered anterior to palpebral areas; moderately convex (tr.), strongly convex (sag.) with anterior margin oriented vertically, fails to overhang the frontal area. Glabellar length 0.8 times cranidial length (sag.); palpebral glabellar width (tr.) equals glabellar length. Two pair of broad, faintly impressed lateral glabellar furrows present on exfoliated specimens. Axial furrows broad, well impressed, curve slightly anterior to palpebral lobes to join moderately impressed preglabellar furrow in smooth curve. Occipital ring short, less than 0.1 times cranidial length (sag.), rectangular, drawn anteriorly at axial furrows. Occipital furrow broad, 0.1 times cranidial length, well

impressed, anterior side more steeply declined than posterior side. Anterior border furrow faintly impressed, parallel to anterior margin on exfoliated specimens, testate examples unknown. Frontal area very short or obscured in dorsal view; in anterior view strong anterior arch present, frontal area 0.25 times total cranidial height, moderately convex (sag.), with ventral edge turned under and beneath remainder of frontal area. Anterior fields narrow (tr.), slightly convex (exsag.), steeply declined. Palpebral lobes large, 0.33–0.5 times (exsag.) glabellar length (sag.), semielliptical in outline with well-impressed palpebral furrows defining narrow rim; centered posteriorly, at 0.66 times glabellar length. Palpebral areas narrow, moderately convex (tr.), rise above axial furrows, slightly declined distally. Posterior areas triangular, short (exsag.), broad (tr.), with well-impressed posterior border furrow. Anterior course of facial sutures initially divergent, slightly curved adaxially to intersect anterior margin in line with extension of axial furrows. Posterior branch of facial sutures strongly divergent, recurved to meet posterior margin at acute angle.

Librigena triangular in outline, up to 1.8 cm long. Librigenal field very slightly convex, steeply declined (tr.). Lateral border furrow moderately impressed, shallowed anteriorly and at genal angle, continuous with well-impressed posterior border furrow. Lateral border broad (tr.), width constant until genal angle; moderately convex (tr.) with lateral margin overturned to face ventrally. Librigenal spine short, stout, paddle-like, rounded posteriorly. Eye socle thick, eye retained.

Pygidium up to 1.2 cm long (sag.), moderately convex (sag., tr.), parabolic in outline with pygidial width (tr.) only 1.3 times pygidial length (sag.) due to distinct posteroventral extension of post-axial border. Axis broad (tr.), moderately long (sag.), moderately tapered, bluntly rounded posteriorly; composed of short articulating half-ring, 4 successively shorter (sag.) axial rings, trapezoidal terminal axial piece. Axis moderately convex anteriorly (tr.), decreasing posteriorly until terminal axial piece stands at or only slightly above pleural field. Anterior axial width 0.4–0.5 times maximum pygidial width (tr.) at third axial ring; axial length 0.70–0.75 times pygidial length (sag.). Ring furrows moderately impressed anteriorly, successively shallowing until faintly impressed; shallowest axially. Axial furrows broad, moderately impressed anteriorly, shallowing posteriorly until obsolete post-axially on larger specimens. Border furrow absent, border defined by distal ends of pleural furrows and inflection in convexity of pleural regions. Pleural fields triangular, broad anteriorly (tr.), slightly convex (tr.), moderately declined distally; crossed by 3 pairs of straight, moderately to faintly impressed pleural furrows. Border moderately declined, narrow (tr.) and slightly concave anteriorly, flattened and longest post-axially due to ventral extension of posterior margin. Articulating facet unknown. Doublure broad, strongly concave; deepest, broadest post-axially.

Prosopon smooth on testate surfaces (lost during preparation), except for coarse ridges on librigenal border. Exfoliated surfaces with pits, some pits on glabella surrounded by low annuli, pits on cranidial and libriginal border closely spaced and set in shallow grooves parallel to margin.

Remarks.—The posterior extension of the pygidial border compliments the strong anterior arch of the cranidium that would have settled cleanly into the concave pygidial doublure when an individual of *Gelasinocephalus whittingtoni* enrolled.

Etymology.—In honor of H. B. Whittington, in recognition of his 1953 revision of North American bathyurid trilobites.

Material.—Total 10 cranidia, 3 pygidia, 1 librigena. Holotype: UMC 16954 (Pl. 9, Figs. 1, 2). Paratypes: UMC 16955–16959.

Occurrence.—Interstate-35 section: 4 collections from 451 to 546 ft (138–166 m) above the base of the section. Recovered from the *Jeffersonia granosa* Zone at I-451 and the *Benthamaspis rhochmotis* Zone I-499, I-521, I-546. Kindblade Ranch measured section: 2 collections recovered from the *Benthamaspis rhochmotis* Zone at 437 and 481 ft (133, 147 m) above the base.

GELASINOCEPHALUS PUSTULOSUS n. sp.

Plate 10, Figures 1–7

Diagnosis.—Pustulose, moderately sized *Gelasinocephalus*, with rectangular glabella; 2 pairs of lateral glabellar furrows as short, faint notches on exfoliated specimens; palpebral lobes set medially; anterior facial sutures intersect anterior margin between extensions of axial furrows; posterior areas moderately long (exsag.); posterior branch of facial sutures straight distally.

Abridged description.—Cranidium up to 0.9 cm long (sag.). Glabella slightly constricted anterior from palpebral areas. Glabellar length 0.75 times cranidial length (sag.); palpebral glabellar width

(tr.) 0.9 times glabellar length. Two pair of lateral glabellar furrows on exfoliated surfaces as short, broad, faintly impressed notches. Axial furrows straight posteriorly, slightly curved anterior to palpebral lobes to join well-impressed preglabellar furrow in smooth curve. Occipital furrow straight axially, distally constricted, shallowed, bent anteriorly. Frontal area very short in dorsal view (sag.), in anterior view 0.3 times total cranidial height, strong anterior arch present. Anterior border flat, vertically oriented, with strong ridges on testate specimens, separated from preglabellar field by weakly impressed anterior border furrow. Exfoliated frontal area very short, lacks border furrow, moderately convex (sag.), with ventral edge turned under and beneath remainder of frontal area. Palpebral lobes large, 0.4 times (exsag.) glabellar length (sag.), centered at glabellar mid-length. Palpebral furrows weakly impressed, define narrow rim; furrow well impressed on exfoliated specimens. Palpebral areas slightly convex (tr.), moderately inclined to rise above axial furrows. Posterior areas moderately long (exsag.), moderately declined (tr.). Anterior course of facial sutures initially slightly divergent, continued slightly curved to intersect anterior margin between extensions of axial furrows. Posterior branch of facial sutures strongly divergent, straight, intersects posterior margin near genal angle.

Librigenae fragmentary, estimated up to 0.9 cm long (exsag.), trapezoidal in outline, slightly convex, steeply declined (tr.). Librigenal field large, of constant width. Lateral border furrow shallow at genal angle. Lateral border flat, steeply declined (tr.). Posterior border absent, posterior branch of facial sutures extended nearly to genal angle. Genal angle unknown. Thick eye socle present, eye detached.

Prosopon of pustules best developed on testate and exfoliated glabella, testate librigenal fields; preglabellar field, fixigenae with subdued pustules on testate surfaces, deep pits on exfoliated frontal area, fixigenae. Testate anterior cranidial and lateral libriginal borders with coarse ridges oriented near parallel to margin.

Remarks.—*Gelasinocephalus pustulosus* differs most obviously from *G. whittingtoni* in its pustulose prosopon that is expressed on both testate surfaces and on internal molds.

Etymology.—From *pustulosus*, Latin, m., for covered by blisters; referring to the pustulose prosopon.

Material.—Total 5 cranidia, 1 librigena. Holotype: UMC 16960 (Pl. 10, Figs. 1, 2). Paratypes: UMC 16961–16963.

Occurrence.—Interstate-35 section: 2 collections recovered from the *Benthamaspis rhochmotis* Zone at 486 and 521 ft (148, 159 m) above the base of the section. Kindblade Ranch measured section: 1 collection recovered from the base of the *B. rhochmotis* Zone at 437 ft (133 m) above the base.

Genus *JEFFERSONIA* Poulsen, 1927

Bathyurina Poulsen, 1937, p. 51. Probable junior subjective synonym (see Fortey, 1986, p. 18 and discussion below).

Type species.—*Jeffersonia exterminata* Poulsen, 1927, p. 303, by monotypy.

Provisional diagnosis.—Genus of Bathyurinae with rectangular, strongly convex (sag.) glabella outlined by well-impressed axial and occipital furrows, 1–2 pairs of lateral glabellar furrows present; anterior border with dorsal arch on anterior edge of thick, commonly cord-like margin rim, rim extends onto librigenae; palpebral lobes elevated, centered at or slightly behind glabellar mid-length, narrow palpebral rim defined by broad, well-impressed palpebral furrow; anterior branch of facial sutures subparallel to slightly divergent. Librigenae with large librigenal field, distinct lateral border, eye socle, narrow librigenal spine. Pygidium with long, tapered, strongly convex (tr.) axis composed of 3–4 axial rings and terminal axial piece; axial furrows well impressed, intersect border furrow; pleural fields strongly convex (tr.) with 3–4 pleural ribs defined by 3–4 moderately to well-impressed pleural furrows; border narrow, declined. Prosopon of fine granules to pustules.

Remarks.—The nomenclatorial history of *Jeffersonia* Poulsen, 1927, and *Bathyurina* Poulsen, 1937, has been discussed by Fortey (1986, p. 18) and Boyce (1989, p. 49). The diagnosis provided above for *Jeffersonia* is, therefore, provisional and contingent upon eventual recovery of the associated sclerites for each of the type species. The provisional diagnosis largely conforms to the concepts discussed by Fortey (1986) and Boyce (1989), but includes cranidial characters ignored by Boyce (1989, p. 49).

In conducting his doctoral research, Cullison (1944) compared the trilobite and mollusc faunas he recovered from the Jefferson City Group with Ulrich's collections assembled at the United States National Museum. Cullison adopted several specific names applied by Ulrich from the museum labels. Seven species were assigned to

Jeffersonia by Cullison (1944), although these represented several significantly different morphotypes (Table 5).

TABLE 5.—Revised Generic Assignment of Species Assigned to the Genus *Jeffersonia* by Cullison (1944)

Cullison (1944)	Revised assignment (this paper)
Jeffersonia crassimarginata	*Strigigenalis crassimarginata*
Jeffersonia delicatula	*Jeffersonia delicatula*
Jeffersonia granosa	*Jeffersonia granosa*
Jeffersonia jenni	*Jeffersonia jenni*
Jeffersonia mediacrista	*Benthamaspis* cf. *mediacrista*
Jeffersonia missouriensis	*Chapmania missouriensis*
Jeffersonia producta	*Cullisonia producta*

JEFFERSONIA GRANOSA Cullison, 1944

Plate 11, Figures 1–11

Jeffersonia granosa Cullison, 1944, p. 72–3, pl. 34, figs. 17–22; Cloud and Barnes, 1948, pl. 42, fig. 20.

Jeffersonia sp. of Cloud and Barnes, 1948, pl. 42, fig. 21.

Diagnosis.—Large *Jeffersonia* with prosopon of pustules to coarse granules; anterior border of cranidium in dorsal view appears as thickened rim, in anterior view as distinct vertical facet with strong arch on dorsal edge, laterally tapered; preglabellar field steeply declined to near vertical; rectangular glabella with well-impressed 1s and 2s lateral glabellar furrows; pits at distal ends of occipital furrow. Librigena with distinct ridge separating lateral and posterior border furrows, ridge confluent with thick, strongly declined lateral border. Pygidium transverse diamond-shape in outline; border declined, slightly convex, narrow in dorsal view, longest and drawn ventrally post-axially; pleural fields extend length of axis; spines on axial rings of some specimens.

Supplemental description.—Cranidium up to 1.3 cm long (sag.), moderately convex (sag.), essentially subrectangular in outline with laterally extended palpebral lobes. Glabella large, rectangular in outline, slightly tapered anteriorly, broadly rounded; moderately convex to anteriorly inflated to overhang frontal area (sag.). Glabellar length 0.7 times cranidial length (sag.); basal glabellar width (tr.) variable, 0.7–0.9 times glabellar length (sag.). Two pairs of well-impressed lateral glabellar furrows: 1s lateral glabellar furrows curved posteriorly, 0.25 times glabellar width (tr.), depressed below axial furrow laterally; 2s lateral glabellar furrows short, pit-like, perpendicular to axis. Axial furrows well impressed, nearly straight, subparallel, join in smooth curve with well-impressed preglabellar furrow. Occipital ring 0.1 times cranidial length (sag.); arcuate in outline, distal ends drawn anteriorly and decrease in slope. Occipital furrow deep, well impressed, steep-sided; straight and broadest axially, anteriorly curved distally, deepened to appear pit-like adjacent to axial furrow. Anterior border in dorsal view as narrow rim, in anterior view doublure bent upward to produce broad, vertical to overturned, slightly concave (sag.), laterally tapered anterior facet with strong arch on dorsal edge. Anterior border furrow moderately impressed, slightly curved with mild angulation axially. Preglabellar field short, narrowest axially, slightly convex (sag.), steeply declined to vertical. Anterior fixigenae steeply declined, slightly convex (tr.), moderately wide. Palpebral lobes short, up to 0.4 times glabellar length (exsag., less for larger specimens); moderately to well elevated on broad, inclined palpebral areas; set at glabellar mid-length, anterior end opposite 1s lateral glabellar furrow, posterior end behind 2s lateral glabellar furrow. Narrow palpebral rim defined by broad, well-impressed palpebral furrow. Posterior areas long (exsag.), broad (tr.), slightly declined (tr.), slightly convex (tr.). Anterior branch of facial sutures slightly divergent, broadly curved adaxially to intersect anterior margin at oblique angle. Posterior branch of facial sutures moderately divergent at roughly 60° to axial line.

Librigenae up to 0.8 cm long (exsag.), moderately convex (tr.), subtriangular in outline excluding librigenal spine. Librigenal fields subtriangular, expanded posteriorly, moderately convex (tr.), steeply declined distally. Lateral border thick, convex, steeply declined along margin. Lateral border furrow well impressed; posterior border furrow broad, separated from lateral border furrow by low ridge which extends from posterolateral corner of librigenal field to librigenal spine in continuous curve. Librigenal spine short, thin; directed laterally at base to interrupt even curve of lateral margin, distally curved adaxially and ventrally. Eye socle present.

Pygidium up to 0.9 cm long (sag.), strongly convex (sag., tr.), transverse diamond shape in outline with maximum pygidial width (tr.) 1.3

times pygidial length (sag.). Axis long, moderately tapered, strongly convex (tr.); composed of robust articulating half-ring, 4 successively shorter axial rings, terminal axial piece. Ring furrows well impressed. Axial rings decline posteriorly in sagittal profile, some specimens with anteriorly set axial spines on each ring. Rectangular terminal axial piece extends to posterior border furrow, with two posterolateral nodes on some specimens. Anterior axial width 0.4 times maximum pygidial width (tr.); axial length 0.9 times pygidial length (sag.). Axial furrows straight, well impressed anteriorly, shallow before joining border furrow posteriorly. Two triangular pleural fields, discontinuous post-axially, moderately convex (tr.), with 4 strong pleural ribs defined by 4 well-impressed, steep-sided pleural furrows. Faint interpleural furrows seen as faint depressions located centrally at distal ends of plural ribs. Broad, weakly impressed border furrow continuous about margin, seen as change in slope of pleural region. Border narrow and of uniform width in dorsal view, ventrally extended and longest post-axially in oblique view.

Prosopon dominantly of pustules on testate specimens, scale varied with granules in some cases, best developed on glabella, absent in furrows and on cephalic border; thin ridges, oblique to margin on libriginal border. Pustules plus pits on exfoliated material.

Remarks.—Several specimens from the Kindblade Formation are judged conspecific with *Jeffersonia granosa* and are assigned to that species based upon the granular prosopon, rectangular glabella, well-impressed lateral glabellar furrows, and dorsally arched anterior border. The specimens from Oklahoma, however, are variable in several characters, including the development of prosopon (Pl. 11, Figs. 1, 3, 4), the width of the glabella, the elevation of the palpebral lobes (Pl. 11, Figs. 2, 5), and the development of the axial ring spines (Pl. 11, Figs. 7, 9). *Jeffersonia granosa* differs from smaller species of *Jeffersonia* in its well-impressed 1s and 2s lateral glabellar furrows and the structure of the anterior border. This species is retained in *Jeffersonia*, however, based upon the quadrate glabellar outline, elevated palpebral lobes, well-developed palpebral rim and furrow, the geometry of the pleural ribs, and its granulose prosopon.

Jeffersonia granosa is known from the Jefferson City Formation of Missouri (the Rich Fountain of Cullison, 1944) and the Honeycut Formation of Texas (Cloud and Barnes, 1948; Toomey, 1964, p. 102).

Material.—Total 26 cranidia, 9 pygidia, and 10 librigenae.

Occurrence.—Interstate-35 section: 5 collections from 266 to 434 ft (81–132 m) above the base of the section. Recovered from the *Jeffersonia granosa* Zone at I-266, I-268, I-271, I-430, I-434. Kindblade Ranch measured section: 8 collections from 254 to 437 ft (77–133 m) above the base. Recovered from the *Jeffersonia granosa* Zone at KR-254, KR-301, KR-305, KR-325, KR-331, KR-339, KR-399, KR-420, and the *Benthamaspis rhochmotis* Zone KR-437.

JEFFERSONIA JENNI Cullison, 1944

Plate 8, Figures 6–8

Jeffersonia jenni Cullison, 1944, p. 76–7, p. 35, figs. 17–2.

?Genus and sp. indet. II of Poulsen, 1946, p. 330, p. 23, fig. 10 (only).

Hystricurus sp. 2 of Lees, 1967, p. 12, fig. 15.

Bathyurina sp. indet. of Fortey, 1979, p. 78, p. 28, figs. 8, 10, 11.

Bathyurina sp. of W. D. Boyce, *in* Stouge and Boyce, 1983, p. 13, fig. 4.

Jeffersonia angustimarginata Boyce, 1989, p. 49–51, pl. 26, fig. 7, 8; pl. 27, figs. 1–10; pl. 28, figs. 1–3.

Diagnosis.—*Jeffersonia* of moderate size with granular prosopon; cranidium with anterior border as thick, recurved rim; preglabellar field absent; frontal area overhung by rectangular to slightly anteriorly expanded glabella, lateral glabellar furrows indistinct. Librigena with thick, cord-like border; lateral and posterior border furrows continuous. Pygidium diamond-like in outline; posterior border narrow, moderately declined; pleural fields extend length of axis.

Description.—The description provided by Boyce (1989, p. 49–50, as *Jeffersonia angustimarginata*) is an adequate description of *Jeffersonia jenni* n. sp.

Remarks.—Following examination of the holotype cranidium (YPM 17405), specimens from the Kindblade Formation are assigned to *Jeffersonia jenni* n. sp. based upon their recurved, cord-like anterior border, elongate glabella, elevated palpebral lobes, and granular prosopon.

Boyce (1989) named a new species of *Jeffersonia*, *J. angustimarginata*, from the Boat Harbour and Catoche Formations of Newfoundland, where it occurs with *Strigigenalis caudata* (Boyce, 1989, fig. 4). In southern Missouri, *Jeffersonia jenni* occurs in the Cotter Formation with *S. cau-*

data (= *Goniotelina semicircularis in* Cullison, 1944, pl. 11). Boyce (1989, p. 50) believed "that the pygidial border of *Jeffersonia jenni* is much narrower" than that of *J. angustimarginata.* Unfortunately, the paratype pygidium of *J. jenni* is obviously missing the border (Cullison, 1944, pl. 35, figs. 21, 22), as noted by Fortey (1979, p. 74). Other differences between these two purported species are minor. *Jeffersonia jenni* lacks a fourth pleural furrow seen on material illustrated by Boyce (1989, pl. 27, figs. 7–10; pl. 28, figs. 1–3). Cullison (1944, p. 74) noted that the occipital ring in *J. jenni* stands above the glabella. This is not apparent for the cranidia from Newfoundland due to the poor preservation of the occipital region (Boyce, 1989, pl. 27, figs. 7–10; pl. 28, figs. 1–3). Cullison (1944, p. 74) observed that the surface of *J. jenni* appeared smooth on the surfaces available, as do exfoliated specimens from Oklahoma. Allowing for breakage and differences in preservation, these two morphologies seem conspecific. Strikingly, each species exhibits a recurved, cord-like anterior border and lacks a preglabellar field. *Jeffersonia angustimarginata* Boyce is regarded as a junior subjective synonym of *J. jenni* Cullison, 1944.

Jeffersonia jenni is known from the Cotter Formation of Missouri (Cullison, 1944), the Axemann Limestone of Pennsylvania (Lees, 1967), and the Barbace Cove Member of the Boat Harbour Formation and the Catoche Formation of Newfoundland (Fortey, 1979; Boyce, 1989).

Etymology.—*Jeffersonia jenni* was named in honor of an avid collector, "Colonel" Clarence M. Jenni, by Cullison (1944). After his retirement from the military, he served as collections curator for the Department of Geology, University of Missouri–Columbia (1965–1970).

Material.—Total 3 cranidia, 1 librigena.

Occurrence.—Interstate-35 section: 3 collections from 1,468 to 1,475 ft (448–450 m) above the base of the section. Recovered from the *Strigigenalis caudata* Zone at I-1468, I-1474, I-1475.

JEFFERSONIA ULRICHI n. sp.

Plate 8, Figures 9, 10, 13–17

Diagnosis.—Small *Jeffersonia* with coarse granules; narrow anterior border with thickened rim; preglabellar field steeply declined to vertical; elongate glabella with faintly impressed 1s and 2s lateral glabella furrows or 2 pairs of prosopon-free patches in corresponding positions; palpebral lobes slightly inclined (tr.), set close to glabella. Librigenae with marginal rim along border, rim extended length of librigenal spine; narrow furrow on librigenal spine separates rim from inflated posterior border bearing coarse ridges. Pygidium transverse diamond-shape in outline; border broadest and extended ventrally post-axially, steeply declined; pleural fields with 4 well-defined pleural ribs extend length of axis.

Abridged description.—Cranidium small, up to 0.7 cm long (sag.), strongly convex (sag.), commonly subtrapezoidal after loss of palpebral lobes. Glabella elongate, evenly rounded anteriorly from 2s lateral glabellar furrows. Glabellar length 0.6–0.7 times cranidial length (sag.); palpebral width (tr.) 0.8–0.9 times glabellar length (sag.). Two pairs of lateral glabellar furrows; 1s lateral glabellar furrows moderately to faintly impressed, posteriorly directed, length (tr.) 0.2 times palpebral width; 2s lateral glabellar furrow vague depression or prosopon-free patch, shorter than 1s lateral glabellar furrow, located anterior to glabellar mid-length. Axial furrows convergent from posterior margin to occipital furrow, parallel anteriorly to 2s furrow; join moderately impressed preglabellar furrow in even curve. Occipital ring long, greater than 0.1 times cranidial length (sag.), posterior margin slightly extended; horizontal axially, posteriorly declined (exsag.) laterally. Occipital furrow narrowed laterally to appear slightly curved, vague pit at distal ends. Anterior border appears as short, thickened rim, of constant length laterally in dorsal view, anterior arch present. Anterior border furrow well impressed, evenly curved. Preglabellar field short (sag.) in dorsal view, less than or equal to length of border. Palpebral lobes up to 0.4 times glabellar length (exsag.), well elevated to stand as high as glabella; centered anterior to 1s lateral glabellar furrow, slightly behind glabellar mid-length, with anterior end behind 2s lateral glabellar furrow. Palpebral areas steeply inclined, strongly convex (exsag., tr.), narrow, less than 0.5 times palpebral glabellar width (tr.). Posterior areas triangular with well-impressed posterior border furrow. Posterior branch of facial sutures diverge at 45° to axial line.

Librigenae small, up to 0.7 cm long (sag.), strongly convex (tr.), trapezoidal outline with short librigenal spine. Librigenal field large, trapezoidal, slightly widened posteriorly, strongly convex (tr.), oriented nearly vertical distally. Lateral border furrow broad, moderately impressed; shallowest at posterolateral corner of librigenal field, joins faintly to moderately impressed posterior border furrow. Lateral border with thickened marginal rim, rim extended from cranidium to end of librigenal spine; anteriorly rim

adjacent to librigenal field, border widened posteriorly where rim and librigenal field separated by flat, steeply declined (tr.) border region. Posterior border extended onto librigenal spine as low, broad ridge bearing 2–4 narrow ridges; broad ridge separated from marginal rim by narrow furrow. Librigenal spine short, narrow.

Pygidium small, up to 0.5 cm long (sag.). Axis distinctly tapered, bluntly rounded posteriorly, strongly convex (tr.); with triangular articulating half-ring, trapezoidal terminal axial piece. Axial spines absent. Anterior axial width 0.4–0.5 times maximum pygidial width (tr.); axial length 0.8 times pygidial length (sag.). Anterior ring furrow well impressed, remainder shallower; shallowest, broadest axially with deepened pits distally. Axial furrows convergent adjacent to axial rings, subparallel flanking terminal axial piece, continued to intersect border furrow. Two disjunct pleural fields, strongly convex; crossed by 4 pairs of pleural furrows, furrows moderately impressed anteriorly, remainder faintly impressed. Three pairs of strong pleural ribs plus faint fourth pair posteriorly. Faintly impressed interpleural furrows present distally on pleural ribs. Border furrow as moderately to well-defined bend coinciding with distal ends of pleural furrows. Border narrowest, nearly horizontal anteriorly; broadest, steeply declined, slightly convex post-axially. Articulating facet long (sag.), steeply declined anterolaterally.

Coarse granulose prosopon on testate specimens, best developed on glabella, librigenal field, pygidial axis; finer granules on pygidial and librigenal borders. Cranidial and librigenal rim with thin ridges parallel to margin; ridges also present on articulating facet of pygidium, posterior border of librigena.

Remarks.—The lateral glabellar furrows, marginal cephalic rim, elevated palpebral lobes with well-impressed palpebral furrows, pronounced pleural ribs, and narrow pygidial border exhibited by *Jeffersonia ulrichi* n. sp. are characteristic of the genus *Jeffersonia.*

Jeffersonia ulrichi most closely compares in its small size and poorly defined lateral glabellar furrows with younger species of this genus such as *Jeffersonia timon* and *Jeffersonia jenni.* The cranidium of *J. timon* (Billings, 1865; see Fortey, 1979, p. 76–78, pl. 25, figs. 1–10; Fortey, 1986, p. 18, pl. 1, fig. 6) lacks a preglabellar field and possesses relatively larger palpebral lobes, in conjunction with a pygidial border of uniform width. Similarly, *J. jenni* (Pl. 8, Fig. 8) differs from *J. ulrichi* in the absence of a preglabellar field and the presence of a pygidial border of uniform width.

In Oklahoma, the small species *Jeffersonia ulrichi* succeeds stratigraphically the larger species *J. granosa* Cullison. *Jeffersonia granosa* exhibits a coarse pustulose prosopon (Pl. 11, Figs. 1–11) rather than the granular prosopon of *J. ulrichi.* Further, the lateral glabellar furrows of *J. granosa* are well impressed and the axial rings commonly display dorsal spines.

Among other described species of *Jeffersonia,* Cullison (1944, p. 75, pl. 34, figs. 30–32) described *Jeffersonia delicatula* from the lower Jefferson City Formation of Missouri and assigned to it a pygidium that exhibited a narrow border which "is not bent downward at the posterior extremity." *Jeffersonia ulrichi* differs from this species in having a declined posterior border on its pygidium. The holotype cranidium of *"Bathyurina" megalops* (Poulsen, 1937, p. 52, pl. 6, fig. 14, pl. 7, fig. 1; Fortey, 1979, pl. 25, fig. 11) is significantly larger than *J. ulrichi* with relatively larger palpebral lobes, 3–4 faint pairs of lateral glabellar furrows, and straight anterior facial sutures. Unlike *J. ulrichi,* the pygidium of *J. exterminata* Poulsen (1927, p. 303, pl. 20, fig. 28) exhibits a border of uniform width and pygidial furrows which are only moderately to weakly impressed.

Etymology.—This species is named for E. O. Ulrich, who suggested the generic name *Jeffersonia* in his infamous unpublished manuscript.

Material.—Total 64 cranidia, 37 pygidia, and 27 librigenae. Holotype: UMC 16983, Pl. 8, Figs. 9, 10. Paratypes: UMC 16984, 16987–16991.

Occurrence.—Interstate-35 section: 9 collections from 482 to 579 ft (147–177 m) above the base of the section. Recovered from the *Benthamaspis rhochmotis* Zone at I-482, I-486?, I-499, I-527, I-542, I-549, I-551, I-556, and I-579.

JEFFERSONIA SP. 1

Plate 11, Figure 12

Remarks.—One large, fragmentary cranidium similar to that of *Jeffersonia granosa* Cullison was recovered from low in the Kindblade Formation below the stratigraphic range of *J. granosa.* This cranidium possesses a nearly rectangular glabella, elevated palpebral lobes, and a coarse prosopon, features characteristic of *J. granosa.* The cranidium, however, exhibited a pair of faintly impressed, anteriorly directed 3s-lateral glabellar furrows and the 1s and 2s lateral glabellar furrows are less well impressed than those of *J. granosa.* Furthermore, the granular prosopon of *Jeffersonia* sp. 1 is finer than those of speci-

mens of *J. granosa* of comparable size (Pl. 11, Fig. 1), even allowing for the established variability of this character. The anterior margin of the glabella of *Jeffersonia* sp. 1 is moderately declined, whereas in *J. granosa* the anterior lobe of the glabella is inflated and tends to overhang the preglabellar field in large specimens.

Occurrence.—Recovered from the *Ranasasus brevicephalus* Zone at 143 ft (44 m) above the base of the Kindblade Ranch measured section.

JEFFERSONIA SP. 2

Plate 8, Figures 18–21

Remarks.—The rectangular glabella, large palpebral lobes with a well-developed palpebral rim, the cord-like marginal rim on the anterior border, and granulose prosopon of this species are typical of the genus *Jeffersonia*. *Jeffersonia* sp. 2 compares most closely with other small species of the genus. *Jeffersonia* sp. 2 differs from *J. ulrichi* n. sp. in its recurved anterior border furrow, moderately long (sag.) anterior border, and narrow palpebral areas. *Jeffersonia* sp. 2 differs from *J. timon* (Billings, 1865; see Fortey, 1979, p. 76–78, pl. 25, figs. 1–10; Fortey, 1986, p. 18, pl. 1, fig. 6).

Material.—Total 9 cranidia, 2 librigenae.

Occurrence.—Interstate-35 section: 5 collections from 809 to 1,064 ft (247–324 m) above the base of the section. Recovered from the *Petigurus cullisoni* Zone from I-809, I-841, I-883, I-897, and the *Bolbocephalus stitti* Zone I-1064. Kindblade Ranch measured section: 2 collections recovered from the *P. cullisoni* Zone at 770 and 805 ft (235, 245 m) above the base.

JEFFERSONIA SP. 3

Plate 8, Figures 11, 12

Remarks.—*Jeffersonia* sp. 3 is a small species included within *Jeffersonia* on the basis of its rectangular glabella with 2 pairs of weakly impressed lateral glabellar furrows, narrow anterior border, and distinct palpebral rims. Among species from the Kindblade, *Jeffersonia* sp. 3 compares most closely with *Jeffersonia ulrichi* in its small size. The preglabellar field of *Jeffersonia* sp. 3, however, is more steeply declined and appears shorter in palpebral view and the occipital ring is more rectangular.

Material.—Total 17 cranidia, 3 pygidia, and 6 librigenae.

Occurrence.—Interstate-35 section: 3 collections from 482 to 579 ft (147–177 m) above the base of the section. Recovered from the *Benthamaspis rhochmotis* Zone at I-631, ?I-635, and from the *Petigurus cullisoni* Zone from I-697.

Genus *PETIGURUS* Raymond, 1913

Type species.—*Bathyurus nero* Billings, 1865, p. 260, 261; by original designation.

Diagnosis.—Genus of Bathyurinae with an inflated, anteriorly protruded, rectangular to posteriorly constricted glabella. Strongly convex pygidium with long axis of 3–4 axial rings plus terminal axial piece defined by well-impressed axial and ring furrows; large, strongly convex pleural fields crossed by well-impressed pleural furrows, border narrow and steeply declined to overturned. Prosopon strongly pustulose.
Remarks.— This diagnosis is slightly modified from Boyce (1989, p. 53).

PETIGURUS CULLISONI n. sp.

Plate 12, Figures 1–14

Gen.(?) and sp.(?) of Cullison, 1944, p. 84, 85, pl. 35, figs. 23, 24.
Hystricurus sp. 1 of Lees, 1967, pl. 12, figs. 13, 14.
Petigurus sp. nov. A of Boyce, 1989, p. 53, 54, pl. 29, fig. 7.
Petigurus sp. 1., identified by J. D. Loch, *in* Derby and others, 1991, fig. 10c.

Diagnosis.—Large *Petigurus* with glabella elongate, nasute, sharply rounded anteriorly; subelliptical outline, defined by broad axial furrows; palpebral areas moderately wide, faint node present on posterior areas. Pygidium with faintly impressed interpleural furrows on distal margins of pleural ribs, posterior margin evenly rounded.

Description.—Cranidium large, fragments up to 2.5 cm long (sag.), pentagonal in outline, elongate, strongly convex (sag). Glabella large, subelliptical outline, sharply rounded anteriorly; constricted opposite occipital furrow, widest opposite palpebral lobes; strongly convex to overhang frontal area and anterior margin. Basal glabellar width 0.66 times glabellar length (sag.), palpebral glabellar width greater than 0.8 times glabellar length (sag.); glabellar length greater than 0.8 times cranidial length (sag.). Axial furrows well impressed, sinuous. Preglabellar furrow sinuous, well impressed, joins axial furrows in smooth curve. Occipital ring short (sag.), extended posteriorly, drawn anteriorly at axial furrows by distal curve in well-impressed occipital furrow. Anterior border overturned, cord-like, widest at axis, tapered laterally until absent. Anterior border furrow faintly impressed, sinuous,

confluent with preglabellar furrow axially. Preglabellar field absent axially, short laterally. Preocular field narrow (tr.), slightly convex, steeply declined. Faint eye ridges present on some specimens. Palpebral lobes moderate in size, 0.3–0.4 times glabellar length (sag.), semi-elliptical in outline, with moderately impressed palpebral furrow; set posteriorly, largely behind glabellar mid-length. Palpebral areas moderately wide (tr.), slightly convex, inclined from axial furrows. Posterior areas short (exsag.), steeply declined from palpebral areas, with mildly inflated node set close to axial furrow, anterior to well-impressed posterior-border furrow. Anterior branch of facial sutures weakly divergent until opposite anterior of glabella, bend sharply toward axis. Posterior branch of facial sutures strongly divergent, meets posterior margin in acute angle.

Libriginae with subtriangular outline, moderately convex (tr.). Librigenal fields large, moderately convex (tr.), widened posteriorly, steeply declined. Lateral border furrow well impressed, broadest posteriorly at confluence with well-impressed posterior border furrow. Unornamented eye socle present. Lateral border convex, tubular; narrow, widened posteriorly. Librigenal spine narrow, pointed, turned slightly outward, length variable.

Pygidium large, up to 2 cm long (sag.), semi-elliptical outline with maximum width (tr.) approximately 1.5 times pygidial length (sag.), strongly convex (sag., tr.) overturned at margin. Axis broad, long, moderately tapered, broadly rounded posteriorly, moderately convex (tr.); composed of articulating half-ring, 4 axial rings, posteriorly rounded terminal axial piece. Anterior axial width approximately 0.33 times maximum pygidial width (tr.); axial length greater than 0.8 times pygidial length (sag.). Ring furrows straight, deep, well impressed, shallowest and broadest axially. Axial furrows well impressed, deep, broad, straight, continuous around low terminal axial piece. Pleural regions large, moderately inflated, strongly convex (tr.), steeply declined laterally. Four pairs of pleural ribs rounded distally, separated by 4 pairs of well-impressed pleural furrows; furrows straight across pleural fields, then appear to curve anteriorly, end in shallow depressions terminating pleural ribs; depressions extend anteriorly to interpleural furrows. Interpleural furrows short, faintly impressed to absent at distal end of pleural ribs. Border furrow absent; border defined by distal ends of pleural furrows and pleural ribs. Border narrow, strongly convex, subvertical to overturned marginally. Articulating facet large, concave. Doublure narrow, concave, smooth.

Prosopon of pustules with intervening granules on glabella, fixigenae, librigenal field of librigenae, pygidial axis, pleural ribs; largest pustules present on posterior margin of occipital ring, anteriorly on axial rings and pleural ribs. Granules restricted to cephalic border, pygidial margin. Pustules with intervening pits on exfoliated surfaces.

Remarks.—The predominant pustulose prosopon, protrusive glabella, inflated pleural regions, well-impressed pleural furrows, and long pygidial axis are all characteristic features of *Petigurus*.

Petigurus cullisoni n. sp. is most similar to *P. groenlandicus* Poulsen (1937, p. 49–51, pl. 6, figs. 1–13) in cranidial morphology, even in the presence of a faint node on the posterior areas. The pygidium of *P. groenlandicus*, however, is diagnosed by interpleural furrows which extend nearly from the lateral margin to the axial furrow. *Petigurus nero* (Billings, 1859; see Fortey, 1979, p. 85, 86, pl. 29, figs. 1–12, 15) features a parallel-sided glabella which is broadly rounded anteriorly, narrow (tr.) palpebral areas, and intersecting pleural and interpleural furrows on the pygidium. The younger *Petigurus inexpectatus* Fortey and Droser (1996, p. 82, figs. 7.1–7.7) features a parallel-sided glabella and a pygidium which lacks interpleural furrows and possesses a pair of nodes on the terminal axial piece.

Comparisons of *Petigurus cullisoni* with *P. cybele* (Billings, 1859) are difficult because of the incomplete descriptions and poor illustrations available (Billings, 1865, p. 353, fig. 341c; Twenhofel, 1938, p. 71, pl. 10, fig. 6 [only]). The glabella of *P. cybele* is tapered rather than parallel-sided. However, E. Billings (1859, quoted *in* Twenhofel, 1938, p. 71) stated that *P. cybele* has 2 faint glabellar furrows and a glabella that is broadly rounded anteriorly. The pygidium and librigenae of *P. cybele* are unknown. *Petigurus* sp. indet. of Fortey (1979, p, 86, pl. 29, figs. 13, 14) also has a glabella that is tapered toward the occipital ring. The glabella, however, is relatively wider at the palpebral lobes and broadly rounded anteriorly, rather than sharply rounded and nasute as in *P. cullisoni*. *Petigurus* sp. of Poulsen (1946, p. 327, 328, pl. 23, figs. 2, 3) differs from *P. cullisoni* in its parallel-sided glabella. A single pygidium illustrated by Hintze (1953, pl. 20, figs. 14a, 14b) from the Fillmore Formation of Utah is assignable to *Petigurus*, although not to *P. cullisoni*. This pygidium lacks the interpleural furrows, laterally

rounded pleurae, and a narrow pygidial border; and, therefore, is not assigned to *P. cullisoni.*

Petigurus cullisoni is also known from the Jefferson City Formation of Missouri (= Theodosia Formation of Cullison, 1944), the Axemann Formation of Pennsylvania (Lees, 1967) and the Boat Harbour and Catoche Formations of Newfoundland, Canada (Boyce, 1989).

Etymology.—Named for J. S. Cullison, first to illustrate the striking pygidium of this species.

Material.—Total 50 cranidia, 30 pygidia, 47 librigenae. Holotype: UMC 16995 (Pl. 12, Figs. 1–3). Paratypes: UMC 16996–17004.

Occurrence.—Interstate-35 section: 24 collections from 691 to 1,185 ft (211–361 m) above the base of the section. Recovered from the *Petigurus cullisoni* Zone at I-691, I-697, I-732, I-738, I-757, I-762, I-841, I-849, I-851, I-854, I-921, I-940, I-948, I-952, I-976, I-994 and from the *Bolbocephalus stitti* Zone at I-1009, I-1012, I-1038, I-1064, I-1098, I-1105, I-1127, and I-1185. Kindblade Ranch measured section: 10 collections from 623 to 907 ft (190–277 m) above base. Recovered from the *P. cullisoni* Zone at KR-623, KR-681, KR-735, KR-770, KR-796, KR-805, KR-809, KR-823, KR-827, KR-849, KR-860 and from the *B. stitti* Zone at KR-907.

PETIGURUS SP. 1

Plate 10, Figures 8–13

Remarks.—Four cranidia and an associated librigena, identified as *Petigurus* sp. 1, are assigned to *Petigurus* on the basis of their anteriorly extended, posteriorly constricted glabella and pustulose prosopon. The anteriorly rounded and broader glabella and narrower palpebral areas serve to differentiate *Petigurus* sp. 1 from *P. cullisoni* n. sp. *Petigurus* sp. 1 with its posteriorly tapered, anteriorly rounded glabella compares broadly with *P. groenlandicus* Poulson (1937, p. 49–51, pl. 6, figs. 1–13), and *Petigurus* sp. indet. of Fortey (1979). *Petigurus groenlandicus* has broad, rather than narrow, axial furrows and flat palpebral lobes. *Petigurus* sp. indet. of Fortey (1979, p. 86, pl. 29, figs. 13, 14) has a glabella which is more convex anteriorly and has relatively broader palpebral areas than *Petigurus* sp. 1. *Petigurus cybele* (Billings, 1865, p. 353, fig. 341c; Twenhofel, 1938, p. 71, pl. 10, fig. 6 [only]) needs restudy before conclusive comparisons may be made.

The librigena of *Petigurus* sp. 1 is similar to that of *Ischyrotoma sila.* The librigena of *I. sila* differs, however, in its dense granular prosopon, better-impressed lateral border furrow, and triangular outline.

Occurrence—Interstate-35 section: 2 collections recovered from the *Benthamaspis rhochmotis* Zone at 546 and 580 ft (166, 177 m) above the base of the section. Kindblade Ranch measured section: 2 collections at recovered from the *B. rhochmotis* Zone at 556 ft (170 m) and the *Petigurus cullisoni* Zone at 677 ft (206 m) above the base.

Genus *RANASASUS* Cullison, 1944

Type species.—*Ranasasus conicus* Cullison, 1944, p. 81, 82, by original designation.

Diagnosis.—Genus of Bathyurinae with glabella that overhangs anterior cranidial margin, slightly convex (tr.), slightly or not constricted posteriorly; axial furrows faintly to weakly impressed, furrows intersect anterior border furrow at anterior corner of palpebral lobes in some species; simple palpebral lobes; short, broadly triangular occipital ring. Librigenae with simple eye socle; broad, bluntly rounded librigenal spine. Pygidium semicircular in outline, strongly convex (sag., tr.); pygidial axis only slightly convex (tr.), terminal axial piece nearly level with post-axial pleural field and border. Smooth prosopon.

Remarks.—Testate specimens of *Ranasasus* are strikingly effaced (Pl. 13, Figs. 3, 4, 6) as seen here for the first time. Exfoliated specimens (Cullison, 1944, pl. 34, figs. 36–44), however, exhibit moderately to faintly impressed furrows. These internal details allowed Whittington (1959, p. O379) to assign *Ranasasus* to the Family Bathyuridae based upon similarities to *Bolbocephalus.* The overall convexity of *Ranasasus* and nearly equant dimensions of its pygidium suggest assignment of the genus to the Subfamily Bathyurinae along with *Bolbocephalus.*

RANASASUS BREVICEPHALUS Cullison, 1944

Plate 13, Figures 1–8

Ranasasus brevicephalus Cullison, 1944, p. 82, pl. 34, figs. 36–40.

Ranasasus aff. *R. brevicephalus* Cullison. Cloud and Barnes, 1948, pl. 42, figs. 16–18.

Diagnosis.—Small *Ranasasus* with parabolic cranidial outline; protrusive, anteriorly rounded glabella; axial furrows weakly impressed, sinuous; preglabellar field present axially; curved occipital furrow. Librigena lacks border furrow. Pygidium with pentagonal terminal axial piece; short interpleural furrows; border furrow absent. Smooth prosopon.

Supplemental description.—Cranidium up to 1.0 cm long, strongly convex (sag.), parabolic in outline with large glabella. Glabella nearly quadrate with parabolic anterior margin, mildly constricted at posterior end of palpebral lobes; slightly convex, faintly keeled (tr.); in sagittal profile glabella slightly convex posterior to palpebral lobes, anterior lobe of glabella inflated to overhang anterior border and preglabellar field, glabella joins smoothly with preglabellar field. Glabellar length greater than 0.9 times cranidial length (sag.); palpebral glabellar width (tr.) 0.9 times glabellar length (sag.), basal glabellar width (tr.) 0.8 times glabellar length. Lateral glabellar furrows absent. Axial furrows faintly impressed, weakly impressed on exfoliated specimens; slightly sinuous posteriorly, anteriorly furrows curve abaxially, turn ventrally to intersect facial sutures. Preglabellar furrow faintly impressed, broadly curved. Occipital ring less than 0.1 times cranidial length (sag.), triangular with straight posterior margin, longest axially, tapered to a point laterally adjacent to axial furrow. Occipital furrow broadly convex anteriorly, faintly impressed. On exfoliated specimens, occipital region with broad, moderately impressed occipital furrow, occipital ring narrower than furrow, faint occipital node set anteriorly on ring. Anterior border overturned, thickened to stand away from preglabellar field; anterior border furrow moderately impressed. Preglabellar field overturned, nearly flat, extended entire width of cranidium. Preocular field narrow, slightly convex, steeply declined. Palpebral lobes short, 0.33 times glabellar length (sag.), simple flap with narrow rim, semielliptical in outline; set posteriorly with anterior end of lobe just anterior to glabellar mid-length. Palpebral areas narrow, slightly declined (exsag., tr.), slightly convex (tr.). Posterior fields short (exsag.), broad (tr.), slightly declined with broad, weakly impressed posterior border furrow. Anterior branch of facial sutures directed ventrally, curved slightly adaxially to anterior margin. Posterior branch of facial sutures moderately divergent.

Librigenae trapezoidal in outline with broad, bluntly rounded librigenal spine, strongly convex (tr.), steeply declined. Librigenal field large, strongly convex (tr.) to overhang lateral margin. Lateral border furrow moderately impressed, posterior border furrow absent. Lateral border narrow, steeply declined (tr.). Eye socle present.

Pygidium small, up to 0.9 cm long (sag.), strongly convex (sag., tr.), semicircular in outline with maximum pygidial width (tr.) 1.5–1.7 times pygidial length (sag.).

On testate specimens, pygidium largely effaced, axial furrows weakly impressed anteriorly to faint or obsolete post-axially; ring, pleural, interpleural furrows absent. On exfoliated specimens axis long, broad, slightly tapered, bluntly pointed posteriorly, axis slightly convex (sag.); composed of articulating half-ring, 4 rectangular axial rings, pentagonal terminal axial piece. Axial furrows moderately impressed about entire axis; nearly straight anteriorly, bent adaxially at terminal axial piece. Ring furrows weakly to faintly impressed. On small specimens (0.5 cm) anterior-most axial ring moderately convex (tr.), decreased posteriorly until terminal axial piece slightly convex; terminal axial piece weakly inflated to stand slightly above adjacent border. For larger pygidia axial convexity reduced, ring furrow, interpleural furrows less well defined. Anterior axial width 0.5 times anterior pygidial width (tr.); axial length 0.9 times pygidial length (sag.). Two small, triangular pleural fields extend to posterior corners of terminal axial piece; 3 moderately to faintly impressed pleural furrows, 3 faint interpleural furrows on small specimens. Border furrow absent; border defined by distal ends of pleural furrows. Border slightly convex (sag., tr.) but steeply declined to overturned marginally; narrowest anteriorly adjacent to articulating facet. Articulating facet narrow (tr.), steeply declined, posterior corner opposite second axial ring. Doublure smooth, steeply inclined, concave marginally; upturned along straight crease from articulating facet toward post-axial margin, crease shallowed posteriorly; adaxially concave with terrace lines, steeply inclined to vertical.

Prosopon smooth; exfoliated surfaces with fine pits.

Remarks.—Preservation and ontogenetic variations among specimens assigned to this species is marked. Testate cranidia and pygidia are largely effaced with, at best, weakly impressed axial furrows. Upon exfoliation the pygidia exhibit additional ring, pleural, and interpleural furrows. In addition, among exfoliated pygidia, a progressive loss of definition to the furrows and a reduction in the convexity of the axis occurs. The stable outline of the glabella, the pygidium, and the pygidial axis, however, serve to unite this disparate assortment of specimens. The quadrate glabella, semicircular pygidial outline, slightly convex pygidial axis, and faintly impressed ring furrows on the exfoliated pygidia from the Kindblade Formation are consistent with features illustrated for *Ranasasus brevicephalus*.

Ranasasus brevicephalus is known from the lower Jefferson City Formation of Missouri (the Rich Fountain Formation of Cullison, 1944) and the Honeycut Formation of Texas (Cloud and Barnes, 1948; Toomey, 1964, p. 102).

Material.—Total 10 cranidia, 8 pygidia, and 1 fragmentary librigena.

Occurrence.—Interstate-35 section: 2 collections recovered from the *Ranasasus brevicephalus* Zone at 40 and 44 ft (12, 13 m) above the base of the section. Kindblade Ranch measured section: 11 collections from 75 to 151 ft (23–46 m) above the base. Recovered from the *R. brevicephalus* Zone at KR-75, KR-75A, KR-76, KR-94, KR-96, KR-103, KR-117, KR-119, KR-120, KR-132, KR-151.

RANASASUS CONICUS Cullison, 1944

Plate 13, Figures 10, 11

Ranasasus conicus Cullison, 1944, p. 82, pl. 34, figs. 36–40; Cloud and Barnes, 1948, pl. 42, figs. 10–15.

Supplemental description (abridged).—One medium cranidium, 0.9 cm long (sag.) excluding missing occipital ring, subtriangular in outline, strongly convex (sag.). Glabella large, protrusive, extended anteriorly to overhang and obscure frontal area in dorsal view, conical in outline anteriorly, slightly constricted posteriorly. Maximum glabellar width (tr.) at anterior corner of palpebral lobes 0.9 times glabellar length, basal glabellar width 0.8 times glabellar length. Axial furrows weakly impressed on exfoliated surfaces, weakly sinuous, approach but fail to intersect anterior facial suture at anterior corner of palpebral lobes. Preglabellar furrow moderately impressed as change in slope of frontal area, continuous with axial furrows. Occipital furrow with slight anteriorly convex curve. Anterior border short, cord-like. Anterior border furrow weakly impressed. Preglabellar field short (sag.), slightly convex, overturned axially. Preocular field very narrow (tr.), slightly convex, overturned distally. Anterior branch of facial sutures directed ventrally, curved adaxially in anterior view, intersect anterior margin at obtuse angle.

Pygidium, librigenae not recovered.

Remarks.—Illustrated specimens of *Ranasasus conicus* exhibit an anteriorly inflated glabella that is conical in outline and is separated from the frontal area by a distinct preglabellar furrow. The specimen from the Kindblade Formation shares these features.

Ranasasus conicus occurs in the lower Jefferson City Formation of Missouri (= Rich Fountain Formation of Cullison, 1944) and in the Honeycut Formation of Texas (Cloud and Barnes, 1948; Toomey, 1964, p. 102).

Material.—Total 1 weathered cranidium.

Occurrence.—Interstate-35 section: 1 collection from the *Ranasasus brevicephalus* Zone at 119 ft (36 m) above the base of the section.

RANASASUS COLOSSUS n. sp.

Plate 14, Figures 1–7

Diagnosis.—Large *Ranasasus* with parabolic cranidial outline; protrusive, anteriorly rounded glabella; axial furrows faintly impressed, straight; preglabellar, anterior border furrows confluent, preglabellar field absent axially; recurved occipital furrow. Librigena with faintly to weakly impressed border furrows, lateral border broad. Pygidium with hexagonal terminal axial piece, faint interpleural furrows from axial furrows to margin. Terrace lines adjacent to anterior cephalic margin.

Abridged description.—Cranidium very large, fragments estimated at up to 3.5 cm long (sag.). Glabella nearly quadrate with broadly rounded anterior margin; in sagittal profile slightly convex posteriorly, protrusive anteriorly to overhang anterior border. Palpebral glabellar width (tr.) equal to glabellar length (sag.). Lateral glabellar furrows absent; 1 pair broad, faint depressions on line between posterior ends of palpebral lobes. Axial furrows straight. Occipital ring short, less than 0.1 times cranidial length, nearly triangular, tapered laterally. Occipital furrow weakly impressed, convex anteriorly, recurved axially, broadest in line with glabellar depressions, narrower axially, laterally. Anterior border overturned, as thickened, broad rim, tapered laterally. Preglabellar furrow weakly impressed, confluent with moderately impressed anterior border furrow. Preglabellar field absent axially, steeply declined, slightly convex laterally. Palpebral lobes centered posterior to glabellar midlength. Posterior fields narrow (tr.), slightly declined with faint posterior border furrow.

Librigena large, up to 3.0 cm long (exsag.), subtriangular in outline. Simple eye socle with fine, radiating ridges on narrow ocular platform. Librigenal field slightly convex (tr.), moderately declined. Lateral border furrow faintly to weakly impressed, curved to join faintly impressed posterior border furrow smoothly. Lateral border strongly convex (tr.), overturned at margin.

Librigenal spine short, paddle-like, bluntly rounded.

Pygidium large, up to 2.0 cm long (sag.), moderately convex (sag., tr.),with a maximum pygidial width 1.25 times pygidial length (sag.). Axis broad, long, tapered, bluntly rounded posteriorly; with hexagonal terminal axial piece. Axis moderately convex anteriorly, slightly convex at terminal axial piece (tr.); axis not elevated posteriorly, passes smoothly to pleural region in sagittal profile. Anterior axial width 0.4 times maximum pygidial width (tr.); axial length 0.6 times pygidial length (sag.). Ring furrows straight, anterior-most weakly impressed, remainder faintly impressed. Axial furrows converge posteriorly until posterior ring furrow, subparallel along terminal axial piece; moderately impressed anteriorly, shallow until faint or absent post-axially. Pleural regions large; moderately convex (sag., tr.), descend directly from axial furrow. Anterior pair of pleural furrows well impressed, 0.5 times width of pleural region; remainder faintly impressed, shorter. Up to 3 pairs of interpleural furrows faintly impressed, continuous from axial furrows to margin. Border nearly flat, moderately declined. Articulating facet large, 0.66 times maximum width of pleural region, flat, steeply inclined; posterior corner opposite second axial ring, marks position of maximum pygidial width.

Prosopon generally smooth; terrace ridges anteriorly on cephalon, decrease in scale posteriorly and dorsally. Exfoliated surfaces smooth with fine, broadly spaced pits.

Remarks.— *Ranasasus colossus* n. sp. is assigned to *Ranasasus* based upon its parabolic cranidial outline, slightly convex (tr.), protrusive glabella, weakly impressed axial furrows, bluntly rounded librigenal spine, and depressed pygidial axis. *Ranasasus colossus* is remarkable in the large size it attains. Smaller specimens of *R. colossus* are closest in cranidial outline to *Ranasasus brevicephalus* Cullison, lacking the conical outline of the type species, *R. conicus* Cullison. The cranidium of *R. brevicephalus* possesses a preglabellar field axially and an occipital furrow which is straight, rather than recurved as on *R. colossus*. Through the ontogeny of *R. brevicephalus*, the definition of the short interpleural furrows on the pygidium decreases. The interpleural furrows on the largest *R. colossus* pygidia are continuous from margin to the axial furrows.

Etymology.—Derived from *colossus*, Latin m., for large statue; referring to the large proportions of the paratype specimens.

Material.—Total 2 cranidia, 3 fragmentary pygidia, 3 libriginae. Holotype: UMC 17015 (Pl. 14, Fig. 1). Paratypes: UMC 17016–17019.

Occurrence.—Kindblade Ranch measured section: 1 collection from the *Benthamaspis rhochmotis* Zone at 437 ft (133 m) above the base of the section.

RANASASUS SP. 1

Plate 13, Figure 9; Plate 14, Figure 8

Remarks.—Two fragmentary pygidia, designated *Ranasasus* sp. 1, are assigned to *Ranasasus* based upon their semicircular outline, strong pygidial convexity, slightly convex pygidial axis, and terminal axial piece which is nearly level with the border. These specimens share a slight dorsal arch to the posterior margin. The short pygidial axis of *Ranasasus* sp. 1 serves to distinguish these large pygidia from the pygidium of *Ranasasus colossus* as well as the smaller pygidia of *R. brevicephalus* and *R. conicus*.

Occurrence.—Interstate-35 section: 2 collections. Recovered from the *Bolbocephalus stitti* Zone at 1,127 ft (344 m) and from the *Strigigenalis caudata* Zone at 1,210 ft (369 m) above the base of the section.

Genus *STRIGIGENALIS* Whittington and Ross, *in* Whittington, 1953

Type species.—*Strigigenalis cassinensis* Whittington 1953, p. 671, by original designation.

Emended diagnosis.—Genus of Bathyurinae with large, moderately convex (tr.), sharply to evenly rounded glabella; anterior border short, of constant length, evenly curved laterally, oriented horizontal to commonly strongly inclined so as to appear as ridge; anterior border furrow deep, well impressed; preglabellar field short in dorsal view, moderately to steeply declined, moderately convex (sag.). Librigena with inclined lateral border anteriorly, short to long librigenal spine. Pygidium with strongly convex axis of 3–4 axial rings; pleural field moderately to strongly convex (tr.), well defined laterally by distal ends of 3–4 pairs of strongly inflated pleural ribs; ribs separated by well-impressed pleural furrows; posterior margin variable, evenly rounded to interrupted by broad-based post-axial spine. Prosopon typically smooth or pitted to granular, with scarce terrace lines marginally.

Remarks.—Whittington's (1953, p. 670–671) generic concept of *Strigigenalis* fortunately omitted

mention of pygidial characters. The pygidium he associated with the holotype cranidium of the type species is more properly assigned to *Bolbocephalus* (see Fortey, 1979, p. 86–88). Resolution of this mistaken association allowed Fortey to appropriately assign *Strigigenalis* to the Family Bathyuridae, Subfamily Bathyurinae.

Boyce's (1989, p. 54) emended generic diagnosis of *Strigigenalis* constrained the genus to only those species with a post-axial pygidial spine. Within *Strigigenalis crassimarginata* (Pl. 16, Figs. 5–12) the character of the post-axial spine appears to have been variable, suggesting that the presence of the spine is not an appropriate character for generic discrimination. Species with a posteriorly rounded pygidial margin, therefore, fall within the generic concept diagnosed above, including *"Jeffersonia" crassimarginata* (Cullison, 1944) and *"Peltabellia" knighti* (Boyce, 1989).

Strigigenalis compares closely with the type species of the genus *Peltabellia* Whittington (1953), in many respects (see Fortey and Peel, 1990, for a diagnosis of *Peltabellia*). Cranidia of both genera include a subquadrate glabella, narrow anterior borders, steeply declined preocular field and preglabellar fields, and relatively large palpebral lobes. Well-defined, moderately tapered pygidial axes, broad pygidial borders, and 3–4 pairs of pleural ribs are present in species of each genus. The anterior cranidial border of *Strigigenalis*, however, is more distinctly inclined, the pleural ribs more strongly inflated, and the overall sagittal convexity is greater than seen in *Peltabellia*.

Fortey and Droser (1996, p. 82–87) describe several species of *Psephosthenaspis* Whittington (1953), from the Lower–Middle Ordovician boundary interval in western Utah and reillustrated the lectotype of the type species. Their association of body parts completed the understanding of an old but little known genus. The narrow anterior border of consistent thickness, well-defined pleural ribs, and granulose prosopon found in *Psephosthenaspis* are seen in *Strigigenalis*. *Psephosthenaspis*, however, has a glabella which is typically anteriorly expanded, lacks a preglabellar field, and has a less well-impressed anterior border furrow.

STRIGIGENALIS CAUDATA (Billings, 1865)

Plate 15, Figures 1–8

Bathyurus caudatus Billings, 1865, p. 261–262, fig. 245.

Strigigenalis caudata (Billings, 1865). Fortey, 1979, p. 88–90, fig. 12D, pl. 30, figs. 1–10; Stouge and Boyce, 1983, pl. 16, fig. 7; Boyce, 1989, p. 55, pl. 31, figs. 1–8; Desbiens and others, 1996, pl. 3, figs. 14, 16–21.

[Not] Gen. et sp. indet., Whittington, 1953, pl. 68, figs. 30, 32.

Remarks.—Fortey (1979, p. 88–90) diagnosed and redescribed *Strigigenalis caudata* based upon material from the Catoche Formation of Newfoundland, Canada. The pygidia assigned from the Kindblade Formation to *S. caudata* exhibit the broad-based, post-axial spine, prominent pleural ribs, and smooth border observed by Fortey (1979). One external librigenal mold conforms closely to Fortey's (1979) description including the presence of punctae on the posterior border. Cranidia associated with *S. caudata* pygidia in Oklahoma differ in exhibiting a finely granulose prosopon and a posteriorly constricted glabella (Pl. 15, Figs. 2, 3). Close examination of the pygidia from Oklahoma reveals fine granules on the pleural ribs and axial rings. These differences are not considered sufficient to exclude the Oklahoma specimens from *S. caudata*.

Goniotelus semicircularis Cullison (1944, p. 84, pl. 35, figs. 25–26) was included previously in synonymies of *Strigigenalis caudata* based upon the post-axial of the pygidial border. The preservation quality of the type specimen (reillustrated by Boyce, 1989, pl. 31, figs. 5–8) is low, even compared with other moldic material from Missouri. Consequently, *G. semicircularis* Cullison (1944) is restricted to type.

Material.—Total 7 cranidia, 12 pygidia, 3 librigenae.

Occurrence.—One collection at the base of the *Strigigenalis caudata* Zone at 1,227 ft (374 m) above the base of the I-35 section.

STRIGIGENALIS CRASSIMARGINATA (Cullison, 1944)

Plate 16, Figures 1–12, Plate 17, Figures 1–3

Jeffersonia crassimarginata Cullison, 1944, p. 75, 76, pl. 35, figs. 13–16.

Peltabellia crassimarginata (Cullison). Boyce, 1989, p. 52.

Diagnosis.—Species of *Strigigenalis* with strongly convex cranidium (sag.), anteriorly sharply rounded glabella, steeply declined to vertical preglabellar field and preocular field, inflated (exsag.) posterior areas. Librigenae with curved posterior border furrow, short librigenal spine. Pygidium with 2–3 pairs of strongly inflated pleural ribs; post-axial border highly variable, concave with posterior margin smoothly curved or

bearing short spine. Prosopon of short ridges to granules.

Supplemental description.—Cranidium up to 1.1 cm in length (sag.), strongly convex (sag.), subtrapezoidal outline with palpebral lobes frequently lost. Glabella large, nearly rectangular in outline, sharply rounded anteriorly, strongly convex (tr.). Glabellar length 0.8 times cranidial length (sag.); glabellar width (tr.) greatest at palpebral lobes, 0.8 times glabellar length (sag.). Lateral glabellar furrows absent. Axial furrows deep, well impressed, slightly sinuous; join moderately impressed preglabellar furrow at oblique angle. Occipital ring long, 0.2 times cranidial length, rectangular in outline, extended posteriorly; slightly convex (tr.) axially with distinct shoulder or decline to axial furrows. Occipital furrow well impressed, broadest axially, nearly straight, drawn anteriorly at axial furrows. Anterior border short, cord-like, oriented vertically to stand high in relief above anterior border furrow; typically lost in preparation. Anterior border furrow deep, well impressed, evenly curved laterally. Preglabellar field short or absent in dorsal view, moderately convex in anterior view, vertical to overturned in orientation. Preocular field moderate in width (tr.), moderately convex, steeply declined to overturned. Palpebral lobes large, nearly 0.5 times glabellar length (exsag.), typically lost in preparation; semielliptical outline with low marginal rim defined by weakly impressed palpebral furrow; centered posterior to glabellar mid-length. Palpebral areas narrow, moderately convex, steeply inclined (tr.). Posterior areas inflated, strongly convex, strongly (exsag.) to slightly (tr.) declined. Posterior border furrow well impressed. Anterior branch of facial sutures straight, slightly divergent. Posterior branch of facial sutures straight, strongly divergent.

Librigena up to 1.0 cm in length (exsag.) with short, broad-based librigenal spine, moderately convex. Librigenal field broad, of constant width; moderately convex (tr.), overturned anteriorly, moderately declined near mid-length; narrow ocular platform present. Inclined anterior cranidial border continued onto librigena, decreased in relief posteriorly to lie flush with surface of posterior border at librigenal spine. Lateral border furrow narrow, well impressed anteriorly, moderately impressed in broad curve posterior to palpebral lobes, intersect posterior border furrow at oblique angle.

Pygidium up to 0.9 cm in length (sag.), moderately to strongly convex, variable in outline with posterior margin ranging from even curve to post-axial flange to short spine. Pygidial width 1.25–1.4 times pygidial length. Axis long, slightly tapered, evenly rounded posteriorly, well elevated, strongly convex (tr.), steep sided on many specimens; composed of short articulating half-ring, 4 axial rings, long terminal axial piece. Anterior axial width 0.33–0.4 times maximum pygidial width (tr.); axial length 0.5–0.8 times pygidial length (sag.). Ring furrows straight, moderately impressed anteriorly, successively weaker, shallowest axially with incomplete forth furrow present as pair of lateral notches anterior to terminal axial piece. Axial furrows straight, well impressed, interrupted by weak post-axial ridge on some specimens. Border furrow absent; border defined by distal termination of pleural ribs. Pleural fields small, triangular with 2–3 pairs of strongly inflated pleural ribs, moderately to strongly convex (tr.). Pleural furrows short, slightly curved; anterior-most deep, notch-like with remainder moderately impressed. Anterior pair of interpleural furrows faintly impressed on few specimens. Border moderately convex anteriorly, variable post-axially from moderately declined and slightly convex to concave (tr.). Posterior margin varies from even curve to short post-axial spine. Posterior band of anterior pleural rib extended to lateral margin with coarse ridges along crest. Articulating facet narrow (tr.), long (sag.), concave.

Prosopon of short ridges and uncommon granules unevenly distributed on testate specimens, concentrated anteriorly and laterally on glabella and at posterior corner of preocular field; present on occipital ring, palpebral and posterior areas, librigenal field, librigenal border, pygidial axis, pleural ribs. Cephalic border with coarse ridges. Pygidial border, preocular field, preglabellar field smooth with fine pits. Exfoliated surfaces pitted.

Remarks.—The strongly inflated pleural ribs, strongly convex axis (tr.), concave post-axial border, and even posterior margin on the pygidium and overturned, strongly convex (exsag.) preocular field on specimens from Oklahoma indicate that they are conspecific with material described by Cullison (1944, p. 75, 76. pl. 35, figs. 13–16) as "*Jeffersonia*" *crassimarginata* from southern Missouri. Originally placed within *Jeffersonia* by Cullison, this species lacks the horizontal cranidial and pygidial borders typical of that genus as revised. The strong pleural ribs, convex pygidial border, sharply rounded glabella, and narrow, steeply inclined anterior bor-

der of the species conform to the diagnosis of *Strigigenalis* given above and it is reassigned.

Strigigenalis crassimarginata, as conceived here, constitutes a highly variable species. Variation is concentrated in the pygidium, especially in the outline of the posterior margin and the convexity of the post-axial border (Pl. 16, Figs. 5–12). These variants are not stratigraphically segregated. The cranidial morphology is relatively consistent in the presence of an overturned preglabellar field and preocular field, a narrow anterior border, the large palpebral lobes, and the nature of its prosopon.

Strigigenalis crassimarginata was described by Cullison (1944, p. 75, 76. pl. 35, figs. 13–16) from the Cotter Formation of Missouri. Boyce (1989, p. 52) reported, but did not illustrate, *S. crassimarginata* from the Barbace Cove Member of the Boat Harbour Formation of Newfoundland (Boyce, 1989). Examination of latex molds of the Newfoundland material provided by Boyce confirms his identification.

Material.—Total 15 cranidia, 30 pygidia, 13 librigenae.

Occurrence.—Interstate-35 section: 10 collections from 893 to 1,241 ft (272–378 m) above the base of the section. Recovered from the *Petigurus cullisoni* Zone at I-893, I-940, from the *Bolbocephalus stitti* Zone at I-1064, I-1113, I-1143, I-1159, I-1178, and the *Strigigenalis caudata* Zone at I-1185, I-1227, I-1241, and I-1272(?). Kindblade Ranch section: 5 collections from 805–1,010 ft (245–308 m) above the base. Recovered from the *Petigurus cullisoni* Zone at KR-805, KR-809, KR-827, KR-860, and from the *Strigigenalis caudata* Zone at KR-1010.

STRIGIGENALIS cf. *S. KNIGHTI* (Boyce, 1989)
Plate 18, Figure 13

Peltabellia sp. nov., identified by W. D. Boyce, *in* Stouge and Boyce, 1983, p. 16, figs. 3–5.
Peltabellia knighti Boyce, 1989, p. 51, 52, pl. 28, figs. 4–10; pl. 29, figs. 1, 2.

Remarks.—The diagnosis and description provided by Boyce (1989) for "*Peltabellia*" *knighti* are sufficient for this species. The strong pleural ribs and steeply inclined anterior border illustrated by Boyce (1989) for this species differ markedly from the type species, *Peltabellia peltabella* (Ross, 1951, p. 76–77, pl. 17, figs. 7, 8, 12, 13, 16–22). These characteristics are, however, typical of *Strigigenalis* and the species is reassigned. One librigena from the Kindblade Formation is comparable with *Strigigenalis knighti* with each exhibiting a flattened, moderately declined, adaxially curved librigenal spine and an angular intersection of the lateral and posterior borders. Lack of material, however, precludes confident assignment of this specimen.

Occurrence.—Recovered from the *Strigigenalis caudata* Zone at 1,272 ft. (388 m) above the base of the I-35 section.

STRIGIGENALIS DERBYI n. sp.
Plate 17, Figures 4–13

Diagnosis.—Species of *Strigigenalis* with moderately convex cranidium (sag.), sharply rounded glabella, moderately declined preglabellar field and preocular field, moderately declined posterior areas. Librigena with straight lateral margin anteriorly, angular posterior border furrow, long librigenal spine. Pygidium with 3–4 pairs of moderately inflated pleural ribs, faintly impressed interpleural furrows on large specimens, evenly rounded posterior margin, lacking post-axial spine. Prosopon of fine granules with uncommon short ridges.

Abridged description.—Cranidia large, fragments up to 2.0 cm in length (sag.), moderately convex (sag.), trapezoidal in outline. Glabella elongate, evenly rounded anteriorly, moderately convex (sag., tr.). Glabellar length (sag.) 0.6–0.7 times cranidial length; palpebral glabellar width (tr.) 0.7–0.8 times glabellar length (sag.). Axial furrows curved. Occipital ring greater than 0.1 times cranidial length (sag.), trapezoidal in outline, widest at posterior margin, medial occipital node present. Occipital furrow straight, slightly shallower axially. Anterior border of constant length laterally, flat, moderately inclined, ventral surface with thin longitudinal threads, anterior arch present (tr.). Anterior border furrow moderately impressed, slightly angular laterally. Preglabellar field short, less than 0.1 times cranidial length (sag.), moderately declined. Preocular field broad (tr.), moderately declined posteriorly, oriented subvertically at anterolateral corners. Palpebral lobes large semicircular in outline with faint palpebral rim, broad palpebral furrow. Palpebral areas broad, moderately inclined (tr.). Posterior areas short (exsag.), broad, slightly convex, slightly declined (tr.). Anterior branch of facial suture strongly divergent, straight anterior to palpebral lobes, strongly curved at anterior border furrow to intersect anterior margin at oblique angle.

Librigenae up to 1.5 cm in length, with short, broad-based librigenal spine. Librigenal field large, broadest at genal angle, moderately de-

clined. Lateral margin straight anteriorly, curved adaxially posterior to eye. Lateral border narrow, oriented horizontally, tapered posteriorly for length of librigenal spine in dorsal view, in lateral view distal portion of upturned doublure bears thin ridges. Lateral border furrow deep, well impressed anteriorly, significantly shallower behind intersection of lateral and posterior border furrows, faintly impressed on librigenal spine. Posterior border furrow moderately impressed, straight, perpendicular to axis adaxially, angled anteriorly to intersect lateral border furrow near mid-length of eye. Eye socle bearing multiple thin threads.

Pygidium moderate in size, up to 1.0 cm in length (sag.), moderately convex, evenly rounded posteriorly, semi-elliptical in outline with pygidial width (tr.) 1.2–1.5 times pygidial length (sag.). Axis moderately convex (tr.), moderately tapered, bluntly rounded posteriorly; with long articulating half-ring, hexagonal terminal axial piece. Axial length 0.7–0.75 times pygidial length (sag.). Ring furrows straight, well impressed anteriorly, posterior furrow incomplete, furrows shallowest axially. Axial furrows slightly curved, well impressed anteriorly, faint to absent posteriorly at faint post-axial ridge. Pleural fields small, moderately convex, triangular with 3–4 pairs of moderately inflated pleural ribs. Anterior pair of pleural furrows moderately impressed, fourth pair faintly impressed or absent. Interpleural furrows faintly impressed on large specimens, restricted to pleural fields, most evident distally, absent on smaller individuals. Border moderately declined, slightly convex to recurved proximally, slightly concave at margin, longest post-axially. Articulating facet moderate in length (exsag.), slightly convex.

Prosopon of granules most common, weakest axially; granules with short ridges on librigenal spine, posterior border of librigena; pygidial border with pits, fine granules, uncommon ridges. Exfoliated surfaces pitted.

Remarks.—The short, inclined, evenly curved anterior cranidial border and inflated pleural ribs on the pygidium of this species are consistent with the diagnosis of *Strigigenalis*. The absence of a post-axial pygidial spine separates *Strigigenalis derbyi* n. sp. from *S. caudata* (Pl. 15, Figs. 5–7; Fortey, 1979, p. 88–90, pl. 30, figs. 1–10; Boyce, 1989, p. 55, pl. 31, figs. 1–8), *S. crassimarginata* (Pl. 16, Figs. 5–12; Cullison, 1944, p. 75, 76, pl. 35, figs. 13–16; Boyce, 1989, p. 55, pl. 31, figs. 1–8), and *S. brevicaudata* (Boyce, 1989, p. 54, 55, pl. 29, figs. 8–10, pl. 30, figs. 1–10). The pygidial border of *S. derbyi* is relatively broader than that of *S. knighti* (Boyce, 1989, pl. 28, figs. 4–10, pl. 29, figs. 1, 2) with 3–4 pleural ribs, rather than 2–3 pairs. The cranidium of *S. knighti* is more strongly convex (sag.), with relatively smaller palpebral lobes, moderately impressed palpebral furrows, and longer (exsag.) posterior areas than those of *S. derbyi.*

Etymology.—Named in honor of J. R. Derby of Tulsa, Oklahoma, in recognition of his biostratigraphic investigations of the Arbuckle Group.

Material.—Total 11 cranidia, 22 pygidia, 15 librigenae. Holotype: UMC 17048 (Pl. 17, Figs. 4, 5). Paratypes: UMC 17049–17056.

Occurrence.—Interstate-35 section: 8 collections from 476 to 556 ft (145–164 m) above the base of the section. Recovered from the *Benthamaspis rhochmotis* Zone at I-476, I-499, I-503, I521, I-525, I-526, I-527, I-556. Kindblade Ranch section: 3 collections from 451 to 538 ft (138–164 m) above the base. Recovered from the *Benthamaspis rhochmotis* Zone at KR-451, KR-458, and KR-538.

STRIGIGENALIS IMPLEXA n. sp.

Plate 18, Figures 1, 2

Peltabellia cf. *P. peltabella* (Ross). Boyce, 1989, p. 52, 53, pl. 29, figs. 2–4.

Diagnosis.—*Strigigenalis* with short, upturned anterior border, low preglabellar field in anterior view, well-impressed axial and occipital furrows, glabella slightly convex axially with pronounced shoulder laterally to descend steeply to axial furrow. Librigena with librigenal spine of moderate length, moderately impressed posterior border furrow. Pygidium elongate to slightly transverse, axial and ring furrows moderately to well impressed, pleural ribs moderately inflated, post-axial border slightly concave.

Abridged description.—Cranidium up to 1.2 cm in length (sag.), subquadrate in outline, moderately convex (sag.). Glabella broadest at palpebral lobes, broadly rounded anteriorly, moderately convex (sag.), slightly convex at axis (tr.) with pronounced shoulder laterally to descend steeply to axial furrow. Glabellar length 0.7–0.75 times cranidial length (sag.); palpebral glabellar width (tr.) 0.75–0.8 times glabellar length (sag.). Axial furrows broad, faint fossula at intersection with preglabellar furrow. Preglabellar furrow evenly curved, weakly impressed axially. Occipital ring slightly convex axially (tr.) but steeply declined laterally at axial furrows. Occipital furrow shallowed at axial furrows. Anterior border

as thickened marginal rim, oriented near vertically, well elevated above deep anterior border furrow; moderately arched dorsally (tr.). Preglabellar field short in dorsal view (sag.), moderately declined axially, near vertical laterally; 0.25 times cranidial height in anterior view. Preocular field narrow (tr.), nearly vertical anteriorly. Palpebral lobes semicircular in outline with broad, faintly impressed palpebral furrow; centered posteriorly, at 0.66 times glabellar length. Palpebral areas broad, slightly convex, moderately inclined, rise nearly to height of glabella. Posterior areas triangular, short (exsag.), broad, slightly convex, slightly declined (tr.). Anterior branch of facial sutures slightly divergent, nearly straight, slightly curved anteriorly, intersect anterior margin at near right angle. Posterior branch of facial sutures slightly curved.

Librigena up to 1.2 cm long, roughly triangular in outline. Librigenal field large, slightly tapered posteriorly, steeply to moderately declined laterally. Narrow border extended from cranidium posteriorly onto librigenal spine; stands high above border furrow anterior to intersection with lateral border furrow, border reduced until flush with surface of librigenal spine posteriorly. Lateral border furrow shallowed opposite palpebral mid-length lateral border furrow at intersection with posterior border furrow. Posterior border furrow broad, moderately impressed; short, straight transverse segment adaxially, curves anteriorly to intersect lateral border furrow.

Pygidium up to 1.3 cm long (sag.), moderately convex (tr.), semicircular in outline with maximum pygidial width (tr.) 1.3–1.6 times pygidial length (sag.). Axis moderately tapered, broadly rounded posteriorly with faint post-axial ridge; flattened axially with distinct lateral shoulder, moderately declined laterally; with 3 axial rings, long terminal axial piece. Anterior axial width 0.3 times maximum pygidial width (tr.); axial length 0.66–0.7 times pygidial length (sag.). Ring furrows best impressed at lateral shoulder, weakly impressed at axial furrows. Axial furrows with slight depression opposite terminal axial piece, weakly impressed at post-axial ridge. Pleural fields moderately convex, with 3–4 pairs of moderately inflated pleural ribs. Short, faintly impressed interpleural furrow seen on anterior pleural rib of one larger specimen. Border broad, broadest post-axially, slightly convex adaxially, slightly concave along posterior margin. Posterior band of anterior pleural rib extended as broad ridge to lateral margin. Articulating facet long distally, broad, concave, moderately declined. Doublure moderate in width, moderately convex, divided by subcentral furrow; moderately inclined distally, steeply declined below ends of pleural furrows.

Testate prosopon varying scales of granules with or without fine ridges on cranidium and librigenal field, granules on axis and pleural fields of pygidium; density of granules decreases as specimens size increases, fine ridges replace granules on larger specimens. Coarse intersecting ridges on librigenal spines, along anterior band of anterior pleural rib. Parallel coarse threads on marginal cephalic rim. Exfoliated surfaces pitted.

Remarks.—*Strigigenalis implexa* n. sp. is assigned to the genus *Strigigenalis* based upon its short, evenly curved cranidial border and pronounced pleural ribs.

Pygidia considered by Boyce (1989, p. 53, 54, pl. 29, figs. 2–4) as *Peltabellia* cf. *P. peltabella* (Ross) are included within *Strigigenalis implexa.* The finely pitted exfoliated surfaces, 3 pairs of pleural ribs, poorly defined posterior axial ring, and broad, moderately declined, slightly concave border shared by the Oklahoma and Newfoundland specimens indicate that they are certainly conspecific.

The concave pygidial border seen in *Strigigenalis implexa* is unique within the genus.

Strigigenalis implexa has been recovered from the Barbace Cove Member of the Boat Harbour Formation of Newfoundland, Canada (Boyce, 1989).

Etymology.—*Implexa,* Latin, uncombed, dishevelled; referring to the irregular prosopon of granules and ridges.

Material.—Total 9 cranidia, 22 pygidia, 30 librigenae. Holotype: UMC 16882 (Pl. 18, Figs. 1, 2). Paratypes: UMC 16883–16890.

Occurrence.—Interstate-35 section: 8 collections from 650 to 711 ft (198–217 m) above the base of the section. Recovered from the *Benthamaspis rhochmotis* Zone at I-650, I-666, I-667, I-671, I-678 and from the *Petigurus cullisoni* Zone at I-691, I-695, I-711. Kindblade Ranch section: 12 collections from 538 to 735 ft (164–224 m) above the base. Recovered from the *Benthamaspis rhochmotis* Zone at KR-538, KR-556, KR-563, KR-571, KR-610 and from the *Petigurus cullisoni* Zone at KR-623, KR-636, KR-638, KR-671, KR-708, KR-714, KR-735.

STRIGIGENALIS INSENTIS n. sp.

Plate 16, Figure 5; Plate 19, Figures 1–10

Diagnosis.—Species of *Strigigenalis* with moder-

ately convex cranidium (sag.), sharply rounded glabella, moderately declined preglabellar field and preocular field, moderately declined posterior areas. Librigena with curved lateral margin anteriorly, angular posterior border furrow, long librigenal spine. Pygidium with 3–4 pairs of moderately inflated pleural ribs, faintly impressed interpleural furrows on large specimens, evenly rounded posterior margin, narrow post-axial border, lacking post-axial spine. Prosopon of granules with uncommon short ridges.

Abridged description.—Cranidia up to 0.8 cm in length (sag.). Glabella subrectangular outline, slightly pointed in anterior view, moderately convex (sag., tr.). Palpebral glabellar width (tr.) 0.75 times glabellar length (sag.). Three pairs of short, broad, faintly impressed lateral glabellar furrows: 1s—perpendicular to axis, posterior to palpebral mid-length, 2s—directed anteriorly, located at anterior end of palpebral lobe, 3s—faint, anteriorly directed prosopon-free patch present on large, testate specimens. Axial furrows well impressed, nearly straight. Preglabellar furrow moderately impressed, slightly angular at axial line. Occipital ring long, less than 0.2 times cranidial length (sag., including occipital furrow), subrectangular in outline, medial occipital node present. Occipital furrow straight, in sagittal profile anterior side of furrow steeply declined, posterior side moderately declined. Anterior border inclined, incompletely known. Preglabellar field steeply declined to overturned axially. Preocular field overturned at anterolateral corners. Palpebral lobes up to 0.5–0.4 times glabellar length (exsag., small to large specimens); semicircular in outline with faint palpebral rim, moderately impressed palpebral furrow; centered slightly posterior to glabellar mid-length. Palpebral areas moderate in width, moderately inclined (tr.). Posterior areas, posterior branch of facial suture unknown.

Librigenae can exceed 1.7 cm long with long, moderately tapered librigenal spine. Librigenal field strongly declined, with well-developed ocular platform. Lateral margin curved anteriorly, slightly curved adaxially posterior to eye. Lateral border inclined anteriorly, decreases in height posteriorly until flush with posterior border. Lateral border furrow significantly shallower behind intersection of lateral and posterior border furrows, absent on distal portions of librigenal spine. Posterior border furrow broad, moderately impressed, straight, posteriorly directed (adaxially), angled anteriorly to intersect lateral border furrow near mid-length of eye. Eye socle present bearing pattern of intersecting, short, thin threads.

Pygidium moderate in size, up to 0.6 cm long (sag.), moderately convex, evenly rounded posteriorly, semicircular in outline with pygidial width (tr.) 1.5–1.6 times pygidial length (sag.). Axis moderately convex (tr.), slightly tapered opposite anterior 3 axial rings; with posteriorly rounded terminal axial piece. Anterior axial width 0.3 times maximum pygidial width (tr.); axial length 0.75 times pygidial length (sag.). Axial furrows well impressed anteriorly, faint to absent posteriorly. Ring furrows straight, weakly impressed laterally to weakly impressed axially. Pleural fields small, slightly convex, moderately declined, with 3 pairs of moderately inflated pleural ribs. Anterior pair of pleural furrows well impressed, remaining pairs weakly to faintly impressed. Interpleural furrows faintly impressed on pleural ribs, continue weakly impressed onto border of larger, testate specimens. Border moderately declined, slightly convex, narrowest post-axially. Articulating facet narrow (tr.), slightly declined, with coarse ridges along crest.

Prosopon of granules and uncommon short ridges, pygidial border with fine pits, lateral librigenal border with short, oblique ridges. Exfoliated surfaces pitted.

Remarks.—The short, inclined anterior librigenal (and cranidial?) border and inflated pleural ribs on the pygidium of this species are consistent with the diagnosis of *Strigigenalis*. *Strigigenalis insentis* n. sp. compares most closely with those species of *Strigigenalis* which also lack a post-axial pygidial spine. The narrower post-axial pygidial border, steeply inclined to overturned preocular field and preglabellar field, and longer librigenal spine of *S. insentis* distinguish it from *S. derbyi* n. sp. (Pl. 17, Figs. 4–13). The glabella of *S. insentis* is parallel-sided and evenly rounded anteriorly compared with *Strigigenalis crassimarginata*. The pygidial border of those specimens of *S. crassimarginata* that lack a post-axial flange or post-axial spine are longer (sag.) than the border of *S. insentis* and concave rather than convex. The cranidium of *S. knighti* (Boyce, 1989, p. 51, 52, pl. 28, figs. 4–10) exhibits a sharply rounded glabella, moderately divergent anterior facial sutures, and well-impressed palpebral furrows. The librigenal spine of *S. knighti* is shorter and more acutely curved than for *S. insentis*. The short post-axial pygidial border of *S. knighti* is reminiscent of *S. insentis*, however, there are fewer (2–3) pairs of pleural ribs on *S. knighti* and the border is broadest post-axially.

Strigigenalis insentis is also known from the

CK Formation (= Cotter Formation of present usage) of Taney County, Missouri. One specimen (UMC 17084) was located among the collections of the University of Missouri–Rolla, identified by Cullison as *Jeffersonia crassimarginata.*

Etymology.—Compounded from *in-*, Latin, (prefix) not, and *sentis*, Latin, for thorn; referring to the absence of a post-axial pygidial spine.

Material.—Total 5 cranidia, 15 pygidia, 8 librigenae. Holotype: UMC 17075 (Pl. 19, Fig. 1). Paratypes: UMC 17076–17083.

Occurrence.—Interstate-35 section: 10 collections from 994 to 1,195 ft (303–364 m) above the base of the section. Recovered from the *Bolbocephalus stitti* Zone at I-994, I-1009, I-1064, I-1066, I-1085, I-1133, I-1143, I-1146, I-1170, and the *Strigigenalis caudata* Zone at I-1195. Kindblade Ranch section: 2 collections. Recovered from the *Petigurus cullisoni* Zone at 805 ft (245 m) and from the *Bolbocephalus stitti* Zone at 1,010 ft (308 m) above the base.

STRIGIGENALIS SP. 1

Plate 19, figs. 11–13

Remarks.—The association of the 4 fragmentary cranidia and 6 pygidia assignable to *Strigigenalis* sp. 1 is based upon the presence of asymmetrical granules on the pygidial border, flanks of glabella, and the occipital ring. This prosopon appear unique to this species for material from the Kindblade Formation.

The evenly curved, continuous pygidial margin of *Strigigenalis* sp. 1 compares most closely with those species of *Strigigenalis* lacking pygidial spines. The marginally concave pygidial border of *Strigigenalis* sp. 1 is reminiscent of that seen on *S. derbyi* and on some specimens of *S. crassimarginata* (Cullison). Specimens of *S. crassimarginata* (Pl. 16, Figs. 5–12), however, have an additional (weakly defined) axial ring contrasted to *Strigigenalis* sp. 1 and lack a granulose prosopon on the pygidial border. The pygidial border of *S. derbyi* is smooth and the granules upon the pleural ribs are of a finer scale than those of *Strigigenalis* sp. 1. The cranidium of *S. derbyi* includes a glabella which is broader (tr.), than that of *Strigigenalis* sp. 1, a more finely granulose prosopon, and a preglabellar field which is less steeply declined. The pygidium of *S. insentis* n. sp. (Pl. 19, Figs. 5–7) is narrowest post-axially, bears an additional axial ring, and lacks granulose prosopon on the border.

Occurrence.—Interstate-35 section: 5 collections from 650 to 821 ft (198–250 m) above the base of the section. Recovered from the *Benthamaspis rhochmotis* Zone at I-650 and the *Petigurus cullisoni* Zone at I-718, I-762, I-800, I-821. Kindblade Ranch section: 4 collections from 636 to 741 ft (194–226 m) above the base. Recovered from the *Petigurus cullisoni* Zone at KR-636, KR-638, KR-735, KR-741.

STRIGIGENALIS SP. 2

Plate 15, Figure 9

Remarks.—The moderately convex pleural ribs, long axis composed of 4 axial rings, and the angulation on the posterior margin suggest placement of this pygidium within *Strigigenalis.* The absence of a well-defined post-axial pygidial spine separates *Strigigenalis* sp. 2 from *S. caudata* (Pl. 15, Figs. 5–8; Billings, 1865; Fortey, 1979), *S. brevicaudata* (Boyce, 1989, pl. 29, figs. 8–10, pl. 30, figs. 1–10), and *Strigigenalis*? sp. 3. The keel present on the border of *Strigigenalis.* sp. 2 distinguishes this species from *S. knighti* (Boyce, 1989, p. 51, 52, pl. 28, fig. 4) and *S. crassimarginata* (Pl. 16, Figs. 5–12).

Occurrence.—Interstate-35 section: 1 pygidium recovered from the *Strigigenalis caudata* Zone at 1,444 ft (440 m) above the base of the section.

STRIGIGENALIS? SP. 3

Plate 15, Figures 10, 11

Remarks.—Three pygidia and a fragmentary librigena are questionably assigned to *Strigigenalis* on the basis of their well-defined pleural ribs, long axis, and incompletely known post-axial spine. Within *Strigigenalis*, the single pygidial spine of *Strigigenalis*? sp. 3 with its triangular cross section is also seen on the pygidium of *S. caudata, S. brevicaudata,* and *S. whittingtoni.* The pygidium of *Strigigenalis*? sp. 3 is closer in form to the short spined pygidium of *S. brevicaudata* (Boyce, 1989, p. 54, 55, pl. 29, figs. 8–10, pl. 30, figs. 1–10), but exhibits a tubercular prosopon lacking from *S. brevicaudata.* The long pygidial spine and smooth prosopon distinguish *S. caudata* (Pl. 15, Figs. 5–8; Billings, 1865) from *Strigigenalis*? sp. 3. The post-axial spine of *S. whittingtoni* (Brett and Westrop, 1996, p. 421, figs. 16.5–16.7) is longer and narrower and the pygidial prosopon is smooth rather than tuberculate.

Occurrence.—Interstate-35 section: 1 collection from the *Strigigenalis caudata* Zone at 1,468 ft (448 m) above the base of the section.

Genus *SPEYERIS* n. gen.

Type species.—*Speyeris hami,* by monotypy and original designation.

Diagnosis.—Pustulose Bathyurinae with large glabella, subquadrate to bullet-like in outline which overhangs the anterior margin, 1 pair of faint lateral glabellar furrows present, well-impressed axial furrows; preglabellar field short to absent axially; frontal area steeply declined to overturned; large palpebral lobes with strong palpebral furrows, set close to glabella, posterior to glabellar mid-length. Pygidium moderately convex (tr.), well-defined pleural ribs with obvious pleural furrows, pygidial border broad, moderately concave with weakly impressed interpleural furrows.

Remarks.—Within the Bathyurinae, the cranidium of *Speyeris* is similar to those genera with inflated glabellas which overhang the anterior margin. The cranidium of *Petigurus* Raymond (1913) (compare Pl. 12 with Fortey, 1979, p. 84–86, pl. 29, figs. 2–4, 6) compares closely with *Speyeris* in also having a distinct pustulose prosopon. *Petigurus*, however, has a posteriorly constricted (tr.) glabella and a strongly concave pygidium. *Psephosthenaspis* Whittington (1953) (see Fortey and Droser, 1996) has a glabella which is more bluntly rounded and is less convex (tr.), and a narrow, tubular anterior border. Further, the pygidium of *Psephosthenaspis* is less convex in the axis and pleural field, has a narrow, inclined border, and lacks interpleural furrows on the border. *Bolbocephalus* Whitfield, 1890, has an inflated glabella that is constricted posteriorly, lacks pustulose prosopon, and has a moderately convex pygidium with a moderately declined border (Pls. 5–7). *Speyeris* lacks the anterior arch that characterizes *Gelasinocephalus* (Pls. 9, 10). The well-impressed furrows of *Speyeris* readily distinguish it from *Ranasasus* (Pls. 13, 14).

Etymology.—In honor of S. E. Speyer, a friend and former office mate at the University of Rochester.

SPEYERIS HAMI n. sp.

Plate 14, Figures 9–13; Plate 25, Figures 8–12

Diagnosis.—As for the genus.

Description.—Cranidium large, up to 3.0 cm long (sag.), trapezoidal in outline, strongly convex (sag., tr.). Glabella large, inflated and strongly convex anteriorly (sag.) to extended beyond anterior margin, bullet-shaped in outline, slightly tapered, moderately convex (tr.). Glabellar length 0.8 times cranidial length (sag.); palpebral width (tr.) 0.8 times glabellar length (sag.). One pair of faintly impressed lateral glabellar furrows, extend in arc from opposite anterior margin of palpebral lobes beyond palpebral mid-length, extend across 0.25 times glabellar width (tr.). Axial furrows well impressed, slightly sinuous, join smoothly with well-impressed preglabellar furrow. Occipital ring long, 0.2 times cranidial length (sag.), slightly arcuate, extended posteriorly beyond posterior margin of fixigenae. Occipital furrow well impressed, broad, straight across axis, bending anteriorly proximal to axial furrows. Anterior border overturned, extended ventrally, thins laterally in anterior view. Anterior border furrow faintly impressed, slightly curved ventrally. Preglabellar field overturned, flat, and narrowest at axis; slightly convex and steeply declined laterally. Preocular field narrow, moderately convex, steeply declined. Palpebral lobes large, greater than 0.33 times glabellar length (exsag.), crescentic, set close to axial furrows, set posterior to glabellar mid-length. Narrow palpebral rim defined by well-impressed palpebral furrow. Palpebral areas narrow, slightly inclined, slightly convex (tr.). Posterior areas short (exsag.), broad (tr.), triangular, steeply declined distally. Posterior border furrow broad. Anterior branches of facial sutures straight to slightly divergent to intersect anterior margin outboard of extension of axial furrows. Posterior branches of facial sutures strongly divergent, straight adaxially then curved to meet posterior border at oblique angle.

Librigenae moderately convex (tr.), triangular in outline with long, gently tapered, adaxially curved librigenal spine. Librigenal field large, widened posteriorly, moderately convex, steeply declined (tr.). Lateral border furrow broad, well impressed, intersects posterior border furrow at acute angle near librigenal spine. Border narrowest, oriented near vertical anteriorly, widened and steeply declined posteriorly. Narrow ocular platform beneath eye socle.

Pygidium large, up to 2.0 cm long (sag.), strongly convex (sag., tr.), semicircular in outline with anterior width (tr.) estimated at 1.7 times pygidial length (sag.). Axis broad, long, evenly tapered, strongly convex (tr.); 4 axial rings, pentagonal terminal axial piece known. Axial width estimated at 0.33 times pygidial width (tr.); axial length roughly 0.66 times pygidial length (sag.). Ring furrows slightly sinuous, well impressed. Axial furrows straight, well impressed anteriorly, shallow until obsolete posterior to terminal axial piece; posterior margin of terminal axial piece declined evenly onto border. Pleural fields large, triangular, moderately convex, moderately declined (tr.), absent posterior to terminal axial piece; 4 pairs pleural ribs with well-impressed pleural furrows. Interpleural furrows weakly im-

pressed on pleural fields, continue onto border as faint, broad depressions. Border furrow absent; lateral border indicated by inflection in slope, change in prosopon, ends of pleural furrows. Posterior border moderately concave, slightly declined, broad, up to 0.33 times pygidial length (sag.), width constant around margin. Articulating facets large, curved, extend adaxially beyond border. Margin with shallow post-axial embayment.

Prosopon of pustules separated by granules on testate surfaces; granules most dense on fixigenae, librigenal field, pleural ribs, pygidial axis, pustules asymmetrical along axial furrows on cranidium. Exfoliated specimens with reticulated pattern of pustules plus fine pits; pustules appear connected by low ridges to produce a hummocky appearance on preglabellar field, fixigenae, librigenae, pleural ribs. Exfoliated pygidial border with pits only. Testate cephalic border with terrace lines parallel to margin on cranidium, anteriorly on librigenae, oblique to margin posteriorly, lines supplemented by pits on exfoliated surfaces.

Remarks.—Although specimens of *Speyeris hami* are scarce, the large size of the specimens and their odd hummocky and coarse pustulose prosopon simplify their identification.

Etymology.—In honor of William E. Ham, for his immense contributions to Arbuckle Group stratigraphy.

Material.—Total 6 fragmentary cranidia, 1 pygidium, 4 librigenae. Holotype: UMC 16899 (Pl. 25, Figs. 8–11). Paratypes: UMC 16900, 17021, 17022.

Occurrence.— Interstate-35 section: 2 collections recovered from the *Petigurus cullisoni* Zone at 732 and 762 ft (223, 232 m) above the base of the section. Kindblade Ranch section: 6 collections from 610 to 671 ft (186–205 m) above the base of the section. Recovered from the *P. cullisoni* Zone at KR-610, KR-623, KR-631, KR-638, KR-653, KR-671.

Subfamily BATHYURELLINAE Hupé, 1955
Genus *BATHYURELLUS* Billings, 1865

Type species.—*Bathyurellus abruptus* Billings, 1865, p. 263, 264; from the Catoche Formation of Newfoundland, Canada; designated by Raymond, 1905, p. 337.

Remarks.—Billings (1865, p. 421) listed 9 species assigned to the genus *Bathyurellus*. Fortey (1979, p. 90, 94) revised the genus, removing those species with transverse pygidia to the genus *Punka* Fortey. Fortey's revised diagnosis of *Bathyurellus* emphasized the presence of a long preglabellar field and an elongate, "spade-like" pygidium with weakly furrowed pleural fields.

Several older species of *Bathyurellus* were beyond the scope of Fortey's (1979) study and require future treatment. These species include, but are not limited to: *"Bathyurellus" marginiatus* Billings (1865) and *"Bathyurellus" expansus* Billings (1865) and *"Bathyurellus" teicherti* Poulsen (1937). The transverse pygidia with obvious interpleural furrows on the border of these species suggest their reassignment to *Punka*. Species of *"Bathyurellus"* with this type of pygidia are excluded from discussions of *Bathyurellus* (*sensu stricto*).

BATHYURELLUS ARBUCKLENSIS n. sp.
Plate 20, Figures 1–5

Diagnosis.—Large, smooth *Bathyurellus* with genal caecae on broad anterior and preglabellar fields; glabella sharply rounded anteriorly, bounded anteriorly by weakly to moderately impressed preglabellar furrow; anterior border of cranidium long (sag.), broad (tr.). Pygidium elongate with parabolic posterior margin; axis broad, bluntly rounded posteriorly; border long (sag.), moderately concave adaxially, downturned marginally.

Description.—Large cranidium, up to 2.0 cm in length (sag.); subrectangular in outline, anterior width (tr.) equal to cranidial length, clavate if posterior areas broken; slightly convex (sag.). Glabella large, elongate; pentagonal in outline, slightly tapered, sharply rounded anteriorly; moderately convex (sag., tr.). Glabellar length 0.5–0.6 times cranidial length (sag.); palpebral glabellar width (tr.) 0.7–0.75 times glabellar length (sag.). Lateral glabellar furrows absent. Axial furrows narrow, well impressed posteriorly, shallowed anteriorly with elongate fossulae at anterolateral corners of glabella; moderately convergent from posterior margin to posterior corner of palpebral lobe, continued sinuous and slightly convergent anteriorly. Preglabellar furrow moderately impressed laterally, faint to obsolete axially. Occipital ring rectangular in outline; long, greater than 0.1 times cranidial length (sag.). Occipital furrow sinuous; broad, moderately impressed, shallowest at axial furrows; anterior side steeply inclined, posterior side moderately inclined. Anterior border long, 0.2 times cranidial length, slightly tapered laterally, slightly concave, oriented subhorizontally (sag.) with

slight dorsal arch (tr.). Anterior border furrow smoothly curved, weakly impressed. Preglabellar field nearly 0.1 times cranidial length (sag.), slightly convex, slightly declined. Preocular fields broad (tr.); slightly convex; slightly inclined near axial furrows, moderately declined at anterolateral corners. Palpebral lobes large, up to 0.5 times glabellar length (exsag.); semicircular in outline with vague palpebral furrow defining broad rim; centered opposite posterior one-third of glabella. Palpebral areas slightly convex, slightly inclined axially (tr.), oriented horizontally at lobe. Posterior areas short (exsag.), broad, slightly declined (tr.), with broad posterior border furrow. Anterior branch of facial sutures broadly curved, strongly divergent anteriorly to anterior border furrow, continued convergent until margin. Posterior branch of facial sutures strongly divergent.

Librigena large, up to 3.1 cm in length, triangular in outline, slightly convex (tr.). Lateral border faintly impressed anteriorly, absent posteriorly; posterior border furrow absent. Librigenal field narrow, slightly convex (tr.), incompletely known. Lateral border broad, slightly concave, downturned at lateral margin (tr.) anteriorly; concave portion of border tapered posteriorly until slightly convex at librigenal spine, moderately declined (tr.) at base of long, flat, sharp librigenal spine.

Pygidium large, up to 2.0 cm long (sag.), moderately convex, parabolic in outline. Axis short (sag.), broad (tr.), slightly convex (tr.), slightly tapered, bluntly rounded posteriorly; composed of short articulating half-ring, 3 axial rings, elongate terminal axial piece. Axial length 0.5 times pygidial length (sag.); axial width 0.3 times pygidial width (tr.). Ring furrows straight; weakly impressed, shallowed axially. Axial furrows sinuous; moderately impressed anteriorly, faintly impressed to obsolete post-axially, weakly impressed fossula at posterior corner of terminal axial piece. Anterior pleural rib elevated, complete from axial furrow to lateral margin with short, straight, well-impressed pleural furrow; anterior facet convex; rib bounded posteriorly by moderately to faintly impressed interpleural furrow. Pygidial border furrow absent, border defined by distal ends of pleural furrows and inflection in convexity of pleural region. Pleural fields small, triangular, slightly convex (tr.); crossed by 2–3 pair of vague pleural furrows, 1–2 pairs of weakly impressed interpleural furrows. Border broad, greatest post-axially; moderately concave adaxially, downturned marginally; bear short, broad extension of interpleural furrows.

Prosopon smooth on testate specimens, except for subdued genal caecae on anterior and preglabellar fields; exfoliated specimens smooth except for genal caecae on anterior, preglabellar, and librigenal fields; pits on cephalic and pygidial borders.

Remarks.—The long, broad anterior cranidial border, long glabella, elongate pygidium, and long pygidial border fall within the concept of *Bathyurellus.*

Among species of *Bathyurellus* illustrated from the western United States only *B. pogonipensis* Hintze (1953, p. 138–140, pl. 10, figs. 11–19) is completely known. *Bathyurellus arbucklensis* differs from this species in exhibiting longer (sag.) cranidial and pygidial borders, a narrower (tr.) librigena with a less distinct lateral border furrow and longer librigenal spine, and better-defined pleural furrow on the pygidium. *Bathyurellus*? sp. of Hintze (1953, p. 140, pl. 10, fig. 6) is known from a fragmentary cranidium which appears to have narrower (tr.) preocular fields than *B. arbucklensis* and a glabella which is parallel-sided rather than tapered. Similarly, the only illustrated large specimens of *Bathyurellus*? *teretus* Young (1973, p. 97, 98, pl. 2, figs. 5, 8–10, 13–14) are fragmentary cranidia which possess a parallel-sided glabella.

The deep parabolic posterior margin of *Bathyurellus arbucklensis* is slightly extended posterolaterally approaching the spatulate outline typical of younger forms like *B. abruptus* and *B. platypus* illustrated by Fortey (1979) from Newfoundland, Canada. The pygidia of both *B. abruptus* Billings (1865, p. 263, 264, figs. 247, 250; Fortey, 1979, p. 92–94, fig. 12, pl. 32, figs. 1–12) and *B. platypus* Fortey (1979, p. 91, 92, pl. 31, figs. 1–13) have the border oriented horizontally near the margin and bounded anteriorly by an angular interpleural furrow. The pygidium of *B. arbucklensis* is downturned marginally (Pl. 20, Fig. 4). The anterior cranidial border for *B. abruptus* and *B. platypus* is short (sag.) and narrower (tr.), the preglabellar furrow is poorly defined and more arcuate axially, the glabella is parallel sided, and the occipital ring bears terrace lines. The cranidium of *B. arbucklensis*, in contrast, exhibits a long, broad anterior border, an angular preglabellar furrow, and a tapered glabella. The cranidium of *B. arbucklensis* is smooth, except for genal caecae on the anterior and preglabellar fields.

The pygidium of *Bathyurus amplimarginatus* Billings (1859, p. 365, fig. 12a,b; Twenhofel, 1938, p. 71, 72, pl. 10, fig. 13) is similar to that of *B. ar-*

bucklensis. Both pygidia have a short, tapered axis, a broad border, and an anterior pleural rib extended to the lateral margin. The pleural ribs on the pleural field of *B. amplimarginatus*, however, are better defined and the pleural fields are larger. The ring furrows of *B. amplimarginatus* are well impressed and separate 4 axial rings. The axis of *B. arbucklensis* is composed of 3 axial rings separated by weakly impressed ring furrows.

Etymology.—Named after the Arbuckle Mountains of southern Oklahoma.

Material.— Total 3 cranidia, 2 pygidia, 2 librigena. Holotype: UMC 16811 (Pl. 20, Fig. 1). Paratypes: UMC 16812–16815.

Occurrence.—Interstate-35 section: 3 collections from 503 to 556 ft (153–170 m) above the base of the section. Recovered from the *Benthamaspis rhochmotis* Zone at I-503, I-521, I-556. Kindblade Ranch section: 2 collections recovered from the *B. rhochmotis* Zone at 437 and 520 ft (133, 159 m) above the base.

BATHYURELLUS INFLATUS n. sp.

Plate 20, Figures 6–12

Diagnosis.—*Bathyurellus* with glabella parallel-sided, evenly rounded anteriorly; moderately impressed preglabellar furrow; concave anterior border longer than preglabellar field (sag.), upturned anteriorly to form thin marginal rim. Marginal rim continued length of librigena and short, broad-based librigenal spine. Slightly transverse pygidium with short axis of 4 axial rings; anterior pleural rib well-defined by anterior pair of interpleural furrows; border longest post-axially.

Abridged description.—Cranidium with fragments more than 0.7 cm in length (sag.), complete cranidia up to 0.5 cm; moderately convex (sag.). Glabella prominent, long (sag.), parallel-sided, evenly rounded anteriorly. Glabellar length 0.6–0.7 times cranidial length (sag.); palpebral glabellar width (tr.) 0.7–0.8 times glabellar length (sag.). Axial furrows moderately impressed, join moderately impressed preglabellar furrows in smooth curve. Occipital ring rectangular in outline, posterior margin slightly extended; long, greater than 0.1 times cranidial length. Frontal area 0.2 times cranidial length (sag.). Anterior border slightly concave (sag.), slightly inclined with raised marginal rim, longer than preglabellar field. Anterior border furrow faintly impressed, broadly curved. Preglabellar field slightly convex, moderately declined (sag). Preocular fields broad (tr.), slightly to moderately convex, moderately declined (exsag.). Palpebral lobes semicircular in outline with faint palpebral furrow; long, 0.6 times glabellar length (exsag.); set posteriorly, centered at 0.66 times glabellar length, posterior end slightly anterior to occipital furrow. Palpebral areas slightly convex (tr.), stand above axial furrows, slightly declined at palpebral furrow. Posterior areas short (sag.) due to posterior position of palpebral lobes; narrow, slightly declined, with sinuous, moderately impressed posterior border furrow. Anterior branch of facial sutures strongly divergent. Posterior branch of facial sutures sinuous, intersect posterior margin at acute angle.

Librigena up to 0.7 cm long (exsag.); roughly triangular in outline with short, broad-based, sharply pointed librigenal spine. Librigenal field moderately declined (tr.), constant in width about ocular surface. Lateral border furrow broad; continued length of librigenal spine, faintly impressed distally. Posterior border furrow moderately impressed, anteriorly curved, joins lateral border furrow at approximately the anterior one-third of eye. Lateral border moderately concave anteriorly with thickened marginal rim; rim narrows posteriorly, continues for length of librigenal spine; lateral border in genal region slightly convex, moderately declined (tr.). Eye long (exsag.), may be retained above thin eye socle.

Pygidium of moderate size, up to 1.2 cm in length (sag.), typically 0.75 cm; moderately convex (sag., tr.); subelliptical in outline with pygidial width (tr.) 1.1–1.4 times pygidial length (sag.). Axis short (sag.), narrow, moderately convex (tr.); bluntly rounded posteriorly with a short, faint post-axial ridge. Axial length 0.5 times pygidial length (sag.); anterior axial width 0.33 times maximum pygidial width at posterior corner of articulating facet (tr.). Two straight, faintly impressed ring furrows, shallowest axially, two weakly impressed ring furrows posteriorly; on exfoliated specimens, anterior 2 furrows moderately impressed with additional third furrow weakly impressed. Axial furrows moderately impressed, slightly deepened opposite mid-length of terminal axial piece. Pleural fields small, triangular, narrow, slightly convex, slightly declined (tr.) Three pair of interpleural furrows; anterior-most well impressed, complete as broad curve from axial furrow to lateral margin, defines elevated anterior pleural rib; second, faintly impressed adaxially, evenly curved, very faintly impressed at margin; third, short, very faintly impressed. Pleural furrows short, nearly

straight, directed slightly posteriorly; furrow on anterior pleural rib moderately impressed, posterior furrows successively shorter, fainter. Border dominant on pygidium, longest post-axially; moderately convex, moderately declined marginally (sag., tr.). Broad articulating facet poorly defined on anterior side of anterior pleural rib.

Prosopon of fine terrace lines on all testate surfaces except preocular fields, frontal area of cranidium; on cranidium terrace lines strongly anteriorly convex on glabella and occipital ring, lines perpendicular to axis on palpebral lobes; on librigena, lines directed posteriorly away from eye on librigenal field, near perpendicular to axis medially on lateral border, parallel to margin on librigenal spine; on pygidium, axis with strongly anteriorly convex lines, lines on pleural border concave.

Remarks.—*Bathyurellus inflatus* n. sp. is assigned to *Bathyurellus* on the basis of its large palpebral lobes, quadrate glabella, divergent anterior branches of the facial sutures, genal spine, long pygidial border, trapezoidal and convex pygidial axis, and prosopon of fine terrace lines. The short anterior border, large eyes, trapezoidal and strongly convex pygidial axis, and its moderately long and convex pygidial border are suggestive of *Benthamaspis*. All other species of *Benthamaspis* for which the librigena is known, however, exhibit rounded genal angles rather than a genal spine. The intermediate character of *B. inflatus* between *Benthamaspis* and the two younger species of *Bathyurellus*, *B. abruptus* and *B. platypus*, suggests an evolutionary association.

Bathyurellus inflatus compares with the type species, *B. abruptus* Billings (1865; Fortey, 1979, p. 92–94, pl. 32, figs. 1–12), *B. platypus* Fortey (1979, p. 91, 92, pl. 31, figs. 1–13), and *B. arbucklensis* (Pl. 20, Figs. 1–5) in the shape of the glabella, the proportions of the palpebral lobes, the trapezoidal pygidial axis, and the post-axial extension of the pygidial border. The anterior border of *B. inflatus*, however, is inclined to appear shorter in a palpebral view. The pygidial border of *B. inflatus* is convex and comparatively short, relative to these other 3 species.

Etymology.—From *inflatus*, Latin, for swollen or puffed up; referring to the post-axially elongate border on the pygidium.

Material.—Total 4 cranidia, 8 pygidia, 6 librigenae. Holotype: UMC 16820 (Pl. 20, Fig. 11). Paratypes: UMC 16816–16819, 16821.

Occurrence.—Interstate-35 section: 4 collections from 630 to 732 ft (192–223 m) above the base of the section. Recovered from the *Benthamaspis rhochmotis* Zone at I-630, I-631, I-650, and the *Petigurus cullisoni* Zone at I-732. Kindblade Ranch section: 2 collections, recovered from the *B. rhochmotis* Zone at 610 (186 m) and the *P. cullisoni* Zone at 805 ft (245 m) above the base.

BATHYURELLUS? SP. 1

Plate 4, Figure 11

Remarks.—Three pygidia are provisionally assigned to *Bathyurellus* based upon the broad, slightly convex border, relatively short axis, elevated anterior pleural rib, small librigenal field, and poorly defined pleural and interpleural furrows. This species differs from *Bathyurellus arbucklensis* n. sp. in being slightly more transverse in outline, in having ring, pleural and interpleural furrows that are relatively more effaced, and in the presence of a more pronounced anterior pleural rib. The pygidium of *Bathyurellus*? sp. 1 bears terrace lines as on *B. inflatus* n. sp., but has a concave rather than convex border. *Bathyurellus arbucklensis* is smooth. The semicircular pygidial outline of *Bathyurellus*? sp. 1 differs from the spatulate pygidia of both *B. abruptus* Billings (1865; Fortey, 1979, p. 92–94, fig. 12, pl. 32, figs. 2, 9) and *B. platypus* Fortey (1979, p. 91, 92, pl. 31, figs. 4, 7) in being more transverse with a rounded posterior margin. The pair of interpleural furrows of *Bathyurellus*? sp. 1 is posteriorly curved, rather than bent in an angular fashion as in *B. abruptus* or *B. platypus*.

Occurrence.—Recovered from the *Petigurus cullisoni* Zone at 671 ft (220 m) above the base of the Kindblade Ranch section.

Genus *BENTHAMASPIS* Poulsen, 1946

Oculomagnus Lochman, 1966, p. 541. Junior subjective synonym (see Fortey, 1979, p. 100).

Type species.—*Benthamaspis problematica* Poulsen, 1946, p. 325, 326, by monotypy, from the Nunatami Formation at Cape Stevens, Ellesmere Island.

Emended diagnosis.—Glabella straight-sided, quadrate to slightly tapered anteriorly; moderately convex. Anterior facial sutures subparallel from palpebral lobes to margin. Palpebral lobes long, crescentic; weakly impressed palpebral furrows. Anterior border horizontal to upturned anteriorly to produce ridged, cord-like anterior border in later species; border continues to genal angle. Librigenae with rounded genal angle. Pygidium semicircular with straight-sided axis,

subtriangular to trapezoidal in outline, moderate in length; post-axial ridge common. Prosopon of fine terrace lines.

Remarks.—Previous diagnoses of *Benthamaspis* (= *Oculomagnus*) have been too broadly drawn (Boyce, 1989, p. 56) or based upon single species (Lochman-Balk, 1959, p. O295; Lochman, 1966, p. 541). The diagnosis provided above is based upon the following 12 species of *Benthamaspis*: *B. gibberula* (Billings, 1865); *B. striata* (Whitfield, 1897); *B. mediacrista* (Cullison, 1944); *B. problematica* Poulsen, 1946; *B. diminutiva* Hintze, 1953; *B. obrepta* (Lochman, 1966); *B. distincta* Young, 1973; *B. conica* Fortey, 1979; *B. canadensis* Dean, 1989; *B. hintzei* Boyce, 1989; *B. sera* Fortey and Droser, 1999; *B. onomeris* n. sp.; and *B. rhochmotis* n. sp.

Benthamaspis mediacrista (Cullison, 1944) is removed from the genus *Jeffersonia* and reassigned to *Benthamaspis* on the basis of its large eyes, moderately wide preocular fields, moderately declined preglabellar field, and well-impressed occipital furrow. Boyce (1989, p. 46) sought to use *"Jeffersonia" mediacrista* as the type species of a new genus, which he called "Genus novum B", within which he included *"J". mediacrista* and his "Gen. nov. B, sp. nov. A". *"Jeffersonia" mediacrista*, however, fits comfortably within *Benthamapsis*, which leaves "Gen. nov. B" of Boyce (1989) without its type species and restricted to the single cranidium of "Gen. nov. B, sp. nov. A". The large, crescentic eyes, rectangular glabella and general cranidial proportions of Gen. nov. B, sp. nov. A are consistent with *Benthamaspis* and with recovery of additional material a formal assignment to this genus might be made.

Fortey (1979, p. 67, 100) discussed the progressive effacement of *Benthamaspis* species through an apparent series of ancestor-descendant relationships, beginning from *B. obrepta*. Progressive loss of definition of the cephalic and pygidial furrows eliminated the preglabellar field and axial rings on *B. gibberula* (Fortey, 1979, p. 100–102, pl. 34, figs. 1–15). This trend continued through *Benthamaspis diminutiva* which, in addition, lacks a well-defined occipital ring, glabella, and pygidial axis (Hintze, 1953, p. 142, pl. 13, figs. 9–12).

Benthamaspis specimens recovered from the lower part of the Kindblade Formation exhibit cephalic and pygidial characters that are less derived than previously known for this genus. The glabella of *Benthamaspis* cf. *B. mediacrista* is quadrate in outline, which R. A. Fortey (*in* Fortey and Peel, 1990, p. 15) suggested represents a relatively "primitive" state for bathyurid trilobites. The glabellas of the younger species are progressively tapered anteriorly, with *B. rhochmotis* having a subquadrate outline and *B. onomeris* a trapezoidal outline. The palpebral areas of *B. onomeris* and younger species are subhorizontal. The palpebral areas in the older species are slightly inclined in larger specimens, however, a small specimen of *Benthamaspis* cf. *B. mediacrista* exhibits slightly declined fixigenae. This suggests a neotenous retention of this character within the lineage. The prosopon also exhibits a progressive change from *Benthamaspis* cf. *B. mediacrista* (smooth), to *B. rhochmotis* (terrace lines except for post-axial pygidial border) to *B. onomeris* (ubiquitous terrace lines). Most significantly, the pygidium of *B. rhochmotis* has retained 3 pleural ribs on the internal mold, a feature unknown on younger species.

Fortey (1979, p. 100) assigned *Benthamaspis* to the Lecanopygidae based upon the absence of pleural furrows on the pygidium. The pleural ribs and furrows of *B. rhochmotis*, however, in conjunction with the character of the anterior cephalic border, the subquadrate glabellar outline, the continuous cephalic border, and strongly convex (tr.) pygidial axis firmly establish *Benthamaspis* as a member of the Family Bathyuridae. Previously, Lochman (1966) and Boyce (1989) have assigned *Benthamaspis* to the bathyurid Subfamily Bathyurellinae, an assignment with which I concur based upon the intermediate character of *Bathyurellus inflatus* between *Benthamaspis* and *Bathyurellus* (as discussed previously).

BENTHAMASPIS cf. *B. MEDIACRISTA* (Cullison, 1944)

Plate 22, Figures 1, 2

Jeffersonia mediacrista Cullison, 1944, p. 74, 75, pl. 34, figs. 25–27; Boyce, 1989, pl. 21, figs. 1–4.

Diagnosis.—*Benthamaspis* with quadrate, moderately to slightly convex (tr.), broadly keeled glabella, 2 faintly impressed pairs of lateral glabellar furrows; axial furrows moderately impressed, occipital furrow well impressed; preglabellar field well defined by moderately impressed preglabellar furrow.

Supplemental description.—Small cranidia, up to 0.6 cm in length (sag.), subtrapezoidal in outline, moderately convex (sag.). Glabella large, subquadrate in outline, bluntly rounded anteriorly, moderately declined anteriorly, slightly to moderately convex and keeled (tr.). Glabellar length 0.66 times cranidial length (sag.); palpebral glabellar width (tr.) 0.9–1.0 times glabellar

length (sag.). Lateral glabellar furrows faintly impressed; 1s—perpendicular to axis for 0.33 times glabellar width, sharply turned, continued posteriorly an equal length, 2s—short, straight furrows oriented perpendicular to axis. Axial furrows straight, parallel, weakly (small specimens) to moderately impressed. Preglabellar furrow moderately impressed, straight axially. Occipital ring long, some greater than 0.1 times cranidial length, rectangular in outline. Occipital furrow well impressed, straight and broadest axially, constricted at axial furrows. Anterior border moderate in length, up to 0.1 times cranidial length, moderately concave, oriented horizontally at margin. Anterior border furrow nearly straight, weakly to moderately impressed. Preglabellar field slightly convex, moderately declined; short in dorsal view, less than 0.1 times cranidial length (sag.). Preocular fields slightly convex, moderately declined, moderate in width (exsag.). Palpebral lobes crescentic in outline, large, up to 0.7 times (exsag.) glabellar length; centered posterior of glabellar mid-length, opposite 1s lateral glabellar furrow, anterior end of lobe anterior to 2s glabellar furrow. Palpebral furrows weakly impressed at ends, faintly impressed medially (exsag.). Palpebral areas slightly convex, moderate in width, slightly declined (small specimens) to slightly inclined. Anterior branch of facial sutures initially slightly divergent, curved adaxially to approach anterior margin at right angle. Posterior areas and posterior branch of fixigenae unknown. Prosopon smooth.

Librigenae, pygidium not recovered.

Remarks.—Two specimens recovered from the lower part of the Kindblade Formation may be compared with cranidia of *"Jeffersonia" mediacrista* Cullison (1944, p. 74, 75, pl. 34, figs. 25, 26), based upon the presence of a broad medial keel and faint lateral glabellar furrows. The Oklahoma specimens differ from that of Missouri (reillustrated by Boyce, 1989, pl. 21, figs. 1–4) in having a slightly longer anterior border. The smaller specimen from Oklahoma has only faintly impressed axial furrows, a slightly convex glabella (tr.), and slightly declined palpebral areas. Its relatively long eyes, quadrate glabella, and moderately declined preglabellar field effectively link it with the larger, less-effaced specimen.

Benthamaspis mediacrista was originally recovered in southern Missouri by Cullison (1944) from the Jefferson City Formation (= Rich Fountain Formation of Cullison).

Material.—Total 2 cranidia.

Occurrence.—Recovered from high in the *Ranasasus brevicephalus* Zone at 254 ft (77 m) above the base of the I-35 section and 253 ft (77 m) above the base of the Kindblade Ranch section.

BENTHAMASPIS ONOMERIS n. sp.

Plate 21, Figures 1–4

Diagnosis.—*Benthamaspis* with tapered glabella; preglabellar furrow moderately impressed, distinct preglabellar field in dorsal view; occipital furrow weakly impressed abaxially; prosopon of terrace lines on both glabella and fixigenae, lines on palpebral areas lie oblique to axis. Pygidial axis faintly segmented, truncated posteriorly, length roughly 0.6 times pygidial length. Moderately convex pleural regions with 1–2 pairs of pleural furrows, 1 pair interpleural furrows, all weakly impressed; abaxial pleural region subhorizontal.

Description.—Cranidium small, up to 0.6 cm in length (sag.); trapezoidal in outline; strongly convex (sag.). Glabella large, nearly equant; subtrapezoidal in outline, slightly tapered, broadly rounded anteriorly; moderately convex, (sag., tr.). Glabellar length 0.7–0.75 times cranidial length; basal glabellar width 0.9–1.0 times glabellar length. Lateral glabellar furrows absent. Axial furrows straight, moderately impressed. Preglabellar furrow faintly impressed. Occipital ring rectangular; long, 0.15 times cranidial length (sag.). Occipital furrow moderately impressed, shallowed abaxially; straight axially. Anterior border thin. Anterior border furrow broad, moderately impressed. Preglabellar field less than 0.1 times glabellar length (sag.); steeply declined. Preocular area broad, moderately convex (tr.), steeply declined. Palpebral areas moderately inclined to rise above axial furrows proximally, oriented horizontally proximal to palpebral lobe. Posterior areas steeply declined (tr.). Palpebral lobes large, crescentic, 0.5 times glabellar length (exsag.); centered posterior of glabellar mid-length. Palpebral furrows faint. Posterior border furrow well impressed. Anterior branch of facial sutures slightly divergent, straight to anterior margin. Posterior branch of facial sutures strongly divergent.

Librigenae unknown.

Pygidium up to 0.8 cm long (sag.), strongly convex (sag., tr.), semicircular in outline with pygidial width 1.4–1.7 times pygidial length (large to small specimens, respectively). Axis triangular in outline, rounded posteriorly, some specimens with sinuous post-axial ridge; strongly convex (tr.); composed of short articulating

half-ring, 4 successively shorter (sag.) axial rings, triangular terminal axial piece. Anterior axial width 0.33 times maximum pygidial width; axial length 0.6 times pygidial length (sag.). Three ring furrows faintly impressed; best developed abaxially, anteriorly. Axial furrows straight, well impressed, shallow rapidly posteriorly; terminal axial piece merges onto posterior pleural region evenly due to loss of axial furrows or presence of post-axial ridge. Border furrow absent; border defined by flexure circumscribing distal ends of pleural furrows. Pleural fields triangular; moderately convex (tr.), rise above axial furrows; crossed by 2–3 pairs of pleural furrows, anterior pair weakly impressed, 0.5 times width of pleural region, remainder shorter, faintly impressed. Border moderately declined, slightly longer postaxially. One pair of faintly impressed interpleural furrows.

Prosopon of fine terrace lines on testate specimens; glabellar terrace lines are convex anteriorly, fixigenal terrace lines are directed anteriorly from axial furrows at an angle of approximately 15° to cross palpebral areas.

Remarks.— *Benthamaspis onomeris* n. sp. is assigned to the genus *Benthamaspis* based upon its relatively large eyes, prosopon of fine terrace lines, subtrapezoidal glabella, and semicircular pygidium with its triangular axis.

Benthamaspis onomeris is best compared with the relatively older species of *Benthamaspis* (Zone G, the *Hintzeia celsaora* and *Protopliomerella contracta* Zones, Ross and others, 1997), especially those with a distinct preglabellar furrow and preglabellar field. *Benthamaspis onomeris* differs from *B. obrepta* (Lochman, 1966, p. 541–542, pl. 62, fig. 6) in having a more steeply declined preglabellar field and terrace lines that cross the fixigenae at an acute angle rather than transversely. Comparisons with *B. hintzei* Boyce (1989, p. 56, 57, pl. 32, figs. 1–8) from the Boat Harbour and Catoche Formations, Newfoundland, Canada, are difficult due to the smaller size (meraspids?) and fragmentary nature of the material. Although the pygidia appear similar, the axis of *B. hintzei* appears more rapidly tapering and the border seems more convex. Cranidial comparisons are more difficult, but Boyce (1989) noted that terrace lines were lacking from the fixigenae of *B. hintzei*. *Benthamaspis conica* Fortey (1979, p. 102–104, pl. 35, figs. 1–10) is more effaced than any of the previously discussed species with a faintly impressed preglabellar furrow, an occipital furrow which shallows abaxially, and a pygidium with a more distinctly triangular outline.

Etymology.—From *onoma*, Greek, m., for name and *eris*, Greek, for quarrel; for the discussions generated in assigning these specimens at the species level.

Material.—Total 6 cranidia, 7 pygidia. Holotype: UMC 16822 (Pl. 21, Fig. 1). Figured paratypes: UMC 16823–16825. Unfigured paratypes: UMC 16826–16835.

Occurrence.—Interstate-35 section: 9 collections from 994 to 1,234 ft (303–376 m) above the base of the section. Recovered from the *Bolbocephalus stitti* Zone, at I-994, I-996, I-1006, I-1034, I-1045, I-1064, I-1080, and from the *Strigigenalis caudata* Zone at I-1227, I-1234.

BENTHAMASPIS RHOCHMOTIS n. sp.

Plate 21, Figures 5–12

Benthamaspis sp. 1, identified by J. D. Loch *in* Derby and others, 1991, fig. 10B.

Diagnosis.—*Benthamaspis* with subquadrate glabella bounded by well-impressed axial and occipital furrows; fixigenae moderately convex (tr.), rise from axial furrows; preglabellar field well defined, narrow preglabellar platform adjacent to broad, moderately impressed preglabellar furrow. Testate pygidia with 3 pairs of pleural and 3 pairs of interpleural furrows, exfoliated specimens with 2–3 distinct pleural ribs. Prosopon of fine terrace lines on cephalon and anterior of pygidium; fine pits on posterior of pygidial border.

Abridged description.—Cranidium small, up to 0.7 cm in length (sag.). Glabella subquadrate in outline, moderately tapered. Glabellar length 0.66–0.7 times cranidial length. Preglabellar furrow broad, moderately impressed. Occipital ring rectangular; long, 0.2 times cranidial length (sag.); slopes sagittally toward occipital furrow; occipital node set anteriorly on some specimens. Occipital furrow well impressed; straight axially, anteriorly curved laterally. Anterior border thin, cord-like; anterior surface with 2–4 fine ridges. Preglabellar field 0.1 times glabellar length (sag.); slopes steeply downward except for narrow platform adjacent to preglabellar furrow. Fixigenae broad, moderately convex (tr.), rise above axial furrows proximally; anterior, posterior areas steeply declined. Palpebral lobes large, crescentic, 0.6 times glabellar length (exsag.); centered posterior of glabellar mid-length.

Librigenae up to 0.7 cm long (exsag.); slightly convex (tr.) with broadly rounded genal angle. Lateral border furrow moderately impressed, becoming shallower posteriorly. Posterior bor-

der furrow angular, bent to intersect lateral border furrow near palpebral mid-length. Lateral border thin, cord-like, looses definition approaching genal angle. Librigenal field narrow, of constant width, slightly convex; narrow ocular platform. Low eye socle, with thin transverse ridge.

Pygidium up to 1.2 cm long (sag.). Anterior axial width 0.2–0.33 times maximum pygidial width; axial length 0.66 times pygidial length (sag.). Border of moderate width defined by flexure circumscribing distal ends of pleural furrows. Pleural fields rise above axial furrows; crossed by 3 pairs of pleural furrows, anterior pair well impressed, 0.5 times width of pleural region, remainder shorter, weakly to faintly impressed. Border steeply declined, of constant width. Three weakly to faintly impressed interpleural furrows continuous from margin to axial furrows. Articulating facet long, 0.66 times width of pleural region. Exfoliated pygidia with 3 raised pleural ribs extending length of pleural furrows, 4 well-impressed ring furrows.

Prosopon of fine terrace lines on testate specimens except on palpebral areas (smooth), posterior of pygidium. Pits on post-axial border of pygidium; decreasing, mixing with terrace lines anteriorly. Exfoliated pygidia pitted, cranidia smooth.

Remarks.—This species is assigned to the genus *Benthamaspis* based upon its relatively large eyes, prosopon of fine terrace lines, quadrate glabella, rounded genal angle, and semicircular pygidium with its triangular axis. *Benthamaspis rhochmotis* is distinguished from *B. onomeris* on the basis of its more quadrate glabella, better impressed preglabellar and occipital furrows, more furrowed pygidium, and narrower pygidial border. The cranidium of *B. mediacrista* (Cullison, 1944, p. 74, 75, pl. 34, figs. 25–27; Boyce, 1989, pl. 21, figs. 1–4) is closely comparable to that of *B. rhochmotis*. The glabella of *B. mediacrista*, however, is faintly keeled and slightly convex (tr.), bounded anteriorly by a weakly impressed preglabellar furrow. The pygidium assigned to *B. mediacrista* has a broad axis which tapers only slightly and 2–3 moderately impressed pleural furrows. *Benthamaspis rhochmotis* differs from *B. obrepta* (Lochman, 1966, p. 541, 542, pl. 62, fig. 6; Ross, 1951, pl. 29, figs. 20–22 as "Undetermined Genus and Species C") in having a glabella that is more quadrate, more steeply inclined preocular areas, better impressed occipital and preglabellar furrows, and inclined palpebral areas.

Etymology.—From *rhochmas*, Greek. m., for cleft or gully, referring to the well-impressed nature of the cranidial furrows, relative to the more effaced members of the genus.

Material.—Total 22 cranidia, 23 pygidia, 6 librigenae. Holotype: UMC 16826 (Pl. 21, Figs. 5, 6). Paratypes: UMC 16827–16832.

Occurrence.—Interstate-35 section: 11 collections from 476 to 650 ft (145–198 m) above the base of the section. Recovered from the *Benthamaspis rhochmotis* Zone at I-476, I-482, I-486, I-499, I-503, I-525, I-542, I-556, I-578, I-631, I-650. Kindblade Ranch section: 5 collections from 437 to 610 ft (133–186 m) above the base. Recovered from the *Benthamaspis rhochmotis* Zone at KR-437, KR-481, KR-483, KR-489, KR-610.

Genus *CHAPMANIA* n. gen.

Type species.—*Chapmania oklahomensis* n. sp., designated herein.

Diagnosis.—Genus of Bathyurellinae with short to long, thin, slightly convex, nearly horizontal anterior border; declined to vertical preglabellar field of moderate length; subrectangular, slightly to moderately convex evenly rounded glabella; anterior facial sutures moderately divergent to the anterior border furrow. Librigena with long librigenal spine; lateral border extended well onto librigenal spine, posterior border furrow which swept anteriorly to intersect lateral border furrow opposite the eye. Transverse pygidium with tapered, posteriorly rounded axis; 2–5 faintly defined ring furrows; pleural furrow limited to small pleural fields; broad border, slightly convex, with faintly impressed interpleural furrows. Prosopon generally smooth.

Assigned species.—*Bathyurellus permarginatus* Cullison, 1944; *Jeffersonia missouriensis* Cullison, 1944; *Licnocephala sminue* Fortey and Peel, 1990; *Chapmania taylori* n. sp., *C. carterensis* n. sp.; *C. oklahomensis* n. sp.; and *Chapmania* sp. 1.

Remarks.— *Chapmania* is erected to accommodate several species of Bathyurellinae with a subquadrate glabella, a flat, subhorizontal, short to long anterior cranidial border, preglabellar fields of moderate length, transverse pygidia, and broad pygidial borders which bear weakly impressed interpleural furrows. Size related variation in the length of the anterior border and preglabellar field is evident in some species. *Chapmania* is similar to *Peltabellia* Whittington (1953) in its overall degree of convexity, glabellar outline, and in the overall shape and proportions

of the pygidium. However, the cranidium of the type species, *Peltabellia peltabella* (Ross, 1951), has an anterior border that is short and sharply upturned to expose portions of the doublure, rather than long, slightly convex and nearly horizontal. *Punka* Fortey, 1979, is closely similar to *Chapmania* in its transverse pygidial morphology, in the presence of a flat anterior cranidial border, and in the course of the posterior border furrow on the librigena. The glabella of *Punka*, however, is elongate and pentagonal in outline and its preglabellar field is absent or very short.

Three species reassigned to *Chapmania* were previously reported from Missouri and included within the genera *Jeffersonia* Poulsen (1927) and *Bathyurellus* Billings (1865). *Jeffersonia* as revised herein excludes those trilobites with only slightly to moderately convex cranidia and pygidia that have broad borders and weakly to faintly impressed pleural furrows restricted to the pleural lobes. *Jeffersonia missouriensis* Cullison (1944, pl. 34, figs. 10, 12–16) lacks the strongly convex cranidium and pygidium typical of other species of *Jeffersonia* (Pls. 8, 11), has a flat anterior cranidial border, and has a consistently broader pygidial border. In these characters it conforms with the diagnosis of *Chapmania* n. gen. *Bathyurellus permarginatus* Cullison (1944, p. 70, pl. 34, figs. 23, 24; Fortey and Peel, 1990, p. 24, fig. 8) is known only from its transverse pygidium. When Fortey (1979) redefined and restricted *Bathyurellus* to those species of Bathyurellinae with a spatulate pygidium "*B.*" *permarginatus* was excluded from that genus. The transverse pygidium with its broad pygidial border and small pleural fields conform well to the type species of *Chapmania* and the species is reassigned pending recovery of an associated cranidium.

Historically, three species have been assigned to *Licnocephala*: *L. bicornuta* Ross (1951), *L. clavigadius* Hintze (1953), and *L. ovata* Ross (1953). These 3 species have a broad (tr.), horizontal anterior border bounded by broadly divergent and curving anterior facial sutures and an ovate outline to the glabella. Fortey and Peel (1990, p. 18, 19, figs. 4A–G, 5A–C) described *Licnocephala sminue* from the Ordovician of Greenland. The breadth of the frontal area and subrectangular outline of the glabella are strikingly different from those species previously assigned to *Licnocephala*. Several features of *L. sminue*, however, reflect the morphology of the type species of *Chapmania*. Both species feature a rectangular, moderately convex glabella, a long anterior border, a declined preglabellar field, and moderately divergent anterior facial sutures. Based upon these similarities, *L. sminue* is reassigned to *Chapmania*.

Etymology.— Named after the Chapman Ranch, located in the Arbuckle Mountains of Oklahoma, which is the site of the I-35 section.

CHAPMANIA OKLAHOMENSIS n. sp.

Plate 23, Figures 5–9

Diagnosis.— Species of *Chapmania* with slightly convex, keeled glabella (tr.), sinuous axial furrows opposite the palpebral lobes, long anterior border, weakly to moderately impressed anterior border furrow, broad (tr.) and slightly convex preocular fields, occipital furrow faintly impressed to absent. Pygidium moderately convex, semielliptical in outline, transverse with pygidial width 1.7–1.8 times pygidial length, axial furrows convergent until opposite terminal axial piece, furrows curved at axial piece; pleural fields steeply declined distally; border flat and near horizontal post-axially, slightly convex and slightly declined anteriorly; 4 pairs of weakly to faintly impressed interpleural furrows restricted to proximal half of the border.

Description.—Cranidium large, up to 1.6 cm long (sag.), moderately convex, expanded anteriorly. Glabella large, rectangular in outline, acutely rounded anteriorly; moderately convex (sag.), slightly convex and faintly keeled (tr.). Glabellar length 0.5 times cranidial length; occipital glabellar width 0.8–0.9 times glabellar length. Lateral glabellar furrows absent, on some small specimens 2 pairs of faint pits present on glabella opposite mid-length and anterior corner of palpebral lobe. Axial furrows weakly impressed, sinuous. Preglabellar furrow faintly to weakly impressed, angled medially. Rectangular occipital ring poorly defined by faint to absent occipital furrow. Small medial occipital node on large specimens. Anterior border flat, horizontal (sag.), tapered laterally; length variable, increasing in larger specimens, long, up to 0.3 times cranidial length (sag.) in large specimens; broad, 1.25 times glabellar length (tr.). Anterior border furrow broad, weakly impressed, evenly curved. Preglabellar field short, up to 0.1 times cranidial length, but longer in larger specimens; slightly convex, moderately to slightly declined anteriorly (small to large specimens). Preocular fields broad, widest at border furrow, slightly convex, moderately declined laterally. Palpebral lobes semielliptical in outline with faintly impressed palpebral furrow, large, 0.5–0.66 times glabellar

length, centered slightly posterior to glabellar mid-length. Palpebral areas narrow, flat to slightly convex, slightly declined from axial furrows (tr.). Posterior areas short (exsag.), broad, spike-like (tr.), lack posterior border furrow. Anterior branch of facial sutures strongly divergent at 45° angle to axis, broadly and evenly curved to intersect anterior border tangentially. Posterior branch of facial sutures strongly divergent.

Librigenae up to 1.4 cm long, moderately convex, triangular in outline with long, broad based librigenal spine. Librigenal fields moderately declined, slightly convex, of constant width. Lateral border furrow broad, weakly impressed, highlighted by change in slope. Border broad, flat, horizontal anteriorly, evenly tapered onto librigenal spine past intersection with posterior border furrow. Posterior border furrow faintly impressed, angled anteriorly to intersect lateral border furrow at mid-length of eye. Posterior border broad, moderately declined (tr.).

Pygidium uncommonly large, up to 1.5 cm in length (sag); moderately convex; transverse, semielliptical in outline with maximum pygidial width (tr.) 1.7–1.8 times pygidial length (sag.). Axis long, moderately tapered, rounded posteriorly, slightly convex; composed of short articulating half-ring, 1–4 poorly defined axial rings, long terminal axial piece. Terminal axial piece of variable length, may bear paired notches anteriorly; low, flush with post-axial pleural fields; fails to extend onto posterior border. Ring furrows slightly recurved axially; weakly impressed anteriorly, fainter successively; 0–3 pairs of pits on long terminal axial piece may represent incomplete ring furrows. Axial furrows straight anterior to terminal axial piece, subparallel along terminal axial piece; moderately impressed anteriorly, weakly impressed opposite terminal axial piece, faintly impressed to absent post-axially. Pleural fields small, slightly convex, steeply declined distally. Anterior pair of pleural furrows well impressed, 2 additional pairs weakly impressed, restricted to pleural fields. Border furrow absent; border defined by inflection in convexity at end of pleural furrows. Interpleural furrows faintly impressed, short, present as 2–3 pairs of depressions along adaxial portions of border. Border flat, slightly declined, shortest post-axially, slightly concave, moderately declined anteriorly. Articulating facet long (exsag.), convex, moderately declined.

Prosopon of fine ridges on testate articulating facet, librigenal spines, along cephalic and pygidial margin, ridges sparse on pygidial border at second pleura; otherwise smooth. Exfoliated glabella with 5 pairs of patches of small muscle scars, patches crescentic, posteriorly directed; pygidial axis with 1 pair per axial ring.

Remarks.—The cranidium of *Chapmania oklahomensis* n. sp. differs from that of *C. missouriensis* (Cullison, 1944, p. 71, 72, pl. 34, figs. 10–16) in having a longer anterior border, a more angular anterior lobe of the glabella, and palpebral lobes that are less elevated above the axial furrows. The pygidium of *C. oklahomensis* is more transverse than that of *C. missouriensis* with an axis that is narrower and less evenly tapered. The pygidium of *Chapmania oklahomensis* differs from that of *C. permarginata* (Cullison, 1944, p. 70, pl. 34, figs. 23–24; Fortey and Peel, 1990, fig. 8) in appearing more transverse and having pleural fields that extend to the posterior end of the axis. The cranidium of *Chapmania oklahomensis* differs from *C. sminue* (Fortey and Peel, 1990, p. 17–18, figs. 4A–H, figs. 5A–C) in having a flat anterior border, a moderately declined preglabellar field, declined palpebral areas, and a faintly impressed occipital furrow. The pleural fields on the pygidium of *C. oklahomensis* are not as well defined as those of *C. sminue*, the interpleural furrows better impressed on the border, and the border concave to post-axially flattened.

Etymology.—Name *oklahomensis*, derived from the name of the State of Oklahoma.

Material.—Total 39 cranidia, 56 pygidia, 29 librigenae. Holotype: UMC 16857 (Pl. 23, Fig. 3). Figured paratypes: UMC 16858, 16860, and 16165. Unfigured paratypes:UMC 16859, 168161–168164, 16867, and 16868.

Occurrence.—Interstate-35 section: 11 collections recovered from 302 to 371 ft (92–113 m) above the base of the section. Recovered from the *Jeffersonia granosa* Zone at I-302, I-305, I-307, I-314, I-326, I-338, I-346, I-349, I-361, I-368, I-371. Kindblade Ranch section: 2 collections recovered from the *Jeffersonia granosa* Zone at 319 and 349 ft (97, 106 m) above the base.

CHAPMANIA TAYLORI n. sp.

Plate 22, Figures 3–12

Jeffersonia missouriensis Cullison, 1944, pl. 34, fig. 24 [*non* pl. 34, fig. 23].

Diagnosis.—Species of *Chapmania* with a long anterior border, moderately convex (tr.) glabella, moderately impressed occipital furrow; semicircular pygidial outline, axial furrows straight, moderately convergent; border broad, with faint

pleural furrows and lacking interpleural furrows; prosopon smooth.

Abridged description.—Cranidium up to 1.4 cm long (sag.), subrectangular outline. Glabella elongate, very slightly tapered anteriorly, evenly rounded anteriorly, faintly keeled. Glabellar length 0.6 times cranidial length (sag.); palpebral glabellar width (tr.) 0.8 times glabellar length. Lateral glabellar furrows absent. Axial furrows moderately impressed, converge slightly from posterior margin to posterior corners of palpebral lobes, continue subparallel. Preglabellar furrow moderately impressed, evenly curved; joins axial furrows smoothly. Occipital ring 0.15 times cranidial length, nearly rectangular, drawn anteriorly at axial furrows. Faint occipital node present anteriorly on some specimens. Occipital furrow slightly curved, convex anteriorly, moderately impressed axially, constricted and shallowed at axial furrows. Anterior border variably long, up to 0.2 times cranidial length (sag.) in larger specimens; slightly concave, nearly horizontal (sag.); broad (tr.), with slight anterior arch in anterior view. Anterior border furrow moderately impressed, accented by change in slope; recurved axially on some specimens. Preocular fields long (sag.), moderately convex, steeply declined at anterolateral corner. Palpebral lobes large, 0.4–0.5 times glabellar length; semielliptical in outline with faint palpebral rim defined by broad palpebral furrow. Palpebral areas moderate in width, slightly convex, slightly inclined (tr.). Posterior areas wider than palpebral lobes; curved posteriorly; slightly declined. Posterior border furrow well impressed. Anterior branch of facial sutures moderately divergent, at roughly 30° angle from axis; slightly curved until border, strongly curved on border to approach anterior margin tangentially. Posterior branch of facial suture strongly divergent, slightly curved, intersects posterior margin at acute angle.

Librigenae large, up to 2.2 cm long, subtriangular outline with gently tapered librigenal spine. Librigenal field moderately convex, moderately declined generally, steeply declined at anterior corner. Lateral border furrow weakly impressed, accented by change in slope at border, intersected by faintly impressed posterior border furrow at oblique angle. Lateral border slightly concave, nearly horizontal anteriorly, constricted at intersection of lateral and posterior border furrows, continued onto librigenal spine, tapered until absent. Posterior border slightly convex.

Pygidium up to 1.4 cm long (sag.), semicircular in outline with pygidial width (tr.) 1.3–1.6 times pygidial length (sag.). Axis broad, pointed to bluntly truncated posteriorly, moderately convex (tr.); composed of triangular articulating half-ring, 2–4 faintly defined axial rings, trapezoidal terminal axial piece. Terminal axial piece stands in relief above border, with 2 posterolateral nodes; triangular post-axial ridge of variable definition present on specimens, may extend onto border. Anterior axial width 0.3 times pygidial width (tr.); axial length 0.66–0.75 times pygidial length. Ring furrows best impressed at axial furrows, 1–2 pairs of incomplete furrows present as paired notches posteriorly on axis. Axial furrows straight, moderately impressed anteriorly. Anterior-most pleural furrow well impressed, remaining 3 pair weakly to faintly impressed, largely restricted to pleural field. Up to 3 pairs of interpleural furrows, faintly impressed, restricted to pleural fields. Border slightly convex, of constant moderate width about margin. Adaxial portion of border on some specimens crossed by faint extension of 2 anterior pleural furrows or faint ridge drawn from posterior band of second pleura. Articulating facet long (exsag.), width of border, moderately convex, moderately declined.

Testate material smooth. Exfoliated specimens with broadly spaced pits on anterior cranidial, librigenal, pygidial borders; genal caecae on preglabellar field, fixigenae, librigenal field. Coarse ridges on articulating facet.

Remarks.—Cullison (1944, pl. 34, fig. 23) illustrated two pygidia as *Chapmania permarginata*. R. A. Fortey (*in* Fortey and Peel, 1990, p. 18, 24) treated these pygidia separately, considering the paratype pygidium to be significantly more transverse than the holotype (Cullison, 1944, pl. 34, fig. 24). Pygidia of *Chapmania taylori* n. sp. recovered from the Kindblade Formation of Oklahoma (Pl. 22, Figs. 7–10), exhibit similar pygidial proportions, the weakly furrowed pleural fields, the weakly impressed ring furrows, the sharp downturn at the distal end of the pleural fields, and the slightly convex, slightly declined pygidial border of Cullison's paratype specimen.

Chapmania taylori n. sp. differs from *C. oklahomensis* n. sp., the type species, in having a more convex cranidium, a shorter anterior border, and a moderately impressed occipital furrow. The pygidium of *C. taylori* differs from that of *C. oklahomensis* in being less transverse with an evenly tapering axis. *Chapmania taylori* differs from *C. missouriensis* (Cullison, 1944, p. 71, 72, pl. 34, figs. 10–16) in having a longer anterior border, an occipital furrow that widens axially, a broader pygidial border, and a narrower pygidial

axis. The axially recurved anterior border furrow of *C. taylori* is also seen on *C. sminue* (identified by R. A. Fortey *in* Fortey and Peel, 1990, p. 15–19, figs. 4A–G, 5A–C). *Chapmania taylori* differs, however, from *C. sminue* in having a moderately impressed occipital furrow, a slightly narrower glabella, and inclined palepebral areas.

Etymology.—Named for John F. Taylor, my undergraduate mentor.

Material.—Total 14 cranidia, 24 pygidia, 8 librigenae. Holotype: UMC 16837 (Pl. 22, Figs. 5, 6). Paratypes: UMC 16835, 16836, 16838–16842.

Occurrence.—Interstate-35 section: 2 collections from the *Ranasasus brevicephalus* Zone at 35 and 40 ft (11, 12 m) above the base of the section. Kindblade Ranch section: 12 collections from 66 to 152 ft (20–46 m) above the base. Recovered from the *R. brevicephalus* Zone at KR-66, KR-73, KR-75, KR-75A, KR-76, KR-82, KR-83, KR-108, KR-128, KR-132, KR-151, KR-152.

CHAPMANIA CARTERENSIS n. sp.

Plate 23, Figures 1–4

Diagnosis.—Species of *Chapmania* with moderately convex glabella (tr.)bounded by straight, subparallel axial furrows, short anterior border, moderately impressed anterior border furrow, moderately impressed occipital furrow. Librigena with moderately convex (tr.) librigenal field, lateral border slightly tapered posterior to intersection with posterior border furrow. Pygidium with straight-sided axis, moderately convex (tr.), with moderately inflated terminal axial piece (sag.); pleural fields moderately declined distally; border slightly convex, slightly declined, shortest axially, with 4 broad, weakly impressed interpleural furrows present adaxially. Prosopon of fine pits with terrace lines on librigenal spines and pygidial border.

Abridged description.—Large cranidia up to 1.8 cm uncommon, typically 0.5–1.2 cm in length (sag.), subquadrate outline. Glabella rounded anteriorly, subrectangular in outline with some specimens weakly constricted at posterior end of palpebral lobes, small specimens elongate. Glabellar length 0.7 times cranidial length (sag.); palpebral glabellar width (tr.) 0.7–0.85 (small to large) times glabellar length (sag.). Lateral glabellar furrows absent. Axial furrows moderately impressed, slightly convergent from posterior border to posterior corner of palpebral lobes, continue subparallel to slightly divergent. Preglabellar furrow moderately impressed laterally, weakly impressed axially and slightly angular, joins axial furrows at oblique angle. Occipital ring long, greater than 0.1 times cranidial length (sag.), subtrapezoidal in outline with broad posterior base, anterior and posterior margins arcuate. Occipital furrow moderately impressed axially, weakly impressed at axial furrows; straight across axis, anteriorly curved at axial furrows. Anterior border short, slightly greater than 0.1 times cranidial length (sag.), of constant length laterally, with slight anterior arch (tr.); slightly concave and horizontal for small specimens, flat and horizontal for larger specimens. Anterior border furrow moderately impressed, well defined by change in slope below preglabellar field. Preocular fields moderate in width (tr.), moderately convex. Palpebral lobes large (exsag.), 0.4–0.5 times glabellar length (sag.). Palpebral areas moderate in width, horizontal to slightly inclined in orientation (tr.). Posterior areas triangular in outline, slightly declined, extended posteriorly in slight curve. Anterior branch of facial sutures moderately to slightly divergent (small to large specimens), nearly straight until opposite anterior end of glabella, continued slightly curved. Posterior branch of facial sutures slightly curved to intersect posterior margin at acute angle.

Librigena up to 3.0 cm long, typically less than 1.8 cm long, subtriangular in outline with broad, adaxially curved librigenal spine of moderate length. Librigenal field moderate in width, slightly wider posteriorly, moderately convex (tr.). Lateral border furrow moderately impressed, shallower posterior to intersection with posterior border furrow until obsolete near midlength of librigenal spine. Lateral border slightly declined, nearly flat, narrow, of constant width anteriorly, slightly constricted at posterior border furrow, obsolete posteriorly. Posterior border furrow weakly impressed adaxially, angled anteriorly slightly inside facial suture, continued straight and faintly impressed until intersection with lateral border furrow. Eye socle with multiple fine threads on well preserved testate specimens.

Pygidium up to 1.8 cm long (sag.). Axis moderately long and wide, moderately convex (tr.), bluntly rounded posteriorly; with 4 successively shorter (sag.) axial rings, short terminal axial piece. Anterior axial width 0.25–0.3 times maximum pygidial width (tr.); axial length 0.6–0.75 times pygidial length (sag.). Terminal axial piece slightly inflated (sag.) set with 1 pair of faint, posterolateral nodes, poorly defined posteriorly. Short post-axial ridge extends onto border on some specimens. Anterior ring furrow moderately impressed, remainder weakly to faintly im-

pressed, nearly straight and shallowest axially, drawn anteriorly at axial furrows. Axial furrows shallowed at terminal axial piece to be faintly impressed or obsolete post-axially. Pleural fields moderate in size. Anterior pair of pleural furrows straight and well impressed, 3 additional pairs weakly impressed. Up to 4 pairs of interpleural furrows faintly to weakly impressed on pleural fields, continued onto border as broad folds posterior to faint ridges continued from posterior band of pleurae, furrows fail to reach lateral margin. Border broad, slightly shorter post-axially, slightly convex and slightly declined on small specimens, flat and horizontal for largest specimens.

Prosopon on small, testate specimens of fine, ubiquitous pits with fine terrace lines on librigenal spine, articulating facet, and anterior half of pygidial border; terrace lines on larger specimens on entire border and portions of pleural fields, pitting less evident; large pits on librigenal spine. Exfoliated specimens pitted.

Remarks.—*Chapmania carterensis* n. sp. differs from the type species, *C. oklahomensis* n. sp., in having a shorter (sag.) cephalic border, a more convex glabella, more well-impressed cranidial furrows, narrower preocular fields, a pygidium of greater convexity, and a broader pygidial border. Similarly, the anterior border of *C. carterensis* is shorter than that of *Chapmania sminue* (Fortey and Peel, 1990, p. 18, 19, pl. 4, figs. A–H, pl. 5, figs. A–C), and the preglabellar field is only moderately declined. The length of the border (sag.) in *C. carterensis* is comparable to that of *Peltabellia elegans* (Fortey and Peel, 1990, p. 22–25, pl. 6, figs. A–H, pl. 7, figs. A–H). *Chapmania missouriensis* (Cullison, 1944, p. 71, 72, pl. 34, figs. 10–16) exhibits a less well-impressed anterior border furrow, a relatively narrower glabella (tr.), and a broader occipital furrow on the cranidium than seen on *C. carterensis*. The pygidium of *C. missouriensis* possesses fainter ring furrows on a relatively broader axis, lacks the interpleural furrows on the border, and is less transverse than that of *C. carterensis* with fainter ring furrows. The pygidium illustrated by Ross (1951, pl. 15, fig. 15) as "*Jeffersonia*" *missouriensis* exhibits a distal downturn on the pleural region which justifies its inclusion in *Chapmania*. Ross' specimen, however, is less transverse with a longer (sag.) border than *C. carterensis*.

Material.—Total 27 cranidia, 47 pygidia, 17 librigenae. Holotype: UMC 16845 (Pl. 23, Fig. 1). Paratypes: UMC 16846–16856.

Occurrence.—Recovered in 7 collections from the *Jeffersonia granosa* Zone between 260 and 398 ft (79–121 m) above the base of the Interstate-35 section. I-260, I-266, I-305, I-314, I-368, I-371, I-396, I-398. Recovered in 1 collection from *J. granosa* Zone at 409 ft (125 m) above the base of the Kindblade Ranch section.

CHAPMANIA sp. 1

Plate 23, Figure 10

Remarks.—The transverse pygidium, identified herein as *Chapmania* sp. 1, with its broad border bearing interpleural furrows lies within the concept of *Chapmania*. This pygidium is significantly less convex than other species assigned to *Chapmania*, including: *C. permarginata* (Cullison, 1944), *C. missouriensis* (Cullison, 1944), *C. carterensis* n. sp., and *C. oklahomensis* n. sp. *Chapmania* sp. 1 resembles an undescribed pygidium from the Fillmore Formation, assigned to Zone G, in the Great Basin (Ross, 1951, pl. 30, fig. 27) in its slight convexity and broad border. The axial and ring furrows of *Chapmania* sp. 1, however, are better impressed and the axis relatively less tapered.

Occurrence.—One exfoliated pygidium recovered from the *Jeffersonia granosa* Zone at 305 ft (93 m) above the base of the Kindblade Ranch section.

Genus *LUTESVILLIA* Cullison, 1944

Type species.—*Lutesvillia bispinosa* Cullison, 1944, p. 79–80; by original designation.

Diagnosis.—Large, smooth Bathyurellinae with elongate, slightly convex (tr.), anteriorly expanded glabella; anterior border furrow strongly recurved axially; anterior border flat, longest axially; preglabellar field short, moderately declined; palpebral lobes set posteriorly; anterior branch of facial suture curved, divergent. Librigena slightly convex (tr.); broad, faintly impressed posterior border furrow crosses librigena to intersect lateral border furrow; lateral border broad anteriorly, constricted at intersection of border furrows, tapered until obsolete on librigenal spine. Pygidium quadrate to trapezoidal in outline with pronounced posterolateral spines drawn from border; axis with 3 axial rings; pleural and interpleural furrows restricted to pleural fields; border furrow weakly impressed.

Remarks.—The prominent posterolateral pair of pygidial spines of the type species, *Lutesvillia bispinosa*, is unique within the Bathyuridae. The only additional bathyurid genera to exhibit lat-

eral pygidial spines are *Pseudoolenoides* and *Ceratopeltis*. *Pseudoolenoides* Hintze (1953) features a prominent post-axial spine in addition to 1 or more pairs of small lateral spines. *Ceratopeltis* Poulsen (1937) has 2 pairs of pygidial spines which led Fortey and Peel (1983, p. 54) to suggest it may be congeneric with *Lutesvillia*. The glabella of *Ceratopeltis latilimbata*, however, is parallel-sided and moderately convex (tr.), the anterior border furrow is straight, the preglabellar field is oriented horizontally, and the pygidium is only slightly convex with poorly defined pleural fields (Fortey and Peel, 1983, pl. 6). *Ceratopeltis* and *Lutesvillia* are maintained as separate genera.

LUTESVILLIA BISPINOSA Cullison, 1944

Plate 24, Figures 1–13

Lutesvillia bispinosa Cullison, 1944, p. 79, 80, pl. 35, figs. 1–6; J. D. Loch, *in* Derby and others, 1991, fig. 10A.

Diagnosis.— Slightly convex (sag.) *Lutesvillia* with broad (tr.) bullet-shaped glabella; anterior border furrow strongly recurved and best defined axially, broad and weakly impressed laterally; anterior border flat axially, concave laterally; preglabellar field flat; occipital furrow straight; posterior areas of moderate width. Pygidial, librigenal characters as for the genus.

Supplemental description.—Whole cranidia to 1.0 cm in length (sag.), with larger fragments known; subquadrate in outline; slightly convex (sag.). Glabella large, elongate, pentagonal in outline, sharply rounded anteriorly, slightly expanded anteriorly, slightly convex (sag., tr.). Glabellar length 0.7 times cranidial length (sag.); palpebral glabellar width (tr.) 0.8 times glabellar length (sag.). Lateral glabellar furrows absent. Axial furrows moderately impressed, slightly sinuous, moderately divergent anterior to occipital ring furrows on small specimens to slightly divergent for larger specimens. Preglabellar furrow bent medially; moderately impressed, shallowest axially; intersects axial furrows at oblique angle. Occipital ring trapezoidal, broadest at posterior margin; length greater than 0.1 times cranidial length (sag.). Occipital furrow straight; moderately impressed, shallowest laterally. Anterior border furrow strongly recurved to posterior at axis; best seen axially as weakly impressed furrow, poorly defined laterally as change in slope. Anterior margin thick. Anterior border flat, slightly declined axially; longest axially due to recurved anterior border furrow, slightly greater than 0.1 times cranidial length (sag.); tapered, slightly concave laterally. Preglabellar field short axially, less than 0.1 times cranidial length (sag.); flat, moderately declined axially, slightly convex laterally. Preocular fields broad (tr.), slightly convex, moderately declined. Palpebral lobes simple, semicircular in outline; 0.4–0.5 times glabellar length (exsag.); centered posterior to glabellar mid-length. Palpebral furrows weakly impressed. Palpebral areas moderate in width, slightly convex, slightly inclined (tr.). Posterior areas short (exsag.), broad (tr.), slightly declined, triangular in outline with moderately impressed posterior border furrow. Anterior branch of facial sutures continuously curved, moderately divergent to anterior border furrow, curve adaxially to intersect anterior margin at oblique margin. Posterior branch of facial sutures sinuous, strongly divergent.

Librigenae large, up to 2.5 cm in length, slightly convex (tr.), elongate, triangular with stout librigenal spine of moderate length. Librigenal field of constant width, slightly convex (tr.), moderately declined laterally. Broad, weakly impressed posterior border furrow crosses librigena, intersects lateral furrow opposite posterior end of eye socle. Lateral border furrow broad, moderately impressed anteriorly; shallowed until absent posterior to intersection with posterior border furrow. Lateral border flat, narrow, of constant width anteriorly; constricted at intersection of border furrows; tapered posteriorly from intersection of posterior border furrow until absent, replaced by narrow marginal rim. Librigenal spine broad, moderately declined (tr.), sharply pointed.

Pygidium large, up to 1.6 cm in length (sag.), moderately convex, quadrate to trapezoidal in outline with prominent spines at posterolateral corners. Maximum pygidial width at posterior corners of articulating facets (tr.) 1.3–1.8 times pygidial length (sag.). Axis long, broad, moderately tapered, poorly defined posteriorly, moderately convex (tr.); composed of short articulating half-ring, 3 successively shorter axial rings, long terminal axial piece. Axial length 0.8 times pygidial length (sag.); axial width 0.3–0.33 times pygidial width (tr.). Ring furrows straight; 3 furrows weakly impressed on small or exfoliated specimens, on larger or testate specimens posterior furrows absent or incomplete, represented by lateral notches on axis. Axial furrows well impressed, fail to extend around terminal axial piece. Terminal axial piece declined evenly to post-axial border. Border furrow absent, border defined by abrupt inflection in convexity of pleural region and distal ends of pleural furrows.

Pleural fields small, discontinuous, triangular; crossed by 3 pairs of pleural furrows, anterior pair well impressed, remainder successively shorter, fainter; 2 pairs of faintly impressed interpleural furrows restricted to pleural fields best seen on exfoliated specimens. Posterior pleural band of anterior pleural rib extended onto border toward margin; articulating facet on anterior margin. Border broad, slightly concave away from posterolateral spines; spines drawn from border, extend beyond post-axial margin 0.33–0.5 times sagittal length of pygidium, horizontal to slightly upturned in orientation. Pygidial doublure broad, flat; narrow rim present along proximal edge; covered by terrace lines.

Prosopon of testate specimens largely smooth. Fine ridges on testate specimens along anterior cranidial margin, extended onto librigenae to end of librigenal spine; pygidia bear transverse ridges on articulating facet and adjacent to lateral margin of pygidium, parallel ridges on posterior margin of some pygidia, oblique ridges on pygidial spines. Exfoliated librigenae with faint genal caecae on librigenal field and proximal librigenal spine; exfoliated pygidia with deep pits.

Remarks.—The posterolateral spines on the pygidium of this species are unique to *Lutesvillia bispinosa*. Within the specimens from Oklahoma, however, there is marked ontogenetic change evident. Small specimens have relatively better impressed furrows, greater glabellar convexity (tr.), and more strongly divergent axial furrows resulting in a glabella which is more distinctly expanded anteriorly. The orientation and scale of the pygidial spines is also variable, but not as a function of size (compare Pl. 24, Figs. 5–7, 12). The spines may be oriented horizontally or be slightly upturned. The base of the spines on some specimens lies at the posterior corner of the articulating facet with the lateral margin extended posteriorly nearly straight to the end of the spine. The lateral margin on other specimens can exhibit a distinct angulation indicating the base of a spine of smaller scale.

Lutesvillia bispinosa was first recovered in southeastern Missouri where Cullison (1944) collected it from strata he assigned to the Theodosia Formation, the upper Jefferson City Formation of present usage.

Material.—Total 31 cranidia, 80 pygidia, 25 librigenae.

Occurrence.—Interstate-35 section: 27 collections from 255 to 650 ft (77–198 m) above the base of the section. Recovered from the *Jeffersonia granosa* Zone at I-255, I-260, I-266, I-283, I-289, I-305, I-314, I-346, I-347, I-371, I-373, I-396, I-398, I-413, I-430, I-446, I-451. Recovered from the *Benthamaspis rhochmotis* Zone at I-486, I-556, I-580, I-596, I-619, I-621, I-623, I-626, I-639, I-650.

Kindblade Ranch section: 7 collections from 313 to 571 ft (95–174 m) above the base. Recovered from the *Jeffersonia granosa* Zone at KR-313, KR-331, KR-349 and the *Benthamaspis rhochmotis* Zone at KR-437, KR-564, KR-568, KR-571.

LUTESVILLIA sp. 1

Plate 24, Figure 14

Remarks.—This cranidium is assigned to *Lutesvillia* based upon the strongly recurved anterior border furrow, the anteriorly expanded glabella, and the tapered occipital ring. The longer anterior border, evenly curved anterior lobe of the glabella, narrower glabella, and curved occipital furrow server to separate *Lutesvillia* sp. 1 from *L. bispinosa.*

Occurrence.—One cranidium recovered from the *Petigurus cullisoni* Zone at 805 ft (245 m) above the base of the Kindblade Ranch section.

Genus *PUNKA* Fortey, 1979

Type species.—*Bathyurellus nitidus* Billings, 1865, p. 265, 266; from the boulder at Lower Head, Newfoundland, Canada; by original designation (Fortey, 1979, p. 94).

Remarks.—*Punka* was erected and diagnosed by Fortey (1979, p. 94–96) to accommodate several trilobite species originally assigned to the genus *Bathyurellus* Billings (1865) but which possess a transverse pygidium with interpleural furrows on the border (see *Bathyurellus* remarks). Fortey (1979) selected *Bathyurellus nitidus* as the type species for *Punka* and described a new species *P. flabelliformis.* Several species earlier assigned to *Bathyurellus* may merit reassignment to *Punka* following restudy. These species include *"Bathyurellus" marginiatus* Billings (1865), *"B." expansus* Billings (1865), *"B." teicherti* Poulsen (1937), and *"Bathyurellus" pogonipensis* Hintze (1953).

Punka akoura possesses interpleural furrows which extend onto the pleural fields, indicating that these furrows are not restricted to the pygidial border as suggested by Fortey (1979, p. 94).

PUNKA AKOURA n. sp.

Plate 25, Figures 1–7

Diagnosis.—Large *Punka* with slightly convex cranidium (sag.); glabella subrectangular, broadly

rounded anteriorly, slightly convex (tr.); axial furrows weakly impressed; preglabellar field slightly declined; occipital furrow weakly impressed. Pygidium semicircular, slightly convex; 4 pairs of moderately impressed interpleural furrows on pleural field continued across border as broad folds. Smooth with fine pits on cephalon; genal caecae on preglabellar field, preocular areas, librigenal field of librigena.

Description.—Cranidium large, up to 2.0 cm long (sag.), moderately to slightly convex (sag.), mushroom-like in outline with a laterally expanded frontal area. Glabella moderate in size, relatively short (sag.), subquadrate in outline, slightly tapered and broadly rounded anteriorly, slightly convex (sag., tr.), faint keel on some specimens. Glabellar length 0.6 times cranidial length (sag.); palpebral glabellar width (tr.) 0.8–0.9 times glabellar length. Faint lateral glabellar furrows suggested by 2 pairs of faint, broad depressions at anterior end and mid-length of palpebral lobes. Axial furrows narrow, slightly sinuous opposite palpebral lobes; weakly impressed at palpebral lobes, shallower anteriorly and posteriorly. Preglabellar furrow faintly impressed, broadly curved across axis. Occipital ring rectangular in outline, short, less than 0.1 times glabellar length (sag.), small occipital node present on some specimens. Occipital furrow slightly curved, broad, weakly impressed axially, shallower laterally. Anterior border long, 0.25 times cranidial length; broad, 2.0 times palpebral glabellar width (tr.); slightly concave posteriorly (sag.), oriented horizontally at mid-length, recurved downward at anterior margin. Anterior border furrow faintly impressed, gently arcuate (tr.). Preglabellar field slightly concave, moderately declined, shortest axially, less than 0.1 times cranidial length (sag.). Preocular areas slightly convex, moderately declined, narrowest at palpebral lobes, widen rapidly anteriorly. Palpebral lobes semicircular with weakly impressed palpebral furrow; long, 0.4 times glabellar length (sag.); set posteriorly, centered posterior to cranidial mid-length. Palpebral fields narrow, slightly inclined, slightly convex (tr). Posterior fields short (sag.), triangular, moderately declined (tr.). Posterior border furrow absent. Anterior branch of facial sutures diverge sharply at 60° angle to axis, curve broadly opposite preglabellar field, converge at 45° angle, intersect anterior margin obliquely. Posterior branch of facial sutures diverge sharply at 70°, continue nearly straight to posterior margin.

Librigenae subtriangular in outline, with long, flat, broad librigenal spine. Lateral border furrow as broad fold, continued onto librigenal spine. Posterior border furrow absent. Librigenal field, librigenal spine slightly convex, moderately declined, broad (tr.). Lateral border narrow, slightly inclined, tapered posteriorly. Doublure broad, horizontal marginally, slightly upturned adaxially, extends anteriorly to axial line.

Pygidium large, up to 2.0 cm in length (sag.), moderately convex, semicircular in outline with pygidial width (tr.) estimated at 2.0 times pygidial length (sag.). Axis evenly tapered, moderately convex (tr.), composed of articulating half-ring, 4 axial rings, pentagonal terminal axial piece. Anterior axial width 0.2 times pygidial width (tr.); axial length 0.7 times pygidial length (sag.). Ring furrows straight, moderately impressed. Axial furrows narrow, straight, well impressed anteriorly; curve adaxially, shallow rapidly until obsolete posterior to fourth pair of interpleural furrows. Pleural fields small, triangular, slightly concave (tr.). Border furrow absent; border defined by distal ends of pleural furrows, inflection in slope. Four pairs of narrow, well-impressed pleural furrows, length of anterior pair (tr.) equal to anterior axial width. Four pairs of interpleural furrows arranged radially; narrow across pleural fields, deepest medially across inner half of border, continue to lateral margin as broad folds resulting in corrugated appearance. Articulating facet broad, width of border; rounds over in profile to join first pleural rib smoothly (exsag.). Doublure broad, corrugated.

Testate prosopon smooth, fine pits on exfoliated cephalic surfaces. Fine threads (2–4) along margin of cephalon, pygidium of smaller specimens. Genal caecae present on preglabellar field, preocular areas, librigenal fields of some specimens, best seen on exfoliated surfaces. Abundant terrace lines on doublure.

Remarks.—A large pygidium (UMC 16894; Pl. 25, Fig. 3) is selected as holotype for the species. This transverse pygidium is assigned to *Punka* based upon its semicircular outline and well-developed interpleural furrows. Several large cranidia and librigenae are assigned to *Punka akoura* based upon their relative size, dorsoventral height, and concurrent stratigraphic ranges. These associations, however, are open to discussion. Differences exist between the cephalon and the pygidium when examining the character of the prosopon of the exfoliated surfaces, the convexity of the axial lobe, and the impression of the axial furrows. Small specimens, however, consistently exhibit 2–4 thin, marginal threads on cranidia, pygidia, and librigenae. These threads are absent on larger specimens.

Punka akoura is most similar to those species with moderately to well-impressed furrows extending across the pygidial border to the margin: *"Bathyurellus" expansus, Punka flabelliformis* and *Punka*? sp. indet. of Fortey (1979). The pygidium of *"B." expansus* Billings (1865, p. 318–320, fig. 306a,b) features 4 pairs of interpleural furrows which extend from the axial furrows across the border to the lateral margin, as in *P. akoura.* The pygidial axis of *"B." expansus,* however, is relatively broader and shorter and there is a distinct angulation to the anterior margin not seen on *P. akoura.* In *P. flabelliformis* Fortey (1979, p. 96–99, pl. 33, figs. 1–10) the glabella overhangs the frontal area, the librigena bears a posterior border furrow, the prosopon is of fine terrace lines, and on the pygidium the pleural furrows are weakly impressed adaxially. The pygidium identified as *Punka*? sp. indet. (Fortey, 1979, p. 99, pl. 34, figs. 12, 14, 15) is most similar to *P. akoura,* although scarce and in open nomenclature. In *Punka*? sp. indet., however, interpleural furrows are absent and the pleural furrows extend across the border. Fortey has suggested that *Punka*? sp. indet. is likely associated with *"Bathyurellus" marginiatus* Billings (1865, p. 264, 265, fig. 248; Fortey, 1979, p. 99, pl. 35, figs. 11, 13). The cranidium of *"B." marginiatus* has a longer preglabellar field, deeper axial furrows, broader palpebral fields, and a glabella which is more inflated (tr.) and acutely rounded anteriorly.

The strongly furrowed pygidium and anteriorly rounded glabella of *Punka akoura* readily serve to distinguish it from *P. verecunda,* the other common *Punka* species in the Kindblade Formation.

A single fragmentary pygidium has been identified from the Kindblade in the collections made by Derby for Amoco as *Punka akoura* from 444 ft (135 m) above the base of the formation.

Etymology.—*Akoura* compounded from *akos,* Greek f., for furrow and *oura,* Greek f., for tail; referring to the strongly developed pleural and interpleural furrows on the pygidium.

Material.—Total 19 cranidia, 7 pygidia, 12 librigenae. Holotype: UMC 16894 (Pl. 25, Fig. 3). Figured paratypes: UMC 16892, 16893, 16895–16897. Unfigured paratype: UMC 16898.

Occurrence.—Interstate-35 section: 15 collections from 346 to 696 ft (105–212 m) above the base of the section. Recovered from the *Jeffersonia granosa* Zone at I-346, I-361, I-373, I-431, the *Benthamaspis rhochmotis* Zone I-476, I-482, I-486, I-499, I-503, I-523, I-525, I-556, I-625, I-626 and the *Petigurus cullisoni* Zone at I-696. Kindblade Ranch section: 6 collections from 411 to 564 ft (125–172 m) above base of section. Recovered from the *J. granosa* Zone at KR-411, KR-429, KR-431, and the *B. rhochmotis* Zone KR-451, KR-564, KR-568.

Punka verecunda n. sp.

Plate 26, Figures 1–10

Diagnosis.—Large *Punka* with moderately convex cranidium (sag.); glabella strongly tapered, sharply rounded anteriorly, keeled; axial furrows moderately impressed; preglabellar field slightly declined; occipital furrow moderately impressed. Pygidium elliptical, moderately convex; border moderately concave; 3 pairs of interpleural furrows faint on pleural fields, moderately impressed medially, obsolete before margin. Prosopon of ubiquitous deep pits.

Abridged description.—Cranidium moderately convex (sag.), mushroom-like in outline with a laterally expanded frontal area. Glabella large, elongate, pentagonal in outline, strongly tapered, sharply rounded anteriorly, moderately convex (sag.), weakly convex (tr.). Glabellar length 0.7 times cranidial length (sag.); basal glabellar width (tr.) 0.8 times glabellar length (sag.). Lateral glabellar furrows absent. Axial furrows sinuous, broad, constricted at both ends of palpebral lobes; moderately impressed at occipital furrow, shallower anteriorly. Preglabellar furrow sinuous, broad, faintly impressed, coincident with decrease in slope below glabella. Occipital ring strap-like. Occipital furrow broad, straight, moderately impressed axially, shallowest at axial furrows. Anterior border concave, broad, 0.33–0.4 times glabellar length (sag.); separated from preglabellar field by low, curved ridge which weakens abaxially. Preglabellar field and broad preocular areas slightly concave, highlighted by genal caecae. Palpebral lobes simple, crescentic, with weakly impressed palpebral furrow; 0.4 times glabellar length (sag.) centered posteriorly, anterior end at or posterior to glabellar mid-length. Palpebral fields narrow, horizontal (tr.). Posterior fields with faintly impressed posterior border furrow. Anterior branch of facial sutures strongly divergent at roughly 40° to axis, curve broadly to meet at axial line. Five pairs of muscle scars may be present on exfoliated glabellae.

Librigenae long, broadly concave (tr.), arcuate appearance due to elongate librigenal spine. Librigenal field small, exfoliated specimens with genal caecae. Border flat, broad. Posterior border furrow weakly impressed, fails to intersect lateral border furrow.

Pygidium elliptical in outline with pygidial width 1.8–2.0 times pygidial length. Axis keeled, evenly tapered, slightly convex (sag., tr.). Ring furrows weakly impressed. Axial length 0.5–0.7 times pygidial length (sag., larger to smaller specimens, respectively). Terminal axial piece stands in moderate relief above and descends evenly onto border, posterior margin poorly defined, appears bluntly rounded. Axial furrows moderately impressed anteriorly, shallowing until obsolete posterior to terminal axial piece. Pleural fields crossed by 4 pairs of pleural furrows, anterior pair well impressed, remainder faintly impressed. Border furrow faint anteriorly, obsolete posterior to terminal axial piece. Three pairs of interpleural furrows faint on pleural fields, widened at position of border furrow; anterior pair continues onto border well impressed, extends nearly to lateral margin with remainder fainter, shorter. Border broad, narrowest postaxially, gently concave (sag., tr.). Muscle scars on exfoliated specimens, 2 pairs per axial ring, 4 pairs on terminal axial piece. Doublure wide, narrowest at axis, inner margin upturned at position of border furrow, prosopon of terrace lines oblique to margin.

Prosopon of deep pits on testate, exfoliated material, best seen on anterior border. Subparallel terrace lines confined to testate libriginal border, articulating facets, distal margins of pygidial border.

Remarks.—This species is assigned to the genus *Punka* based upon the transverse pygidium with interpleural furrows on the border, the concave cranidial border, the large palpebral lobes set close to the glabella, the short preglabellar field, and the long librigenal spine on the librigenae.

Punka verecunda n. sp. is most similar to the type species, *P. nitida* (Billings, 1865; Whittington, 1953, p. 661, pl. 67, figs. 9, 13–15; 1963, p. 55–57, pl. 10, figs. 8, 9, 11, 12, 14–17, pl. 11, figs. 1–12, 14, 15). These species share a pentagonal glabella which fails to overhang a wide anterior border, anterior facial sutures which diverge at roughly 40°, weakly impressed interpleural furrows on the pygidial border, and a terminal axial piece with a poorly defined posterior margin. *Punka verecunda* differs, however, in having a cranidium of lower convexity (tr.) defined by sinuous axial and preglabellar furrows, 4 axial rings on the pygidium, and prosopon of deep pits. *Punka flabelliformis* Fortey (1979, p. 96–98, pl. 33, figs. 1–10) is distinct in having the anterior of the glabella rounded with deeper axial and preglabellar furrows, a better defined terminal axial piece, and deeper interpleural furrows on the pygidial border. The pygidium identified as *Punka*? sp. indet. by Fortey (1979, p. 99, pl. 35, figs. 12, 14, 15) differs from *P. verecunda* in having strong interpleural furrows which reach to pygidial margin and lacking pleural furrows.

Etymology.—*Verecundus*, Latin, for modest, shy, or demure; referring to the modestly impressed interpleural furrows on the pygidial border.

Material.—Total of 8 cranidia, 44 pygidia, 9 librigenae. Holotype: UMC 16901 (Pl. 26, Fig. 1). Paratypes: UMC 16902–16910.

Occurrence.—Interstate-35 section: 21 collections from 499 to 1,093 ft (152–333 m) above the base of the section. Recovered from the *Benthamaspis rhochmotis* Zone at I-499, I-503, I-556, I-584, I-586, I-671, I-685, the *Petigurus cullisoni* Zone at I-738, I-741, I-762, I-851, I-857, I-868, I-883, I-940, I-943, I-966 and the *Bolbocephalus stitti* Zone at I-996, I-1009, I-1034, I-1093.

Kindblade Ranch section: 13 collections from 489 to 823 ft (149–251 m) above the base. Recovered from the *Benthamaspis rhochmotis* Zone at KR-489, KR-520, KR-556, KR-564, KR-568 and the *Petigurus cullisoni* Zone at KR-671, KR-681, KR-684, KR-685, KR-741, KR-805, KR-809, KR-823.

PUNKA sp. 1

Plate 26, Figures 12, 13

Remarks.—These 3 cranidia are assigned to *Punka* on the basis of their long, convex anterior border, short preglabellar field, and posteriorly set palpebral lobes. *Punka* sp. 1 compares most closely with those *Punka* species with concave anterior borders separated from a short preglabellar field by a well-impressed anterior border furrow. *Punka nitida* (Billings, 1865; Whittington, 1953, p. 661, pl. 67, figs. 9, 13–15; 1963, p. 55, 57, pl. 10, figs. 8, 9, 11, 12, 14–17, pl. 11, figs. 1–12, 14, 15) features a relatively short preglabellar field, approximately 0.1 times the length of the anterior border, in conjunction with a broad glabella and anteriorly set palpebral lobes. The length of the preglabellar field of *Punka* sp. 1 is roughly 0.5 times that of the anterior border. The lengths of the anterior border and preglabellar field of *"Bathyurellus" marginiatus* Billings (1865, p. 264, 265, fig. 248; Fortey, 1979, p. 99, pl. 35, figs. 11, 13) are equal and the axial furrows are distinctly curved. The preglabellar field of *"Bathyurellus" expansus* Billings (1865, p. 318–320, fig. 306a,b) is greater than that of the anterior border and the anterolateral corners of the glabella are rounded. *"Bathyurellus" teicherti* Poulsen (1937, p. 53–55, pl. 7, figs. 2–5) and *"B." pogonipensis* Hintze (1953, p. 138–140, pl. 10, figs. 11–19) each

exhibit a prosopon of fine terrace lines. Additionally, "*B.*" *teicherti* features strongly inclined palpebral fields and the glabella of "*B.*" *pogonipensis* is posteriorly constricted.

The contemporaneous *Punka* species from the Kindblade Formation, *P. verecunda* n. sp. and *P. akoura* n. sp., have poorly defined anterior border furrows. *Bathyurellus arbucklensis* n. sp. is superficially similar to *Punka* sp. 1, however, the anterior border of *B. arbucklensis* is longer and the anterior border furrow is less well defined.

Occurrence.—Recovered from the *Benthamaspis rhochmotis* Zone at 471 ft (144 m) above the base of the Interstate-35 section and 429 ft (131 m) above base of the Kindblade Ranch section.

Genus *RANDAYNIA* Boyce, 1989

Type species.—*Randaynia saundersi* Boyce, 1989, p. 62, 63, by original designation.

Emended diagnosis.—Cranidium largely effaced, slightly convex transversely but highly convex sagittally with long, vertically oriented preglabellar field. Glabella quadrate in outline, nearly equant. Palpebral fields narrow, axial furrow nearly coincident with anterior facial suture. Librigenae with narrow lateral border and broad librigenal spine. Pygidium slightly convex (sag., tr.) with axial lobe poorly defined; terminal axial piece weakly inflated, commonly with 2 small tubercles. Pygidial border broad, nearly horizontal.

Discussion.—The generic diagnosis provided by Boyce (1989, p. 62) is, perhaps, too strictly drawn for those species he described under and assigned to *Randaynia.* The emended diagnosis is written to emphasize cranidial characters of the species included, at the expense of the tubercles on the pygidial axis.

Boyce (1989, p. 62) described two species of *Randaynia* and assigned 3 additional species to this genus. Among the assigned species Boyce (1989) included *Asaphellus gyracanthus* Raymond (1910, p. 39, 40, pl. 14, figs. 5–7; Fischer, 1954, pl. 4, fig. 10; Westrop and others, 1993, pl. 2, figs. 1–15). The presence of the medial glabellar node on *A. gyracanthus,* a feature unknown in other bathyurids, would argue for its exclusion from *Randaynia* (see Westrop and others, 1993).

The species *Bathyurellus*? *affinis* Poulsen (1937, p. 55, pl. 7, figs. 6, 7) was based upon pygidia recovered from Greenland. Boyce (1989, p. 59, 60, pl. 33, figs. 7–10, pl. 34, figs. 1–4) associated cranidia and librigenae from Newfoundland typical of *Randaynia* with the previously described pygidia, and agreed with Whittington (1953) and Fortey (1979) that this species belonged in the genus *Uromystrum.* This species is herein reassigned to *Randaynia,* based upon its effaced, highly sagittally convex, slightly transversely convex cranidium, quadrate glabella, narrow anterior border, strongly convex librigenae, and effaced pygidium. In contrast, the type species of *Uromystrum, U. validum* (Billings, 1865; Whittington, 1953, p. 659, 660, pl. 67, figs. 1–10), exhibits an elongate, posteriorly constricted, moderately to well-defined glabella; a longer, inclined anterior border; broad (tr.) librigenae; and a broad border. This adjustment restricts the generic range of *Uromystrum,* placing its first occurrence in the Middle Ordovician.

Boyce (1989) suggested that *Randaynia* may be allied to genera of the Subfamily Hystricurinae Hupé (1955) on the basis of the pygidial tubercles. I disagree with this suggestion, because hystricurids have cord-like librigenal borders with spike-like librigenal spines, glabellae that tend to be transversely inflated, and pygidia that typically possess a long, well-defined axis and only a very narrow border.

I include *Randaynia* within the Family Bathyuridae, Subfamily Bathyurellinae, based upon the presence of a cranidium which is highly convex sagittally but only slightly convex transversely, a long preglabellar field, a quadrate glabella, and the presence of a distinct, horizontal pygidial border. The prosopon of pits and terrace lines is typical of bathyurellines.

RANDAYNIA LEATHERBURYI n. sp.

Plate 27, Figures 1–7

Diagnosis.—*Randaynia* with weakly divergent anterior facial sutures, thin anterior border that continues onto the librigenal spine, large palpebral lobes centered near the glabellar midlength, and no occipital furrow. Pygidium with distinctly defined pleural fields crossed by pleural furrows, pygidial border with downward flexure along the margin.

Description.—Cranidium up to 1.0 cm in length (sag.), subconical outline, strongly convex (sag.). Glabella large, in dorsal view appears to extend length of cranidium; subquadrate, tapers anteriorly only slightly, broadly rounded anteriorly; width at palpebral lobes equal to 0.9 times glabellar length (sag.). Glabella strongly convex (sag.), due to sharp downward flexure anterior to palpebral lobes; slightly convex (tr.), may appear weakly keeled; stands in low relief above palpebral and posterior fields. Axial furrows weakly

impressed posteriorly, shallower anteriorly; converge from posterior margin until palpebral mid-length, then diverge slightly. Weakly impressed preglabellar furrow joins axial furrows at obtuse angle, preglabellar furrow slightly deeper at intersection. Occipital ring and occipital furrow absent, faint pair of depressions flank posterior of glabella. Anterior border narrow, of constant length laterally, oriented horizontally. Anterior border furrow appears as right angle flexure from border to preglabellar field. Preglabellar field near vertical in orientation, narrowest adaxially; long, in anterior view roughly 0.25 times length of glabella in dorsal view (sag.). Preocular fields narrow due to convergence of anterior facial suture and axial furrow at anterior end of palpebral lobes. Palpebral lobes simple, crescentic; large, approximately 0.4 times glabellar length (sag.); set anteriorly, lobe mid-length anterior to glabellar mid-length. Palpebral fields narrow, expand posteriorly, gently declined. Posterior fields large due to foreword position of eyes, triangular, declined, with faint posterior border furrow. Anterior branch of facial sutures straight, slightly divergent until anterior margin. Posterior branch of facial sutures strongly divergent at roughly 60°.

Librigenae subtriangular in outline, strongly convex (tr.). Librigenal fields large, highly convex (tr.), steeply declined, highlighted by genal caecae. Lateral border furrow well impressed as right angle between librigenal fields and border. Lateral border narrow, oriented horizontally, tapered posteriorly. Posterior border furrow faintly impressed, curved anteriorly to meet lateral border furrow anterior to mid-length of eye. Librigenal spine stout, conical in appearance. Lateral margin evenly curved.

Pygidium up to 1.0 cm in length (sag.), semi-elliptical in outline with anterior width equal to 1.4–1.7 times pygidial length (sag.), slightly convex (sag., tr.). Axis broad, long, slightly tapered, slightly convex (sag., tr.); composed of articulating half-ring, up to 6 axial rings, terminal axial piece, each separated by faint ring furrow. Terminal axial piece may be mildly inflated. Anterior axial width roughly 0.33 times maximum pygidial width (tr.); axial length approximately 0.75 times pygidial length (sag.). Axial furrows slightly curved; weakly impressed, shallow posteriorly until obsolete; with shallow depression anterior to terminal axial piece, opposite 5th or 6th axial ring. Pleural fields slightly convex, crossed by 2 weakly impressed pleural furrows. Border furrow absent, border defined by inflection in convexity of pleural regions. Border of constant width, concave adaxially, convex with sharply downturned lateral margin, 1 (–2?) faint pleural furrows extend onto border. Articulating facet concave, steeply declined, width of border (tr.).

Prosopon smooth.

Remarks.—The slightly convex (tr.), quadrate glabella, vertically oriented preglabellar field, narrow anterior cephalic border, and slightly convex pygidial axis argue for the inclusion of this species within the genus *Randaynia*. The sharp downward flexure on the pygidial margin of *R. leatherburyi* is unique among the species assigned to *Randaynia*.

Etymology.—This species is named for Doyle Leatherbury of Apache, Oklahoma, in recognition of his kind permission to collect from the type section of the Kindblade Formation.

Material.—Total 3 cranidia, 3 pygidia, 1 librigena. Holotype: UMC 16913 (Pl. 27, Figs. 1, 2). Paratypes: UMC 16914–16917.

Occurrence.—One collection recovered from the *Bolbocephalus stitti* Zone at 901 ft (275 m) above the base of the Kindblade Ranch section.

RANDAYINA sp. 1

Plate 27, Figures 8–12

Remarks.—Thirteen pygidia are assigned to *Randaynia* based upon the relative effacement of the pygidial furrows, the inflation at the posterior of the axis and the pleurae, and the presence of terminal axial tubercles. An exfoliated, fragmentary glabella and librigena (Pl. 27, Figs. 11, 12) from the same horizon are questionably associated with *Randaynia* sp. 1 based upon pitting on their surface. The broad, moderately convex border on the librigena is comparable to the convexity of the border on the illustrated pygidia of *Randaynia* sp. 1.

Randaynia sp. 1 is most similar to *R. saundersi* Boyce (1989, p. 62, 63, pl. 36, figs. 1–10, pl. 37, figs. 1–10) in the character of its pygidium and the presence of terminal axial tubercles. *Randaynia* sp. 1, however, has a pitted prosopon with terrace lines on the pygidial border, weaker axial furrows so that the axis and pleural field are confluent. The pygidial border of *R. leatherburyi* n. sp. (Pl. 27, Figs. 4, 5) has a distinct downward flexure along the margin, unlike the flat to slightly concave border of *Randaynia* sp. 1. The species *R. langdoni* Boyce (1989, p. 63, 64, pl. 38, figs. 1–11), has pygidia which are distinctly keeled, bear muscle scars on poorly defined axial rings, and are less inflated on the posterior axis. The pygidium of *R. taurifrons* (Dwight, 1884, p. 252,

253, pl. 7, figs. 1, 1a, 2, 2a, 2b, 3) lacks the swelling at the posterior of the axis, has better defined axial furrows, and better impressed pleural furrows. *Randaynia affinis* (Poulsen, 1937, p. 55, pl. 7, figs. 6, 7; see Boyce, 1989, p. 59, 60, pl. 33, figs. 7–10, pl. 34, figs. 1–4) has a pygidium which is more thoroughly effaced and less inflated than *Randaynia* sp. 1.

The pygidium of *R. perkinsi* is unknown (Whitfield, 1897, p. 183). Cady (1945, p. 539, 545), however, suggested that the locality which yielded *R. perkinsi* is stratigraphically younger than the majority of the Kindblade Formation.

Occurrence.—One collection from the *Strigigenalis caudata* Zone at 1,369 ft (417 m) above the base of the Interstate-35 section.

Family DIMEROPYGIDAE Hupé, 1955
Genus *DIMEROPYGIELLA* Ross, 1951

Type species.—*Dimeropygiella caudanodosa* Ross (1951, p. 123, 124), by original designation.

Diagnosis.—The diagnosis of Adrain and others (2001, p. 964) based upon the cladistic analysis of late Ibexian species of *Dimeropygiella* is accepted.

DIMEROPYGIELLA sp. 1
Plate 28, Figures 11–13

?*Hystricurus crassilimbatus* Poulsen, 1937; Boyce, 1989, p. 41.

Remarks.—Four cranidia and 2 fragmentary librigenae are assigned to *Dimeropygiella* based upon their protrusive, triangular anterior border, triangular outline, small eyes, and narrow palpebral areas. One poorly silicified librigena (from I-1227) is associated with the illustrated cranidia. The librigena is triangular in outline with a posterior facial suture which extends nearly to the genal angle, as is typical for other species of *Dimeropygiella.*

Dimeropygiella sp. 1 compares most closely with those species of *Dimeropygiella* with a very short preglabellar field, although comparisons are difficult due to the small size of the Kindblade specimens. *Dimeropygiella* sp. 1 compares most closely with three species of *Dimeropygiella* that have a very short preglabellar field, although comparisons are difficult due to the small size of the Kindblade specimens. These three comparative species are: (1) *Dimeropygiella caudanodosa* Ross (1951, p. 124, 125, pl. 35, figs. 18, 22–28; Ross, 1953, p. 637, 638, text-fig. 1, pl. 63, figs. 28–30; Hintze, 1953, p. 154, pl. 19, figs. 5, 10; Adrain and others, 2001, p. 964, 965, figs. 7.24–7.50, 8, 9), (2) *Dimeropygiella ovata* (Hintze, 1953, p. 155, pl. 19, figs. 1–4; Adrain and others, 2001, p. 965, figs. 10, 11.1–11.8, 11.10, 11.12) and (3) *Dimeropygiella fillmorensis* Adrain and others (2001, p. 965, figs. 11.9, 12). Each of those three species has a longer (sag.) anterior border that is more distinctly triangular, a coarser prosopon overall, and tubercles on the anterior border.

In glabellar proportion, lateral glabellar furrows, and shape of the anterior border *Dimeropygiella* sp. 1 resembles *Ischyrotoma* sp. of Desbiens and others (1996, p. 1147, pl. 2, fig. 19). This latter species, however, also features a pustulose anterior border. *Dimeropygiella blanda* Hintze (1953, p. 155, pl. 19, figs. 6–8; Adrain and others, 2001, p. 967, figs. 13, 14, 15.1–15.11) lacks granules or tubercles on the anterior border, as in *Dimeropygiella* sp. 1, but does exhibit an obvious preglabellar field.

Hystricurus crassilimbatus Poulsen (1937, p. 47, 48, pl. 5, figs. 5–8) features a pustulose cranidium with confluent anterior border and preglabellar furrows, and the free cheek bears a long librigenal spine. This species was recovered from the Cape Weber Formation of Greenland, but was poorly constrained stratigraphically. Boyce (1989, p. 41) identified *H. crassilimbatus* from the Barbace Cove Member of the Boat Harbour Formation of Newfoundland, which he believed equivalent to Ross and Hintze Zone G. In the Great Basin, however, *Hystricurus* is not known to occur above Zone F, the *Rossaspis superciliosa* Zone (Ross, 1951; Hintze, 1953). Boyce (1989, fig. 4) recovered *Isoteloides peri* associated with the specimens he assigned to *H. crassilimbatus.* This species occurs in the Kindblade Formation in the same stratigraphic interval as does *Dimeropygiella* sp. 1. In the absence of illustrations of Boyce's specimens, they are provisionally reassigned to *Dimeropygiella* sp. 1.

Material.—Total 4 cranidia, 2 fragmentary librigenae.

Occurrence.—Interstate-35 section: 2 collections from 1,212 to 1,227 ft (370–374 m) above the base of the section. Recovered from the *Strigigenalis caudata* Zone at I-1212, I-1227.

Genus *ISCHYROTOMA* Raymond, 1925

Type species.—*Ischyrotoma twenhofeli* Raymond, 1925, p. 54–55, by original designation.

Diagnosis.—The diagnosis of Adrain and others (2001, p. 953, 954) based upon the cladistic analysis of late Ibexian species of *Ischyrotoma* is accepted.

ISCHYROTOMA SILA n. sp.
Plate 28, Figures 1–10

Ischyrotoma abruptus (sic) Derby and others, 1991, figs. 3, 8.

Diagnosis.—Large *Ischyrotoma* with anteriorly tapered glabella which fails to overhang moderately declined preglabellar field; anterior border dorsally arched, laterally tapered, only slightly inflated, vertically oriented, short (sag.), breadth of glabella (tr.). Transverse pygidium with axis of 3 convex axial rings, terminal axial piece; 4 pairs of pleural ribs, anterior 2 pairs with pleural furrows. Granulose prosopon.

Description.—Cranidium small, up to 0.7 cm in length (sag.); subtrapezoidal in outline, rectangular if posterior areas lost; strongly convex (sag.). Glabella large, on small specimens subrectangular in outline, larger specimens slightly constricted at occipital furrow; strongly convex (sag.) but fails to overhang preglabellar field, moderately convex (tr.). Glabellar length 0.75 times cranidial length (sag.); palpebral glabellar width 0.9 times glabellar length. Two pair short, posteriorly curved lateral glabellar furrows as smooth patches on testate glabellae, as 2 vague notches on exfoliated specimens. Axial furrows well impressed, nearly straight, join well-impressed preglabellar furrow smoothly. Occipital ring short, 0.1 times cranidial length (sag.); nearly rectangular, drawn slightly anteriorly at axial furrows. Occipital furrow well impressed, broad; straight axially, bent anteriorly, deepened at axial furrows. Anterior border short (sag.), breadth of glabella (tr.) in dorsal view, oriented vertically; mildly inflated to stand slightly above adjacent preglabellar field; in anterior view dorsally arched in even curve, tapered laterally. Anterior border furrow faintly impressed on testate specimens to weakly impressed on exfoliated surfaces, sharply curved axially. Preglabellar field shortest axially, moderately convex, moderately declined (sag.). Preocular fields moderate in width (tr.), steeply declined to vertical in orientation. Palpebral lobes short, 0.33 times glabellar length; semi-elliptical in outline, centered at glabellar mid-length, anterior end at 2s glabellar furrow; with moderately impressed palpebral furrows. Palpebral areas narrow, nearly flat, oriented horizontally. Posterior areas triangular, long (exsag.), broad (tr.); moderately convex (tr.), moderately declined distally with well-impressed posterior border furrow. Anterior branch of facial sutures continuously curved from palpebral lobes to intersect anterior margin in line with axial furrow at obtuse angle. Posterior branch of facial sutures moderately divergent, meet posterior margin near genal angle.

Librigenae small, up to 0.7 cm in length (exsag.), slightly convex (tr.), triangular in outline with small lateral node for librigenal spine. Librigenal field large, slightly convex (tr.), steeply declined. Lateral border tubular, oriented vertically. Lateral border furrow well impressed, deepest medially, shallower anteriorly and toward genal angle; approaching librigenal spine furrow curved adaxially to bisect weakly impressed posterior border furrow. Simple eye socle present, eye commonly retained.

Pygidium small, up to 0.5 cm in length (sag.), strongly convex (sag., tr.), trapezoidal in outline with maximum pygidial width (tr.) 2.0 times pygidial length (sag.). Axis long, broad (tr.), strongly tapered, truncated posteriorly; composed of articulating half-ring, 3 axial rings, terminal axial piece. Anterior axial rings appear curved with convex side directed anteriorly, successively less curved (tr.) and shorter (sag.) posteriorly. Terminal axial piece with 2 posteriorly set tubercles; broad, steeply declined post-axial rib connects terminal axial piece to border. Maximum axial width 0.4 times maximum pygidial width (tr); axial length 0.8 times pygidial length (sag.). Anterior ring furrow moderately impressed; broadest, shallowest axially, notch-like distally; anterior side moderately declined, posterior side vertical; remaining furrows shallower, shorter (sag). Axial furrows straight, convergent; well impressed anteriorly, shallow until obsolete at posterior corner of terminal axial piece near tubercles. Pleural fields strongly convex (tr.), moderately declined adaxial to distinct downward flexure at distal ends of pleural furrows, remainder steeply declined; crossed by 4 pleural ribs and broad post-axial rib, ribs smoothly confluent with border. Four pairs of interpleural furrows moderately to well impressed; slit-like adaxially to flexure in pleural field, broadened marginally. Pleural furrows on anterior 2 pleural ribs; straight, slit-like, intersect preceding interpleural furrow. Border furrow well impressed, interrupted by pleural ribs, post-axial rib. Border tubular, steeply declined, of constant width about margin. Posterior margin horizontal in posterior view on testate specimens, dorsally arched on exfoliated specimens.

Prosopon of granules of varying sizes on testate cranidia, librigenae, pygidial axis, pleural ribs; cranidial, libriginal border prosopon varies from granules to ridges. Exfoliated specimens with deep pits.

Remarks.—The pygidium of this species is readily assigned to the family Dimeropygidae based upon the paired axial tubercles, the distinct downward flexure in the pleural field and the pleural ribs which are continuous with the border. Adrain and others (2001) listed 5 principle characters to diagnose *Ischyrotoma* and an additional 3 for the diagnosis of *Dimeropygiella* Ross (1951). Although the state of the ventral suture cannot be assessed for this species, several other characters do dictate the assignment of this species to *Ischyrotoma*, including the consistent length of the anterior border, convergent anterior facial sutures, the well-incised occipital furrow, and the presence of an obvious pleural furrow upon the second pleural rib of the pygidium.

The cladistic analysis of Adrain and others (2001, fig. 3) separated *Ischyrotoma anataphra* Fortey (1979) and *Ischyrotoma parallela* Boyce (1989) as an ingroup—a group of closely related taxa that is cladistically discrete from the remaining Ibexian taxa of *Ischyrotoma*. Their analysis noted that these two species bear primary fixigenal tubercles that do not differ in size from the adjacent tubercles in an obvious manner and that they have a rim-like, rather than "tab-like", anterior border. *Ischyrotoma sila* shares these characters and would presumably lie close to these species if the cladistic analysis duplicated. *Ischyrotoma sila* compares most closely with *Ischyrotoma anataphra* Fortey (1979, p. 104–106, pl. 36, figs. 1–13; Fortey, 1986, p. 21, pl. 1, figs. 4, 5; Boyce, 1989, p. 61, pl. 34, fig. 6), which also exhibits a dorsally arched, slightly inflated, ridged anterior border, like that of *I. sila*. The palpebral areas of *I. anataphra*, however, are narrower and the lateral glabellar furrows fainter than in *I. sila*. The relatively narrower pygidium of *I. anataphra* includes a more distinct fourth axial ring and a terminal axial piece which stands lower over the border than in *I. sila*. *Ischyrotoma parallela* Boyce (1989, p. 60–61, pl. 34, figs. 7, 8, pl. 35, figs. 1–10) features a long glabella which is more strongly convex than in *I. sila* such that it significantly overhangs the preglabellar field and anterior border (sag.) and rises more strongly above the axial furrow (tr.). The rim-like border of these three species separate them from the younger species of *Ischyrotoma* (listed in Adrain and others, 2001) which all include "tab-like" anterior borders.

Derby (*in* Derby and others, 1991, fig. 8) reported the recovery of *Ischyrotoma abrupta* from the Kindblade Formation based upon his work for Amoco. *Hystricurus abruptus* Cullison (1944, p. 80, pl. 34, figs. 45–49), however, features a medial furrow extending anteriorly from the preglabellar furrow onto the preglabellar field (see Pl. 28, Fig. 21) and may be better assigned to *Mesotaphraspis* Whittington and Evitt (1953). Examination of the cranidia assigned by J. R. Derby to *I. abrupta* from the Amoco collections lacks this medial furrow. The Amoco cranidia along with the available pygidia and librigenae, however, conform in all respects to *I. sila*. The specimens of *I. sila* from the Amoco collection were found at approximately 360 ft above the base of the Kindblade, nearly coincident with the lowest occurrence of the species in the present study.

Etymology.—From *silus*, Latin m., pug-nosed; referring to the slightly inflated, vertically oriented anterior cranidial border.

Material.—Total 33 cranidia, 6 pygidia, and 19 librigenae. Holotype: UMC 17085 (Pl. 28, Figs. 1, 2). Paratypes: UMC 17086–17090.

Occurrence.—Interstate-35 section: 17 collections from 368 to 691 ft (112–211 m) above the base of the section. Recovered from the *Jeffersonia granosa* Zone at I-266(?), I-368, I-371, I-386, I-430, I-434, I-451, I-471, from the *Benthamaspis rhochmotis* Zone at I-476, I-486, I-499, I-503, I-525, I-628, I-631, I-650 and from the *Petigurus cullisoni* Zone at I-691. Kindblade Ranch section: 8 collections from 319 to 770 ft (97–235 m) above the base. Recovered from the *J. granosa* Zone at KR-319, KR-349, KR-431, from the *B. rhochmotis* Zone at KR-441, KR-489, KR-556, KR-671 and from the *P. cullisoni* Zone at KR-770.

ISCHYROTOMA sp. 1

Plate 28, Figures 16–20

Remarks.—Known from 3 cranidia alone, this species is assigned to *Ischyrotoma* based upon the convergent branch of its anterior fixigenae and the "tab-like" nature of its anterior border.

Ischyrotoma sp. 1 shares an anterior border that is not distinctly pronounced with 3 other species. *Ischyrotoma* sp. 1 exhibits a longer and more convex (tr.) glabella than *I. sila*. Similarly, the glabella of *I. anataphra* Fortey (1979, p. 104–106, pl. 36, figs. 1–13; Fortey, 1986, p. 21, pl. 1, figs. 4, 5; Boyce, 1989, p. 61, pl. 34, fig. 6) is longer and more narrow than *Ischyrotoma* sp. 1. In both *I. twenhofeli* Raymond (1925, p. 54, 55, pl. 3, figs. 1, 2; Whittington, 1963, p. 45–47, pl. 7, figs. 1–13) and *Ischyrotoma parallela* Boyce (1989, p. 60, 61, pl. 34, figs. 7, 8, pl. 35, figs. 1–10) the glabella overhangs the anterior margin of the cranidium. *Ischyrotoma juabensis* (Fortey and Droser, 1996, p. 91, fig. 15.1–15.9; Adrain and others, 2001, p. 963, 964) lacks a preglabellar field.

Occurrence.—Interstate-35 section: 2 collections recovered from the *Petigurus cullisoni* Zone at 846 and 849 ft (258, 259 m) above the base of the section. Kindblade Ranch section: 1 collection from the *P. cullisoni* Zone at 770 ft (235 m) above the base.

Family UNCERTAIN
Genus *ROLLA* Cullison, 1944

Type species.—*Rollia goodwini* Cullison, 1944, p. 80, 81, by original designation.

ROLLIA GOODWINI Cullison, 1944
Plate 28, Figures 22, 23

Rollia goodwini Cullison, 1944, p. 80, 81, pl. 34, figs. 33–35.

Diagnosis.—Small trilobite with ovate glabella bearing 2 pairs of lateral glabellar furrows, strongly convex (tr.); preglabellar field long, steeply declined; palpebral lobes posteriorly set; strongly convex librigenal field on librigena, short librigenal spine; prosopon of granules with additional pustules on glabella, preglabellar field, and preocular fields.

Supplemental description.—Single cranidium small, 0.3 cm in length (sag.), subquadrate outline, moderately convex (sag.). Glabella moderate in size, broadly ovate in outline, evenly rounded anteriorly, widest (tr.) at palpebral lobes; moderately convex (sag.) to strongly convex (tr.). Glabellar length 0.6 times cranidial length (sag.); palpebral glabellar width (tr.) 1.2 times glabellar length, basal glabellar width (tr.) equals glabellar length. Two pairs of lateral glabellar furrows, notch-like; 1s—moderately impressed, posteriorly curved, 2s—weakly impressed, perpendicular to axis. Axial and preglabellar furrows well impressed, smoothly confluent. Occipital ring long, posteriorly extended, greater than 0.1 times cranidial length (sag.). Occipital furrow broad, well impressed axially, slightly shallower at axial furrows. Anterior border short (sag.), less than 0.1 times cranidial length, of constant length laterally; nearly flat, moderately declined, anterior arch evident in anterior view. Anterior border furrow well impressed, evenly curved (tr.). Preglabellar field long, greater than 0.1 times cranidial length (sag.), slightly convex, steeply declined. Preocular fields slightly convex, steeply declined laterally, moderate in width, total anterior width including preglabellar field 1.5 times palpebral glabellar width. Palpebral lobes up to 0.6 times glabellar length on small specimen, semicircular in outline with well-impressed palpebral furrow; set posteriorly, centered opposite 1s lateral glabellar furrow, anterior corner opposite 2s furrow. Palpebral areas moderate in width, moderately inclined, moderately convex (tr.). Posterior areas incomplete, probably short (exsag.), narrow (tr., based upon fixigenal suture) with moderately impressed posterior border furrow. Anterior branch of facial sutures moderately divergent, evenly curved adaxially to intersect anterior margin outside anterior extension of axial furrows. Posterior branch of facial sutures strongly divergent, strongly curved distally to intersect posterior margin at high angle.

Librigena up to 1.2 cm in length, moderately convex (tr.), subtriangular in outline with short librigenal spine. Broad ocular platform below thick eye socle. Librigenal field large, moderately convex, steeply declined (tr.). Lateral border furrow broad, well impressed anteriorly, shallowed posteriorly and fails to reach librigenal spine. Lateral border narrow, of constant width in dorsal view, appears thickened in lateral view. Posterior border furrow well impressed, short, deep, pit-like.

Prosopon of granules on testate surfaces, granules common on glabella, scarce on preglabellar field and preocular fields. Exfoliated surfaces deeply pitted.

Remarks.—The cranidium from Oklahoma conforms to material described from the Jefferson City Formation of Missouri by Cullison (1944, as Rich Fountain Formation). The cranidia differ only in the absence of the 3s lateral glabellar furrows from the small cranidium from the Kindblade Formation.

Material.—Total 1 cranidium, 2 librigenae.

Occurrence.—Recovered from the *Jeffersonia granosa* Zone at 268 and 305 ft (82, 93 m) above the base of the Interstate-35 section.

REFERENCES CITED

Adrain, J. M.; Westrop, S. R.; Landing, E.; and Fortey, R. A., 2001, Systematics of the Ordovician trilobites *Ischyrotoma* and *Dimeropygiella*, with species from the type Ibexian area, western U.S.A.: Journal of Paleontology, v. 75, p. 947–971.

Angelin, N.P., 1851–1878, Palaeontologica Scandinavica: Academiae Regiae Scientarum Suecanae (Holmiae). Pars I, Crustacea formationis transitionis, p. 1–24 (1851); Pars II, p. i–ix, 21–92 (1854). [Papers republished in combined and revised form, G. Lindstrom (ed.), p. i–x + 1–96 (1878).]

Bally, A. W.; and Cook, T. D., 1975, Stratigraphic atlas: North and Central America: Shell Oil Company (privately published), unpaginated.

Billings, E., 1859, Descriptions of some new species of trilobites from the Lower Silurian rocks of Canada: Canadian Naturalist, v. 4, p. 367–383.

———1865, Palaeozoic fossils: Volume 1. Containing descriptions and figures of new or little-known species of organic remains from the Silurian rocks: Geological Survey of Canada, 462 p.

Boyce, W. D., 1989, Early Ordovician trilobite faunas of the Boat Harbour and Catoche Formations (St. George Group) in the Boat Harbour–Cape Norman area, Great Northern Peninsula, western Newfoundland: Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 89-22, 169 p.

Boyce, W. D.; and Stouge, S., 1997, Trilobite and conodont biostratigraphy of the St. George Group, Eddies Cove west area, western Newfoundland: Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 97-1, p. 183–200.

Brand, U., 1976, Lower Ordovician conodonts from the Kindblade Formation, Arbuckle Mountains, Oklahoma: University of Missouri–Columbia unpublished M.S. thesis, 110 p.

Brett, K. D.; and Westrop, S. R., 1996, Trilobites of the Lower Ordovician (Ibexian) Fort Cassin Formation, Champlain Valley region, New York State and Vermont: Journal of Paleontology, v. 70, p. 408–422.

Brookby, H. E., 1969, Upper Arbuckle (Ordovician) outcrops in Richards Spur–Kindblade Ranch area, northwestern Wichita Mountains, Oklahoma: University of Oklahoma unpublished M.S. thesis, 73 p.

Burmeister, H., 1843, Die Organisation der Trilobiten aus ihren lebeden Verwandten entwickelt; Nebst einer systematischen Übersicht aller zeiter beischrieben: Arten, Berlin, 147 p.

Butts, Charles, 1945, Hollidaysburg–Huntingdon folio, Pennsylvania: U.S. Geological Survey Geologic Atlas of the United States, no. 227, 20 p.

Butts, Charles; and Moore, E. S., 1936, Geology and mineral resources of the Bellefonte Quadrangle, Pennsylvania: U.S. Geological Survey Bulletin 855, 111 p.

Cady, W. M., 1945, Stratigraphy and structure of west-central Vermont: Geological Society of America Bulletin, v. 56, p. 515–588.

Cloud, P. E., Jr.; and Barnes, V. E., 1948, The Ellenburger Group of central Texas: University of Texas Publication 4621, 473 p.

Cooper, G. A., 1952, New and unusual species of brachiopods from the Arbuckle Group in Oklahoma: Smithsonian Miscellaneous Collections, v. 117, no. 14, p. 1–35.

———1956, Chazyan and related brachiopods: Smithsonian Miscellaneous Collections, v. 127, 1245 p.

Cullison, J. S., 1944, The stratigraphy of some Lower Ordovician formations of the Ozark uplift: University of Missouri, School of Mines and Metallurgy Bulletin, Technical Series v. 15, no. 2, 111 p.

Dean, W. T., 1989, Trilobites from the Survey Peak, Outram, and Skoki Formations (Upper Cambrian–Lower Ordovician) at Wilcox Pass, Jasper National Park, Alberta, Canada: Geological Survey of Canada Bulletin 389, 141 p.

Decker, C. E., 1939a, Two lower Paleozoic groups, Arbuckle and Wichita Mountains, Oklahoma: Geological Society of America Bulletin, v. 50, p. 1311–1322.

———1939b, Classification of the Timbered Hills and Arbuckle Groups of rocks: Oklahoma Geological Survey Circular 22, 62 p.

Decker, C. E.; and Merritt, C. A., 1928, Physical characteristics of the Arbuckle Limestone: Oklahoma Geological Survey Circular 15, 56 p.

Derby, J. R., 1969, Revision of the Lower Ordovician–Middle Ordovician boundary in western Arbuckle Mountains, Oklahoma, *in* Ham, W. E. (ed.), Regional geology of the Arbuckle Mountains, Oklahoma: Oklahoma Geological Survey Guidebook 17, p. 35–37.

———1973, Lower Ordovician–Middle Ordovician boundary in western Arbuckle Mountains, Oklahoma, *in* Ham, W. E. (ed.), Regional geology of the Arbuckle Mountains, Oklahoma: Oklahoma Geological Survey Special Publication 73-3, p. 24–26.

Derby, J. R.; Lane, H. R.; and Norford, B. S., 1972, Uppermost Cambrian–basal Ordovician faunal succession in Alberta and correlation with similar sequences in the western United States: 24th International Geological Congress, Section 7, Paleontology, p. 503–512.

Derby, J. R.; Stitt, J. H.; and Creath, W. B., 1977, Biostratigraphy of Arbuckle and Simpson Groups, Oklahoma—the Cambro-Ordovician boundary through Chazyan: Program of the Third International Symposium on the Ordovician System, Ohio State University, Columbus, p. 8, 9.

Derby, J. R.; Creath, W. B.; Dresbach, R. I.; Ethington, R. L.; Loch, J. D.; Stitt, J. H.; McHargue, T. R.; Miller, J. F.; Miller, M. A.; Repetski, J. E.; Sweet, W. C.; Taylor, J. F.; and Williams, M., 1991, Biostratigraphy of the Timbered Hills, Arbuckle, and Simpson Groups, Cambrian and Ordovician, Oklahoma: a review of correlation tools and techniques available to the explorationist, *in* Johnson, K. S. (ed.), Late Cambrian–Ordovician geology of the southern Midcontinent, 1989 symposium: Oklahoma Geological Survey Circular 92, p. 15–41.

Desbiens, S.; Bolton, T. E.; and McCracken, A. D., 1996, Fauna of the lower Beauharnois Formation (Beekmantown Group, Lower Ordovician), Grand-Isle, Quebec: Canadian Journal of Earth Science, v. 33, p. 1132–1153.

Donovan, R. N.; and Ragland, D. A., 1986, Paleozoic stratigraphy of the Slick Hills, southwestern Oklahoma, *in* Donovan, R. N. (ed.), The Slick Hills of southwestern Oklahoma—fragments of an aulacogen?: Oklahoma Geological Survey Guidebook 24, p. 13–16.

Donovan, R. N.; Ragland, D. A.; and Schaefer, D., 1986, Stop 4: Geology of the Cook Creek road cut, *in* Donovan, R. N. (ed.), The Slick Hills of southwestern Oklahoma—fragments of an aulacogen?: Oklahoma Geological Survey Guidebook 24, p. 100–105.

Dresbach, R. I., 1998, Early Ordovician conodonts and biostratigraphy of the Arbuckle Group in Oklahoma: University of Missouri–Columbia unpublished Ph.D. dissertation, 275 p.

Dresbach, R. I.; and Ethington, R. L., 1991, Conodont biostratigraphy of Lower Ordovician rocks, Arbuckle Group, southern Oklahoma, *in* Johnson, K. S. (ed.), Late Cambrian–Ordovician geology of the southern Midcontinent, 1989 symposium: Oklahoma Geological Survey Circular 92, p. 215–216.

Dunham, R. J., 1962, Classification of carbonate rocks according to depositional texture, *in* Ham, W. E. (ed.), Classification of carbonate rocks: American Association of Petroleum Geologists Memoir 1, p. 108–121.

Dwight, W. B., 1884, Recent explorations in the Wappinger Valley Limestone of Duchess County, New York: American Journal of Science, Third Series, v. 27, p. 249–259.

Edwards, L. E., 1984, Insights on why graphic correlation (Shaw's method) works: Journal of Geology, v. 92, p. 583–597.

————1991, Quantitative biostratigraphy, *in* Gilinsky, N. L.; and Signor, P. W. (eds.), Analytic paleobiology: The Paleontological Society, Short Courses in Paleontology, no. 4, p. 37–58.

Ethington, R. L.; and Clark, D. L., 1981, Lower and Middle Ordovician conodonts from the Ibex area, western Millard County, Utah: Brigham Young University Geology Studies, v. 28, no. 2, 155 p.

Ethington, R. L.; and Dresbach, R. I., 1990, Ordovician conodonts in the Arbuckle Group, southern Arbuckle Mountains, Oklahoma, *in* Ritter, S. M. (ed.), Early to Middle Paleozoic conodont biostratigraphy of the Arbuckle Mountains, southern Oklahoma: Oklahoma Geological Survey Guidebook 27, p. 33–37.

Ethington, R. L.; and Repetski, J. E., 1984, Paleobiogeographic distribution of Early Ordovician conodonts in central and western United States, *in* Clark, D. L. (ed.), Conodont biofacies and provincialism: Geological Society of America Special Paper 196, p. 89–101.

Fay, R. O., 1989, Geology of the Arbuckle Mountains along Interstate 35, Carter and Murray Counties, Oklahoma: Oklahoma Geological Survey Guidebook 26, 50 p.

Fischer, D. W., 1954, Lower Ordovician (Canadian) stratigraphy of the Mohawk Valley, New York: Geological Society of America Bulletin, v. 65, p. 71–96.

Flower, R. H., 1957, Studies of the Actinoceratida: New Mexico Institute of Mining and Technology Memoir 2, 73 p.

————1964, The nautiloid Order Ellesmeroceratida (Cephalopoda): New Mexico Institute of Mining and Technology Memoir 12, 234 p.

Fortey, R. A., 1975, Early Ordovician trilobite communities: Fossils and Strata, no. 4, p. 331–352.

————1979, Early Ordovician trilobites from the Catoche Formation (St. George Group), western Newfoundland: Geological Survey of Canada Bulletin, v. 321, p. 61–114.

————1980, Generic longevity in Lower Ordovician trilobites: relation to environment: Paleobiology, v. 6, p. 24–31.

————1986, Early Ordovician trilobites from the Wandel Valley Formation, eastern North Greenland: Grønlands Geologiske Undersøgelse Rapport, v. 132, p. 15–25.

Fortey, R. A.; and Droser, M. L., 1996, Trilobites from the base of the Middle Ordovician, western United States: Journal of Paleontology, v. 70, p. 73–99.

Fortey, R. A.; and Peel, J. S., 1983, The anomalous bathyurid trilobite *Ceratopeltis* and its homeomorphs: Special Papers in Palaeontology, v. 30, p. 51–57.

————1990, Early Ordovician trilobites and molluscs from the Poulsen Cliff Formation, Washington Land, western North Greenland: Geological Society of Denmark Bulletin, v. 38, p. 11–32.

Fortey, R. A.; Bassett, M. G.; Harper, D. A. T.; Hughes, R. A.; Ingham, J. K.; Molyneux, S. G.; Owen, A. W.; Owens, R. M.; Rushton, A. W. A.; and Sheldon, P. R., 1991, Progress and problems in the selection of stratotypes for the bases of series in the Ordovician System of the historical type area in the UK, *in* Barnes, C. R.; and Williams, H. S. (eds.), Advances in Ordovician geology: Geological Survey of Canada Paper 90-9, p. 5–25.

Gao, G.; and Land, L. S., 1991, Early Ordovician Cool Creek Dolomite, middle Arbuckle Group, Slick Hills, SW Oklahoma, U.S.A.: origin and modification: Journal of Sedimentary Petrology, v. 61, p. 161–173.

Goldhammer, R. K.; Lehmann, P. J.; and Dunn, P. A., 1992, Third-order sequences and high frequency cycle stacking patterns in Lower Ordovician platform carbonates, El Paso Group (Texas): implications for carbonate sequence stratigraphy, *in* Candelaria, M. P.; and Reed, C. L. (eds.), Karst, karst-related diagenesis, and reservoir development: examples from Ordovician–Devonian age strata of West Texas and the Mid-Continent: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Field Trip Guidebook 92-33, p. 59–92.

————1993, The origin of high-frequency platform carbonate cycles and third-order sequences (Lower Ordovician El Paso Group, West Texas): constraints from outcrop data and stratigraphic modeling: Journal of Sedimentary Petrology, v. 63, p. 318–359.

Ham, W. E., 1950, Geology and petrology of the Arbuckle Limestone in the southern Arbuckle Mountains, Oklahoma: Yale University unpublished Ph.D. dissertation, 162 p.

————1955, Geology of the Arbuckle Mountain region: Oklahoma Geological Survey Guidebook 3, 61 p.

Hintze, L. F., 1952 [1953], Lower Ordovician trilobites from western Utah and eastern Nevada: Utah Geological and Mineralogical Survey Bulletin 48, 249 p.

Hupé, P., 1955, Classification de trilobites: Annales de Palaeontologie, v. 41, p. 91–325 .

Lees, J. A., 1967, Stratigraphy of the Lower Ordovician Axemann Limestone in central Pennsylvania: Pennsylvania Geological Survey General Geology Report 52, 79 p.

Lindsay, R. F.; and Koskelin, K. M., 1991, Arbuckle Group depositional parasequences, southern Oklahoma, *in* Johnson, K. S. (ed.), Late Cambrian–Ordovician geology of the southern Midcontinent, 1989 symposium: Oklahoma Geological Survey Circular 92, p. 71–84.

Loch, J. D., 1991, Trilobite succession within the Lower Ordovician Kindblade Formation of southern Oklahoma [abstract]: Geological Society of America Abstracts with Programs, v. 23, p. A296.

————1995, An affirmation of the Jeffersonian Stage (Ibexian) of North America and a proposed boundary stratotype, *in* Cooper, J. D.; Droser, M. L.; and Finney, S. C. (eds.), Ordovician odyssey: Seventh International Symposium on the Ordovician System, Short Papers, p. 45–48.

————1998, Potential boundary stratotype and horizon for the Lower Ordovician (Ibexian) Cassinian Stage for southern Laurentia [abstract]: Geological Society of America Abstracts with Programs, v. 30, p. 10.

Loch, J. D.; Chludzinski, G. P.; and Spreng, A. C., 1993, Lower Ordovician faunas, correlation and bioherms in the lower Jefferson City near Rolla, Missouri [abstract]: Geological Society of America Abstracts with Programs, v. 25, p. 63.

Lochman, C., 1966, Lower Ordovician (Arenig) faunas from the Williston Basin, Montana and North Dakota: Journal of Paleontology, v. 40, p. 512–548.

Lochman-Balk, Christina, 1959, Family Komaspididae, *in* Moore, R. C. (ed.), Treatise on invertebrate paleontology, Part O, Arthropoda 1: Geological Society of America and University of Kansas Press, New York City and Lawrence, Kansas, p. O294–O296.

Ludvigsen, R., 1978, Lower Ordovician trilobites of the Oxford Formation, eastern Ontario: Canadian Journal of Earth Sciences, v. 16, p. 859–865.

Miller, F. X., 1977, The graphic correlation method in biostratigraphy, *in* Kauffman, E. G.; and Hazel, J. E. (eds.), Concepts and methods in biostratigraphy: Dowden, Hutchison, and Ross Publishers, Stroudsburg, Pennsylvania, p. 165–186.

Moore, R. C. (ed.), 1959, Treatise on invertebrate paleontology, Part O, Arthropoda 1: Geological Society of America and University of Kansas Press, New York City and Lawrence, Kansas, 560 p.

Murphy, M. A., 1977, On time-stratigraphic units: Journal of Paleontology, v. 51, p. 213–219.

Osleger, D.; and Read, J. F., 1991, Relation of eustasy to stacking patterns of meter-scale carbonate cycles, Late Cambrian, U.S.A.: Journal of Sedimentary Petrology, v. 61, p. 1225–1252.

Poulsen, C., 1927, The Cambrian, Ozarkian, and Canadian faunas of northeast Greenland: Meddelelser om Grønland, v. 70, p. 233–343.

————1937, On the Lower Ordovician faunas of east Greenland: Meddelelser om Grønland, v. 119, p. 1–72.

————1946, Notes on Cambro–Ordovician fossils collected by the Oxford University Ellesmere Land Expedition, 1934–5: Quarterly Journal of the Geological Society of London, v. 102, p. 299–337.

Ragland, D. A.; and Donovan, R. N., 1986, An environmental analysis of the Lower Ordovician Cool Creek Formation of southwestern Oklahoma, *in* Donovan, R. N. (ed.), The Slick Hills of southwestern Oklahoma—fragments of an aulacogen?: Oklahoma Geological Survey Guidebook 24, p. 21–28.

Raymond, P. E., 1905, The trilobites of the Chazy limestone: Carnegie Museum Annals, v. 3, p. 328–386.

————1910, Notes on Ordovician trilobites; II, Asaphidae from the Beekmantown: Carnegie Museum Annals, v. 7, p. 35–44.

————1913, A revision of the species which have

been referred to the genus *Bathyurus*: Bulletin of the Victoria Memorial Museum, v. 1, p. 51–69.

————1925, Some trilobites of the lower Middle Ordovician of eastern North America: Harvard University, Museum of Comparative Zoology Bulletin 67, 180 p.

Read, J. F., 1980, Carbonate ramp-to-basin transitions and foreland basin evolution, Middle Ordovician, Virginia Appalachians: American Association of Petroleum Geologists Bulletin, v. 64, p. 1575–1612.

Repetski, J. E.; Loch, J. D.; Ethington, R. L.; and Dresbach, R. I., 2000, A preliminary reevaluation of the stratigraphy of the Roubidoux Formation of Missouri and correlative Lower Ordovician units in the southern Midcontinent, *in* Johnson, K. S. (ed.), Platform carbonates in the southern Midcontinent, 1996 symposium: Oklahoma Geological Survey Circular 101, p. 103–106.

Ride, W. D. L. (ed.), 1999, International code of zoological nomenclature (4th edition): International Commission on Zoological Nomenclature, 306 p.

Riding, R.; and Toomey, D. F., 1972, The sedimentological role of *Epiphyton* and *Renalcis* in lower Ordovician mounds, southern Oklahoma: Journal of Paleontology, v. 46, p. 509–519.

Rigby, J. K.; and Toomey, D. F., 1978, A distinctive sponge spicule assemblage from organic buildups in the Lower Ordovician of southern Oklahoma: Journal of Paleontology, v. 52, p. 501–506.

Ross, J. P., 1966, Early Ordovician ectoproct from Oklahoma: Oklahoma Geology Notes, v. 26, p. 218–224.

Ross, R. J., Jr., 1951, Stratigraphy of the Garden City Formation in northeastern Utah and its trilobite fauna: Peabody Museum of Natural History Bulletin 6, 161 p.

————1953, Additional Garden City (Early Ordovician) trilobites: Journal of Paleontology, v. 27, p. 633–646.

————1976, Ordovician sedimentation in the western United States, *in* Bassett, M. G. (ed.), The Ordovician System: proceedings of a Palaeontological Association symposium: University of Wales Press and National Museum of Wales, Cardiff, p. 73–105.

Ross, R. J., Jr.; and 27 co-authors, 1982, The Ordovician System in the United States: International Union of Geological Sciences Publication 12, 73 p.

Ross, R. J., Jr.; Hintze, L. F.; Ethington, R. L.; Miller, J. F.; Taylor, M. E.; and Repetski, J. E., 1997, The Ibexian, Lowermost Series in the North American Ordovician: U.S. Geological Survey Professional Paper 1579-A, 50 p.

St. John, J. W., Jr.; and Eby, D. E., 1978, Peritidal carbonates and evidence for vanished evaporites in the Lower Ordovician Cool Creek Formation, Arbuckle Mountains, Oklahoma: Gulf Coast Geological Association Transactions, v. 28, p. 589–599.

Salvador, Amos (ed.), 1994, International stratigraphic guide (2nd edition): International Union of Geological Sciences and Geological Society of America, Trondheim, Norway, and Boulder, Colorado, 214 p.

Sando, W. J., 1957, Beekmantown Group (Lower Ordovician) of Maryland: Geological Society of America Memoir 68, 161 p.

————1958, Lower Ordovician section near Chambersberg, Maryland: Geological Society of America Bulletin, v. 69, p. 837–854.

Scott, G. H., 1985, Homotaxy and biostratigraphical theory: Palaeontology, v. 28, p. 777–782.

Sepkoski, J. J., Jr., 1982, Flat-pebble conglomerates, storm deposits, and the Cambrian bottom fauna, *in* Einsel, G.; and Seilacher, A. (eds.), Cyclic and event stratification: Springer-Verlag, Berlin and New York City, 536 p.

Shaw, A. B., 1964, Time in stratigraphy: McGraw-Hill, New York City, 365 p.

Smith, G. A.; and Toomey, D. F., 1964, Chitons from the Kindblade Formation (Lower Ordovician), Arbuckle Mountains, southern Oklahoma: Oklahoma Geological Survey Circular 66, 41 p.

Stitt, J. H., 1971, Late Cambrian and earliest Ordovician trilobites, Timbered Hills and Lower Arbuckle Groups, western Arbuckle Mountains, Murray County, Oklahoma: Oklahoma Geological Survey Bulletin 110, 83 p.

————1977, Late Cambrian and earliest Ordovician trilobites, Wichita Mountains area, Oklahoma: Oklahoma Geological Survey Bulletin 124, 79 p.

————1983, Trilobites, biostratigraphy, and lithostratigraphy of the McKenzie Hill Limestone (Lower Ordovician), Wichita and Arbuckle Mountains, Oklahoma: Oklahoma Geological Survey Bulletin 134, 54 p.

Stouge, S.; and Boyce, D. W., 1983, Fossils of northwestern Newfoundland and southeastern Labrador: conodonts and trilobites: Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 83-3, 55 p.

Swinnerton, H. H., 1915, Suggestions for a revised classification of trilobites: Geological Magazine, new series, v. 2, p. 487–496, 538–545.

Tenney, C. M., 1984, Facies analysis of the Kindblade Formation, upper Arbuckle Group, southern Oklahoma: University of Oklahoma unpublished M.S. thesis, 110 p.

Thompson, T. L., 1991, Paleozoic succession in Missouri, Part 2, Ordovician: Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigation 70, 282 p.

Toomey, D. F., 1964, Ellenburger (Lower Ordovician) sponge beds in central Texas: Tulsa Geological Society Digest, v. 32, p. 98–111.

————1978, Observations on the Monument Spring Member of the Lower Ordovician Marathon Formation, Marathon region, southwest Texas, *in* Mazzullo, S. J. (ed.), Tectonics and Paleozoic facies of the Marathon Geosyncline,

West Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Publication 78-17, p. 215–221.

———1980, Distribution of Lower Ordovician *Ceratopea* (gastropod opercula) in the Kindblade Formation, Wichita Mountains, southwestern Oklahoma: Oklahoma Geology Notes, v. 40, p. 19–29.

Toomey, D. F.; and Nitecki, M. H., 1979, Organic buildups in the Lower Ordovician (Canadian) of Texas and Oklahoma: Fieldiana (Geology), new series, no. 2, 181 p.

Twenhofel, W. H., 1938, Geology and paleontology of the Mingan Islands, Quebec: Geological Society of America Special Paper 11, 132 p.

———(ed.), 1954, Correlation of the Ordovician formations of North America: Geological Society of America Bulletin, v. 65, p. 247–298.

Ulrich, E. O.; and Cooper, G. A., 1938, Ozarkian and Canadian Brachiopoda: Geological Society of America Special Paper 13, 323 p.

Wagner, W. R., 1966, Stratigraphy of the Cambrian to Middle Ordovician rocks of central and western Pennsylvania: Pennsylvania Geological Survey General Geology Report 49, 156 p.

Walcott, C. D., 1886, Second contribution to the studies on the Cambrian faunas of North America: U.S. Geological Survey Bulletin 30, 369 p.

Weller, S.; and St. Clair, S., 1928, Geology of Ste. Genevieve County, Missouri: Missouri Bureau of Geology and Mines, series 2, v. 22, p. 1–352.

Westrop, S. R.; Knox, L. A.; and Landing, E., 1993, Lower Ordovician (Ibexian) trilobites from the Tribes Hill Formation, central Mohawk Valley, New York State: Canadian Journal of Earth Sciences, v. 30, p. 1618–1633.

Wickham, J.; and Denison, R. E., 1978, Structural style of the Arbuckle region: Geological Society of America, South-Central Section, Field Trip 3, 111 p.

Whitfield, R. P., 1886, Notice of the geological investigations along the eastern shore of Lake Champlain, conducted by Prof. H. M. Seely and Prest. Ezra Brainerd of Middlebury College, with descriptions of the new fossils discovered: American Museum of Natural History Bulletin, v. 1, p. 293–345.

———1890, Observations on the fauna of the rock at Fort Cassin, Vermont, with descriptions of a few new species: American Museum of Natural History Bulletin, v. 3, p. 25–39.

———1897, Descriptions of new species of Silurian fossils from near Fort Cassin and elsewhere on Lake Champlain: American Museum of Natural History Bulletin, v. 9, p. 177–184.

Whittington, H. B., 1953, North American Bathyuridae and Leiostegiidae: Journal of Paleontology, v. 27, p. 647–678.

———1959, Family Bathyuridae, *in* Moore, R. C. (ed.), Treatise on invertebrate paleontology, Part O, Arthropoda 1: Geological Society of America and University of Kansas Press, New York City and Lawrence, Kansas, p. O376–380.

———1963, Middle Ordovician trilobites from Lower Head, western Newfoundland: Peabody Museum of Comparative Zoology, Harvard University, Bulletin 129, 118 p.

———1997, Morphology of the exoskeleton, *in* Whittington, H. B.; Chatterton, B. D. E.; Speyer, S. E.; Fortey, R. A.; Owens, R. M.; Chang, W. T.; Dean, W. T.; Jell, P. A.; Laurie, J. R.; Palmer, R. A.; Repina, L. N.; Rushton, A. W. A.; Shergold, J. H.; Clarkson, E. N. K.; Wilmot, N. V.; and Kelly, S. R. A. (eds.), Treatise on invertebrate paleontology, Part O, Arthropoda 1, Trilobita (revised): Geological Society of America and University of Kansas Press, New York City and Lawrence, Kansas, p. 1–84.

Whittington, H. B.; and Evitt, W. R., II, 1953, Silicified Middle Ordovician trilobites: Geological Society of America Memoir 59, 137 p.

Yochelson, E. L., 1973, The Late Early Ordovician gastropod *Ceratopea* in the Arbuckle Mountains, Oklahoma: Oklahoma Geology Notes, v. 33, p. 67–78.

Yochelson, E. L.; and Bridge, J., 1957, The Lower Ordovician gastropod *Ceratopea*: U.S. Geological Survey Professional Paper 294-H, p. 281–304.

Young, G. E., 1973, An Ordovician (Arenigian) trilobite faunule of great diversity from the Ibex area, western Utah: Brigham Young University, Geological Studies, v. 20, p. 91–115.

Appendixes

APPENDIX 1: INTERSTATE-35 MEASURED SECTION

Introduction

The Interstate-35 section (Text-fig. 3) lies east of the highway on the property of the Chapman Ranch, north of Ardmore, Oklahoma, in sec. 19, T. 2 S., R. 2 E. and sec. 24, T. 2 S., R. 1 E. (Turner Falls and Springer 7.5′ Quadrangles, Oklahoma). The line of the section lies entirely within the strip adjacent to Interstate-35 mapped by Fay (1989, pl. 1). The units measured and described from the Chapman Ranch correspond very closely with those described by Fay (1989, p. 34–38) from along the Interstate. Average attitude of the beds is strike N. 53° W., dip 53° SW. at the base of the section.

The lower 88 ft (29 m) of the Kindblade Formation are lost from exposures along the highway due to faulting (Fay, 1989, p. 38). By shifting the line of the I-35 section east from the Interstate, this structural complication was avoided (Text-fig. 3).

The base of the I-35 section was placed at the base of the Kindblade Formation, the top of an interval of thin-bedded, light-gray limestones that yield massive chert nodules (Ham, 1950, p. 58). These limestones appear laminated and weather to a chalky appearance. The thin-bedded limestones erode easily to produce a wide swale where the chert nodules are collected easily. Ham (1950, p. 70) located a 1-ft (0.3-m) -thick bed of quartz-sandy limestone at approximately 100 ft (33 m) above the base of the formation. On the I-35 section this bed occurs at 101 ft (33 m) above the base of the section, suggesting that the formational base was selected in accordance with Ham (1950).

The top of the Kindblade Formation was placed at the base of a 6-ft (2-m) -thick dolomitic sandstone (Ham, 1950, p. 66; 1955, p. 8, 24) in accordance with the usage of Decker (1939b). This bed is exposed along the Interstate (Fay, 1989, p. 38) and was traced as a swale onto the line of the I-35 section. The total measured thickness of 1,498 ft (456 m) for the Kindblade Formation compares favorably with measurements by Ham (1950, p. 68), Fay (1989, p. 34), J. R. Derby (*in* Derby and others, 1991, fig. 8), and R. L. Ethington (personal communication, 1989).

The I-35 section parallels the section previously measured along U.S. Highway 77 in the southern Arbuckle Mountains (Decker and Merritt, 1928; Decker, 1939b, p. 42–46; Cloud and Barnes, 1948, p. 373–376; Toomey and Nitecki, 1979, p. 114–126). The easy access available from the Interstate and the recent map and measured section descriptions available from Fay (1989) dictated placement of this study section 0.5 mi west of U.S. Highway 77, in spite of its historical significance. Fortunately, given the lateral continuity of most beds in the region (Fay, 1989, pl. 1), conclusions reached based upon the I-35 section should be applicable to the Highway-77 section.

Permission to access the Chapman Ranch can be obtained from the leaseholders, A. C. and Curtis Pletcher of the Spade Cattle Company, Springer, Oklahoma, following signature of a liability waiver.

Carbonate-rock classifications follow Dunham (1962).

Trilobite taxa identified from each of the collections and the collected elements from the units in the Interstate-35 section are presented in Table A-1 (following description).

Interstate-35 Measured Section

Unit no.	Description	Thickness	Interval
11	Medium- to thick-bedded, poorly fossiliferous intraclastic lime wackestone, with sparse skeletal lime grainstones. Stromatolites at 1,472–1,476, 1,492 ft (449–450, 455 m). Collections from I-901 through I-1010 assigned to *Bolbocephalus stitti* Zone. Base of MS unit #11 at base of Fay's (1989) Kindblade unit #1.	33 ft (10 m)	1,465–1,498 ft (447–457 m)
10	Thick- to medium-bedded lime mudstone to intraclastic lime wackestone, alternating with thin-bedded, argillaceous, dolomitic limestone. Poorly fossiliferous. Erodes to alternating ridges and recesses. Stromatolites at 1,255, 1,269, 1,362, and 1,412 ft (383, 387, 415, 430 m). Base of MS unit # 10 at base of Fay's (1989) Kindblade unit #33. Collections from I-1255 through I-1444 assigned to *Strigigenalis caudata* Zone. Fault at 1,365 ft (386 m), throw = 8 ft (2.5 m), offset 30 ft (10 m) west to avoid fault. Return to original line at 1,379 ft. Traverse at 1,252 ft (382 m), 210 ft (64 m) southeast.	222 ft (68 m)	1,243–1,465 ft (379–447 m)
9	Moderately fossiliferous, medium-bedded lime mudstone with sparse oolitic wackestone to packstone. Collections from I-1234 through I-1234 assigned to *Strigigenalis caudata Zone.* Base of MS unit #9 at base of Fay's (1989) Kindblade unit #37.	16 ft (5 m)	1,227–1,243 ft (374–379 m)
8	Resistant, thick-bedded, lime mudstone and intraclastic wackestone to packstone, moderately fossiliferous, erodes as ledges. Alternates with thin-bedded lime mudstones laminated with argillaceous to dolomitic partings which erode into recesses. Uncommon oolitic wackestones, sparse skeletal grainstones, sparse bioturbated lime mudstones. Stromatolites at 1,080, 1,170, 1,190–1,193 ft (329, 356, 362–364 m). Abundant nautiloid cephalopods at 1,080 ft (329 m). Collection from I-1227 assigned to *Strigigenalis caudata* Zone; from I-1079–1222 to *Bolbocephalus stitti* Zone. Base of MS unit #8 17 ft (5 m) above base of Fay's (1989) Kindblade unit #53.	157 ft (48 m)	1,070–1,227 ft (325–374 m)
7	Common, medium-bedded oolitic wackestone to packstone, with thick-bedded lime mudstone to wackestone eroded as ledges. Alternating thin-bedded lime mudstone and mudstone laminated with argillaceous and dolomitic partings eroded as recesses. Sparse skeletal lime grainstones. Moderately fossiliferous. Distinctive oolitic chert at 1,053–1,056 ft (321 m; base of Fay's, 1989, Kindblade unit #53). Stromatolite at 1,064 ft (324 m). Collections from I-1034 through I-1066 assigned to *Bolbocephalus stitti* Zone. Base of MS unit #7 1 ft (0.33 m) above base of Fay's (1989) Kindblade unit #59.	44 ft (13 m)	1,026–1,070 ft (313–326 m)
6	Thick-bedded, resistant lime mudstone, massive to bioturbated or with argillaceous laminations. Moderately fossiliferous. Rare oolitic and intraclastic wackestone. Stromatolite at 994 ft (303 m) with *Calathium* and *Archeoscyphia*.	69 ft (21 m)	957–1,026 ft (292–313 m)

(continued on next page)

Unit no.	Description	Thickness	Interval
6 *(cont'd.)*	Collections from I–994 through I-1012 assigned to *Bolbocephalus stitti* Zone; from I-996 through I-976 to the *Petigurus cullisoni* Zone. Base of MS unit #6 at base of Fay's (1989) Kindblade unit #64. Traverse at 965 ft (294 m), 20 ft (6 m) northwest.		
5	Alternating thin- to thick-bedded lime mudstone with common intraclastic wackestones to packstones. Sparse thin-bedded lime mudstones with dolomitic laminations. Poorly fossiliferous. Thin, cross-bedded, very fine grained quartz–sandy limestone at 896 ft (273 m). Collections from I-857 through I-955 assigned to *Petigurus cullisoni* Zone. Base of MS unit #5, 10 ft (3 m) above base of Fay's (1989) Kindblade unit #69. Traverse at 870 ft (265 m), 24 ft (7 m) northwest.	101 ft (31.1 m)	856–957 ft (261–292 m)
4	Thin- to thick-bedded lime mudstone with abundant stromatolites. Sparse skeletal grainstones and lime mudstones with dolomitic laminations. Moderately fossiliferous. Collections from I-846 through I-854 assigned to *Petigurus cullisoni* Zone. Base of MS unit #3, 3 ft (1 m) below base of Fay's (1989) Kindblade unit #70 (within #71-72).	15 ft (5 m)	841–856 ft (256–261 m)
3	Thin- to medium-bedded lime mudstone. Common intraclastic lime wackestone, sparse skeletal grainstone and dense lime mudstone with conchoidal fracture. Sparsely fossiliferous. Collections from I-771 through I-841 assigned to *Petigurus cullisoni* Zone. Base of MS unit #3 at base of Fay's (1989) Kindblade unit #75.	76 ft (23 m)	765–841 ft (233–256 m)
2	Thick- to thin-bedded lime mudstone with common intraclastic wackestone to packstone, uncommon skeletal grainstone, and sparse oolitic grainstone. Poorly fossiliferous. Small stromatolites at 630, 650, 691, 741, 762 ft (192, 198, 211, 226, 232 m). Collections from I-691 through I-765 assigned to *Petigurus cullisoni* Zone; from I-578 through I-685 to the *Benthamaspis rhochmotis* Zone (Table A1). Base of unit #2 of measured section at base of Fay's (1989) Kindblade unit #89. Traverse at 724 ft (221 m), 78 ft (24 m) northwest.	206 ft (63 m)	559–765 ft (170–233 m)
1	Resistant, thick-bedded lime mudstones, massive to bioturbated. Alternate with thin- to medium-bedded skeletal lime grainstonesand intraclastic lime wackestones to packstones that erode into recesses. Poorly fossiliferous near base, remainder moderately fossiliferous. Common sponge-algal bioherms and common stromatolites at base (15–60 ft; 5–18 m) and from 255–289 ft (78–88 m). Chiton valves at 291–294 ft (89 m). Cross-bedded quartz-sandy limestone at 101, 145, and 182 ft (31, 44, 55 m). Collections from I-476 through I-556 assigned to *Benthamaspis rhochmotis* Zone; from I-255 through I-471 through the *Jeffersonia granosa* Zone; from I-35 through I-254 to the *Ranasasus brevicephalus* Zone. Traverse at 355 ft (108 m), 110 ft (34 m) southeast.	559 ft (170 m)	0–559 ft (0–170 m)

TABLE A-1. – Identification of Trilobites from Interstate-35 Section

Unit no.	Collection	Taxon	Components*	Zone
11	I-1475	*Jeffersonia jenni*	1-0	*Strigigenalis caudata* Zone
	I-1474	*Bolbocephalus stitti*	0-0-1	
		Jeffersonia jenni	1-0	
	I-1468	*Bolbocephalus stitti*	2-3-1	
		Bolbocephalus sp.	1-0	
		Jeffersonia jenni	1-0-1	
		Strigigenalis? sp. 3	0-3-1	
10	I-1444	*Bolbocephalus stitti*	1-0	
		Strigigenalis sp. 1	0-1	
	I-1440	*Bolbocephalus* sp. 3	0-1	
	I-1369	*Randaynia* sp. 1	1?-13-1?	
	I-1272	*Strigigenalis crassimarginata*	0-0-1?	
		Strigigenalis cf. *S. knighti*	0-0-1	
	I-1270	*Bolbocephalus stitti*	1-1-1	
	I-1269	*Bolbocephalus stitti*	0-2-5	
	I-1255	*Bolbocephalus stitti*	1-1	
9	I-1241	*Strigigenalis crassimarginata*	0-1	
	I-1234	*Benthamaspis onomeris*	0-1	
8	I-1227	*Benthamaspis onomeris*	0-1	
		Bolbocephalus stitti	0-1	
		Dimeropygiella sp. 1	3-0-1	
		Isoteloides peri	0-1	
		Strigigenalis caudata	7-13-3	
		Strigigenalis crassimarginata	0-3-2	
	I-1222	*Bolbocephalus stitti*	1-0	*Bolbocephalus stitti* Zone
	I-1215	*Bolbocephalus* sp. 2	1?-0	
	I-1212	*Bolbocephalus stitti*	0-1	
		Dimeropygiella sp. 1	1-0	
	I-1210	*Ranasasus* sp. 1	0-1	
	I-1195	*Strigigenalis insentis*	0-0-1	
	I-1185	*Petigurus cullisoni*	0-0-1	
		Strigigenalis crassimarginata	1-11-5	
	I-1178	*Bolbocephalus stitti*	2-1	
		Strigigenalis crassimarginata	0-0-1	
	I-1170	*Strigigenalis insentis*	1-1-2	
	I-1159	*Strigigenalis crassimarginata*	0-1	
	I-1146	*Strigigenalis insentis*	0-0-1	
	I-1143	*Strigigenalis crassimarginata*	0-0-1	
		Strigigenalis insentis	0-1	
	I-1135	*Bolbocephalus stitti*	11-15-2	
		Bolbocephalus sp.	1-0	
	I-1133	*Strigigenalis insentis*	0-1?	
	I-1127	*Petigurus cullisoni*	8-3	
		Ranasasus sp. 1	0-1	
	I-1121	*Bolbocephalus* sp.	0-1	
	I-1113	*Strigigenalis crassimarginata*	0-0-1	
	I-1106	*Isoteloides peri*	(Hy.)	
	I-1105	*Petigurus cullisoni*	2-1	

*Components a-b, cranidia-pygidia, or a-b-c, cranidia-pygidia-librigenae, where appropriate, with "(Hy.)" indicating associated hypostomes.

(continued on next page)

Unit no.	Collection	Taxon	Components*	Zone
8 (cont'd.)	I-1098	*Isoteloides peri*	0-1	*Bolbocephalus stitti* Zone
		Petigurus cullisoni	1-0	
	I-1093	*Punka verecunda*	0-1	
	I-1085	*Strigigenalis insentis*	1-0	
	I-1080	*Benthamaspis onomeris*	1-0	
		Bolbocephalus stitti	2-5	
	I-1079	*Bolbocephalus stitti*	6-5-1	
7	I-1066	*Isoteloides peri*	1-2-1 + articulated exoskeleton	
		Strigigenalis insentis	0-3	
	I-1064	*Benthamaspis onomeris*	3-1	
		Bolbocephalus stitti	4-3	
		Ischyrotoma sp.	1-0-1	
		Jeffersonia sp. 2	1-0	
		Petigurus cullisoni	1-0-1	
		Strigigenalis crassimarginata	9-8-1	
		Strigigenalis insentis	2-9-2	
	I-1045	*Isoteloides peri*	2-0-3	
		Benthamaspis onomeris	1-0	
	I-1044	*Isoteloides peri*	1-0	
	I-1041	*Isoteloides peri*	0-1	
	I-1038	*Isoteloides peri*	0-3-1 (Hy.)	
		Petigurus cullisoni	1-0-1	
	I-1036	*Isoteloides peri*	0-0-1	
	I-1034	*Benthamaspis onomeris*	0-1	
		Punka verecunda	0-0-2	
6	I-1012	*Petigurus cullisoni*	0-1	
	I-1009	*Bolbocephalus stitti*	0-1	
		Petigurus cullisoni	16-6-19	
		Punka verecunda	0-0-2	
		Strigigenalis insentis	0-0-1?	
	I-1006	*Benthamaspis onomeris*	1-0	
	I-996	*Benthamaspis onomeris*	0-2	
		Punka verecunda	0-2	
	I-994	*Benthamaspis onomeris*	0-1	
		Isoteloides peri	0-1	
		Petigurus cullisoni	0-0-1	
		Strigigenalis insentis	0-1-1	
	I-976	*Isoteloides peri*	0-1	*Petigurus cullisoni* Zone
		Petigurus cullisoni	0-1-1	
	I-966	*Punka verecunda*	0-1	
5	I-955	*Isoteloides peri* (Hy.)	(Hy.)	
	I-954	*Isoteloides peri* (2 Hy.)	(2 Hy.)	
	I-952	*Isoteloides peri*	1-0	
		Petigurus cullisoni	0-0-1	
	I-951	*Isoteloides peri*	0-1	
	I-950	*Isoteloides peri*	0-2	
	I-948	*Petigurus cullisoni*	0-1	
	I-945	*Isoteloides peri*	0-0-1	
	I-944	*Isoteloides peri*	2-1	
	I-943	*Ischyrotoma* sp. indet.	0-0-1	
		Isoteloides peri	1-0-1	
		Punka verecunda	0-0-1	

(continued on next page)

Unit no.	Collection	Taxon	Components*	Zone
5 (cont'd.)	I-940	*Isoteloides peri*	0-1-2	*Petigurus cullisoni* Zone
		Petigurus cullisoni	0-0-1	
		Punka verecunda	0-1	
		Strigigenalis crassimarginata	1-0	
	I-926	*Isoteloides peri*	0-0-1	
	I-921	*Petigurus cullisoni*	0-1	
	I-918	*Isoteloides peri*	0-0-1	
	I-917	*Isoteloides peri*	0-1	
	I-897	*Jeffersonia* sp. 2	1-0-1	
	I-893	*Strigigenalis crassimarginata*	0-1	
	I-883	*Isoteloides peri*	1-0	
		Jeffersonia sp. 2	2-0-1	
		Punka verecunda	1-0	
	I-868	*Punka verecunda*	0-1	
	I-857	*Punka verecunda*	0-1	
4	I-854	*Petigurus cullisoni*	0-1-1	
	I-851	*Isoteloides peri*	0-3-1 (Hy.)	
		Petigurus cullisoni	0-0-1	
		Punka verecunda	0-0-1	
	I-849	*Ischyrotoma* sp. 1	1-0	
		Petigurus cullisoni	0-2	
	I-846	*Bolbocephalus* sp.	0-1	
		Ischyrotoma sp. 1	1-0	
		Isoteloides peri	1-0-1	
3	I-841	*Bolbocephalus* cf. *B. convexus*	0-2	
		Isoteloides peri	3-1	
		Jeffersonia sp. 2	1-0	
		Petigurus cullisoni	2-4	
	I-821	*Strigigenalis* sp. 1	0-1	
	I-809	*Jeffersonia* sp. 2	1-0	
		Isoteloides peri	2-6-2 (Hy.)	
	I-805	*Isoteloides peri*	0-0-1	
	I-800	*Strigigenalis* sp.	1-1	
	I-771	*Isoteloides peri*	0-2-1	
2	I-765	*Isoteloides peri*	0-0-1	
	I-762	*Bolbocephalus* cf. *B. convexus*	0-1	
		Bolbocephalus sp.	0-1	
		Petigurus cullisoni	3-1	
		Speyeris hami	1-0	
		Punka verecunda	1-0	
		Strigigenalis sp. 1	0-1	
	I-757	*Isoteloides peri*	3-10-2 (Hy.)	
		Petigurus cullisoni	1-1	
	I-741	*Punka verecunda*	0-1-1	
	I-739	*Isoteloides peri*	0-1	
	I-738	*Isoteloides peri*	2-1	
		Petigurus cullisoni	1-0	
		Punka verecunda	0-1	
	I-732	*Bathyurellus inflatus*	0-1	
		Petigurus cullisoni	3-0-1	
		Speyeris hami	1-0	
	I-721	*Isoteloides peri*	2-1-1 (Hy.)	
	I-718	*Strigigenalis* sp. 1	0-1	
	I-711	*Strigigenalis implexa*	0-0-1	

(continued on next page)

Unit no.	Collection	Taxon	Components*	Zone
2 (cont'd.)	I-697	*Petigurus cullisoni*	1-0	*Petigurus cullisoni* Zone
	I-696	*Jeffersonia ulrichi*	1-0	
		Punka akoura	0-2	
	I-695	*Peltabellia implexa*	0-1-1	
	I-691	*Ischyrotoma sila*	2-0	
		Peltabellia implexa	2-0-3	
		Petigurus cullisoni	0-1	
1	I-685	*Punka verecunda*	0-1	*Benthamaspis rhochmotis* Zone
	I-678	*Peltabellia implexa*	0-1	
	I-671	*Bathyurellus*? sp. 1	0-3	
		Peltabellia implexa	0-1-1	
		Punka verecunda	0-1	
	I-667	*Peltabellia implexa*	2-1	
	I-666	*Peltabellia implexa*	1-0	
	I-650	*Bathyurellus inflatus*	2-7-4	
		Benthamaspis rhochmotis	0-1	
		Ischyrotoma sila	2-0	
		Lutesvillia bispinosa	2-4	
		Peltabellia implexa	1-12-13	
		Strigigenalis sp. 1	0-1	
	I-639	*Lutesvillia bispinosa*	3-1-1	
	I-635	*Jeffersonia ulrichi*	0-1?	
	I-631	*Benthamaspis rhochmotis*	1-5	
		Bathyurellus inflatus	0-0-1	
		Ischyrotoma sila	10-4-8	
		Jeffersonia ulrichi	16-3-6	
	I-630	*Bathyurellus inflatus*	1-0	
		Bolbocephalus sp.	0-1	
	I-628	*Ischyrotoma sila*	0-0-1	
	I-626	*Lutesvillia bispinosa*	0-1	
		Punka akoura	1-0-1	
	I-625	*Punka akoura*	1-0	
	I-623	*Lutesvillia bispinosa*	10-20-2	
	I-621	*Lutesvillia bispinosa*	1-2	
	I-619	*Lutesvillia bispinosa*	1-0	
	I-596	*Lutesvillia bispinosa*	0-1	
	I-586	*Punka verecunda*	0-1	
	I-584	*Punka verecunda*	0-1	
	I-580	*Lutesvillia bispinosa*	0-1	
		Petigurus sp. 1	1-0	
	I-579	*Jeffersonia ulrichi*	1-0	
	I-578	*Benthamaspis rhochmotis*	0-2	
	I-556	*Bathyurellus arbucklensis*	0-0-1	
		Benthamaspis rhochmotis	0-1-1	
		Jeffersonia ulrichi	24-11-26	
		Lutesvillia bispinosa	0-2	
		Punka akoura	1-0-5	
		Punka verecunda	0-3	
		Strigigenalis derbyi	2-3-1	
	I-551	*Jeffersonia ulrichi*	0-1	
	I-549	*Jeffersonia ulrichi*	0-0-1	
	I-546	*Gelasinocephalus whittingtoni*	0-0-1	
		Petigurus sp. 1	2-0	
	I-542	*Benthamaspis rhochmotis*	2-3	
		Jeffersonia ulrichi	0-1	
	I-527	*Jeffersonia ulrichi*	1-0	

(continued on next page)

Unit no.	Collection	Taxon	Components*	Zone
1 (cont'd.)		*Strigigenalis derbyi*	1-5-5	*Benthamaspis rhochmotis* Zone
	I-526	*Strigigenalis derbyi*	0-0-2	
	I-525	*Benthamaspis rhochmotis*	2-1	
		Bolbocephalus sp. 2	0-1	
		Ischyrotoma sila	0-0-1	
		Punka akoura	0-1	
		Strigigenalis derbyi	2-3-2	
	I-523	*Punka akoura*	0-0-1	
	I-521	*Bathyurellus arbucklensis*	2-2-1	
		Gelasinocephalus pustulosus	4-0-2	
		Gelasinocephalus whittingtoni	4-3	
		Strigigenalis derbyi	4-0	
	I-503	*Bathyurellus arbucklensis*	1-0	
		Benthamaspis rhochmotis	1-1	
		Ischyrotoma sila	0-0-2	
		Punka akoura	0-0-1	
		Punka verecunda	0-1	
		Strigigenalis derbyi	0-6-3	
	I-499	*Benthamaspis rhochmotis*	8-4-1	
		Bolbocephalus sp. 2	0-2	
		Gelasinocephalus whittingtoni	1-0	
		Ischyrotoma sila	2-0-1	
		Jeffersonia ulrichi	38-22-9	
		Punka akoura	5-3	
		Punka verecunda	0-2-1?	
		Strigigenalis derbyi	1-1-1	
	I-486	*Benthamaspis rhochmotis*	4-0-2	
		Ischyrotoma sila	0-0-1	
		Isoteloides? sp. 1	(Hy.)	
		Jeffersonia ulrichi	1?-0	
		Gelasinocephalus pustulosus	0-0-1	
		Lutesvillia bispinosa	0-1	
		Punka akoura	0-1	
	I-482	*Benthamaspis rhochmotis*	2-1	
		Bolbocephalus spp.	1-1	
		Jeffersonia ulrichi	0-0-1	
		Punka akoura	1-0	
	I-476	*Benthamaspis rhochmotis*	0-0-1	
		Ischyrotoma sila	1-0	
		Punka akoura	0-1	
		Strigigenalis derbyi	0-1	
	I-471	*Ischyrotoma sila*	1-0	*Jeffersonia granosa* Zone
	I-451	*Gelasinocephalus whittingtoni*	1-0	
		Ischyrotoma sila	1-1	
		Lutesvillia bispinosa	0-1	
	I-446	*Lutesvillia bispinosa*	0-1	
	I-434	*Ischyrotoma sila*	1-0	
		Jeffersonia granosa	0-0-1	
	I-431	*Punka akoura*	1-0	
	I-430	*Ischyrotoma sila*	1-0	
		Jeffersonia granosa	6-3-2	
		Lutesvillia bispinosa	0-1	
	I-413	*Lutesvillia bispinosa*	0-2	
	I-398	*Lutesvillia bispinosa*	10-16-14	
		Chapmania carterensis	26-45-17	
	I-396	*Chapmania carterensis*	1-6	

(continued on next page)

Unit no.	Collection	Taxon	Components*	Zone
1 (cont'd.)		*Lutesvillia bispinosa*	2-2-4	*Jeffersonia granosa* Zone
	I-386	*Ischyrotoma sila*	0-0-1	
		Punka akoura	1-0	
	I-373	*Lutesvillia bispinosa*	0-3	
		Punka akoura	1-0	
	I-371	*Chapmania oklahomensis*	3-4-4	
		Ischyrotoma sila	2-0-1	
		Lutesvillia bispinosa	0-2-2	
	I-368	*Chapmania carterensis*	0-1	
		Chapmania oklahomensis	0-0-1	
		Ischyrotoma sila	0-0-1	
	I-361	*Chapmania oklahomensis*	23-20-11	
		Punka akoura	2-0	
	I-349	*Chapmania oklahomensis*	1-0	
	I-347	*Lutesvillia bispinosa*	0-1	
	I-346	*Chapmania oklahomensis*	2-0	
		Lutesvillia bispinosa	0-1-1	
		Punka akoura	2-0	
	I-338	*Chapmania carterensis*	1-1	
		Chapmania oklahomensis	0-1	
	I-326	*Chapmania oklahomensis*	0-1	
	I-314	*Chapmania oklahomensis*	5-21-11	
		Lutesvillia bispinosa	0-3	
	I-307	*Chapmania oklahomensis*	0-1	
	I-305	*Chapmania oklahomensis*	3-6-2	
		Chapmania carterensis	0-1	
		Lutesvillia bispinosa	0-1	
		Rollia goodwini	0-0-1	
	I-302	*Chapmania oklahomensis*	1-0	
	I-289	*Lutesvillia bispinosa*	0-1	
	I-283	*Lutesvillia bispinosa*	0-1	
	I-275	*Bolbocephalus myktos*	0-1	
	I-271	*Jeffersonia granosa*	1-0	
	I-268	*Chapmania oklahomensis*	0-1	
		Jeffersonia granosa	1-0	
		Rollia goodwini	1-0-1	
	I-266	*Chapmania carterensis*	0-1	
		Ischyrotoma sila	0-0-1?	
		Jeffersonia granosa	4-1-2	
		Lutesvillia bispinosa	0-1	
	I-260	*Chapmania carterensis*	1-0	
		Lutesvillia bispinosa	0-1	
	I-255	*Lutesvillia bispinosa*	0-1	
	I-254	*Benthamaspis* cf. *B. mediacrista*	0-1	*Ranasasus brevicephalus* Zone
	I-119	*Cullisonia producta*	0-1	
		Ranasasus conicus	1-0	
	I-115	*Cullisonia producta*	0-0-1	
	I-44	*Ranasasus brevicephalus*	0-1	
	I-40	*Bolbocephalus jeffersonensis*	2-1	
		Chapmania taylori	2-0	
		Ranasasus brevicephalus	1-1	
	I-35	*Chapmania taylori*	0-1	

APPENDIX 2: KINDBLADE RANCH MEASURED SECTION

Introduction

The Kindblade Ranch section follows the type section of the Kindblade Formation at the Kindblade Ranch, southwest of Carnegie, Kiowa County, Oklahoma (Text-fig. 3; sec. 24 and 25, T. 6 N., R. 14 W., Bally Mountain 7.5′ Quadrangle, Oklahoma; section 4 of Decker, 1939b, p. 47, 48).

The base of the Kindblade Formation was placed 3 ft (1 m) above the base of the section at the top of the highest thick-bedded limestone containing white, oolitic chert, which is common in the upper part of the underlying Cool Creek Formation. Decker (1939b) measured 957 ft (292 m) of Kindblade Formation above these oolitic cherts using a strike of N. 45° W. and a dip of 45° NE. The section described below totals 1,025 ft (313 m) based upon the same strike and a dip of 30° NE. (0–350 ft; 0–107 m) and 25° NE. (350 ft [107 m] to top of section). Table A-2 (following description) lists approximate correlation of Decker's (1939b) measured section units and those described below. Cloud and Barnes (1948, p. 372–373) examined the section in the company of Decker and Ham and provided some paleontological data.

Toomey and Nitecki (1979, p. 94–105) examined the sponge-algal buildups at the type section of the Kindblade Formation. Their discussions highlighted a 45 ft (14 m) thick zone of abundant *Archeoscyphia* from 37 to 82 ft (11–25 m) above the base of the formation. Using the measurements below, *Archeoscyphia* is most abundant through a thickness of 35 ft (11 m) between 75 and 110 ft (23, 34 m) above the base of the section. This interval begins 3 ft (1 m) below the top of measured section unit 2 and continues upward to the middle of measured section unit 3.

In a synopsis of the Paleozoic stratigraphy in the Wichita Mountains, Donovan and Ragland (1986, p. 16, 21) selected the lowest occurrence of the gastropod operculum *Ceratopea* to mark the base of the Kindblade Formation. The lowest *Ceratopea* observed in this study was at 242 ft (74 m) above the base of the section at the base of unit 6. Toomey (1980) discussed the distribution of *Ceratopea* within the Kindblade Formation in the Wichita Mountains, including a 775-ft (236-m) section at the type locality.

Permission to access the Kindblade Ranch measured section should be secured from Mr. Doyle Leatherbury of Apache, Oklahoma, before visiting the section.

All of the trilobite taxa identified from each of the collections from the units in the Kindblade Ranch section are presented in Table A-3.

Kindblade Ranch Measured Section

Unit no.	Description	Thickness	Interval
11	Thick, 1–3-ft (0.3–1-m) -thick benches of medium- to thick-bedded, poorly fossiliferous intraclastic to pelloidal, lime mudstone to wackestone. Uncommon massive lime mudstones. Mudstones and wackestones locally bioturbated. Collections from KR-902 through K-1010 assigned to *Bolbocephalus stitti* Zone.	82 ft (25 m)	940–1,022 ft (287–312 m)
10	Thin-bedded, laminated to bioturbated, poorly fossiliferous lime mudstone. Uncommon massive lime mudstone, sparse intraclastic to pelletal wackestone. Interval of thick-bedded, bioturbated lime mudstone 899–916 ft (274–279 m). Interval at 875–900 ft (267–274 m) poorly exposed. Collections from KR-849 through KR-861 assigned to *Petigurus cullisoni* Zone. Traverse at 930 ft (283 m), 230 ft (70 m) northwest. Traverse at 835 ft (255 m), 400 ft (122 m) northwest.	108 ft (33 m)	832–940 ft (254–287 m)
9	Thick, 1–4-ft (0.3–1-m) -thick benches of medium-to thick-bedded, bioturbated, poorly fossiliferous intraclastic wackestone and bioturbated lime mudstone. Collections from KR-770 through KR-827 assigned to *Petigurus cullisoni* Zone.	64 ft (20 m)	768–832 ft (234–254 m)
8	Thick, 1–10-ft (0.3–3-m) benches of medium- to thick-bedded, laminated to bioturbated, lime mudstone. Common massive intraclastic wackestones, sparsely bioturbated. Moderately fossiliferous. Small thrombolites at 735, 648, 631, 620 ft (224, 198, 192, 189 m). *Archeoscyphia* at 670–680 ft (204–207 m). Collections from KR-623 through KR-741 assigned to *Petigurus cullisoni* Zone; collection from KR-610 to *Benthamaspis rhochmotis* Zone. Traverse at 656 ft (200 m), 140 ft (43 m) northwest. Traverse at 730 ft (226 m), 200 ft (61 m) northwest. Traverse at 755 ft (230 m), 400 ft (122 m) northwest.	160 ft (49 m)	608–768 ft (185–234 m)
7	Thick, 2–5-ft (0.7–1.5-m) benches of medium- to thick-bedded, burrowed to massive to laminated, moderately fossiliferous, lime mudstone and intraclastic wackestone to packstone. Distinctive bedding plane exposure with multiple thrombolites separated by aligned high-spired gastropods and orthoconic nautiloid cephalopods at 556 ft (170 m). Collections from KR-556 through KR-571 assigned to *Benthamaspis rhochmotis* Zone.	66 ft (20 m)	542–608 ft (165–185 m)
6	Uncommon oolitic wackestone with laminated lime mudstone and intraclastic wackestone. Thin- to medium-bedded. Poorly fossiliferous. Traverse at 535 ft (163 m), 300 ft (91 m) northwest. Collections from KR-520 through KR-538 assigned to *Benthamaspis rhochmotis* Zone.	39 ft (12 m)	503–542 ft (153–165 m)

(continued on next page)

Unit no.	Description	Thickness	Interval
5	Thick, 1–6-ft (0.3–2-m) -thick benches of medium- to thick-bedded, bioturbated to massive lime mudstones. Common intraclastic wackestones to packstones, rare skeletal lime grainstones. Moderately fossiliferous. Six thick benches of bioturbated lime mudstone up to 10-ft (3-m) thickness from 340 to 380 ft (104–116 m). Thin oolitic wackestone at 470 ft (143 m). Robust thrombolitic bed at 480–481 ft (146 m), another thin thrombolitic bed at 411 ft (125 m), small stromatolite at 446 ft (136 m). Common *Ceratopea* at base from 335 to 389 ft (102–119 m). Collections from KR-437 through KR-489 assigned to *Benthamaspis rhochmotis* Zone; those from KR-339 through KR-431 through *Jeffersonia granosa* Zone.	168 ft (51 m)	335–503 ft (102–153 m)
4	Alternating thrombolitic boundstone and massive lime mudstone. Common intraclastic lime wackestone, common bioturbated lime mudstone, sparse skeletal lime grainstone. Upper half, 240–335 ft (73–102 m) moderately fossiliferous, lower half very sparsely fossiliferous, 146–239 ft (45–73 m). Commonly medium- to thick-bedded. Chert common from 301 to 330 ft (92–101 m). Collections from KR-254 through KR-331 assigned to *Jeffersonia granosa* Zone; those from KR-151 through KR-253 to *Ranasasus brevicephalus* Zone. Traverse at 180 ft (55 m), 120 ft (46 m) southeast.	189 ft (58 m)	146–335 ft (45–102 m)
3	Thick, 1–15-ft (0.3–5-m) -thick benches of thick- to medium-bedded lime mudstone. Uncommon intraclastic wackestone and bioturbated lime mudstone. Poorly fossiliferous, *Archeoscyphia* from 75 to 110 ft (23–34 m). Collections from KR-82 through KR-143 assigned to *Ranasasus brevicephalus* Zone.	68 ft (21 m)	78–146 ft (24–45 m)
2	Thrombolitic, thin- to thick-bedded, lime mudstone of nearly continuous exposure. Sparse bioturbated lime mudstone, intraclastic wackestone. Very sparsely fossiliferous Collections from KR-66 through KR-76 assigned to *Ranasasus brevicephalus* Zone.	38 ft (12 m)	40–78 ft (12–24 m)
1	Thin- to medium-bedded, very sparsely fossiliferous, lime mudstone and intraclastic wackestone. Dense, conchoidal lime mudstone from 27 to 40 ft (8–12 m). Common intraclastic wackestone. Small thrombolite at 4 ft (1 m). Base of section at base of 3 ft (1 m) thick, massive lime mudstone bearing white, oolitic chert. Base of Kindblade Formation placed at top of basal bed (3 ft [1 m] above base of section). Collection from KR-04 is not assigned to trilobite zone.	40 ft (0–40 ft)	12 m (0–12 m)

TABLE A-2. – Comparison of Measured-Section Intervals on Kindblade Ranch by Decker (1939b, p. 47, 48) and Loch (present study)

Decker units	Lithologic description	Decker thickness	Loch units	Loch thickness
1–3	Thick-bedded, gray limestones, some chert present	132 ft (40 m)	Part # 11 896–1,022 ft (273–312 m)	126 ft (38 m)
4–5	Thin- to thick-bedded limestones	60 ft (18 m)	Base # 10 836–895 ft (255–273 m)	59 ft (38 m)
11	Dense beds of gray limestone	54 ft (16 m)	Part # 8 638–895 ft (194–273 m)	63 ft (19 m)
15	Limestone with abundant chert	90 ft (27 m)	Part # 5 393–480 ft (120–146 m)	87 ft (27 m)
16–17	Gray limestone, stromatolites abundant within at base unit 17	57 ft (17 m)	Base # 5 331–393 ft (101–120 m)	62 ft (19 m)
19	Gray limestones, 4–12 in. (10–30.5 cm) thick, *Ceratopia*	19 ft (6 m)	Part # 4 250–270 ft (67–82 m)	20 ft (6 m)
20–21	Thick gray limestone	66 ft (20 m)	Low # 4 177 ft (54 m)	73 ft (22 m)
22	Medium-bedded limestone, common stromatolites, chert	70 ft (21 m)	High # 3–low # 4 135–177 ft (41–54 m)	42 ft (13 m)
23	Thin (at base) to thick limestone, *Archeoscyphia*	137 ft (42 m)	# 1–3 3–135 ft (1–41 m)	132 ft (40 m)
	BASE OF KINDBLADE FORMATION–TOP OF COOL CREEK FORMATION			
24	Thin beds of limestone with oolitic chert	82 ft (25 m)	Base # 1, lower 3 ft (1 m) bed with oolitic chert	

TABLE A-3. – Identification of Trilobites from Kindblade Ranch Section

Unit no.	Collection	Taxon	Components*	Zone
11	KR-1010	*Bolbocephalus stitti*	3-0	*Bolbocephalus stitti* Zone
		Strigigenalis insentis	1?-0-2	
		Strigigenalis crassimarginata	1-0	
	KR-907	*Petigurus cullisoni*	0-0-1	
	KR-901	*Bolbocephalus stitti*	5-3	
		Randaynia leatherbury	3-3-1	
10	KR-861	*Isoteloides peri*	0-1	*Petigurus cullisoni* Zone
	KR-860	*Isoteloides peri*	1-0-2	
		Petigurus cullisoni	1-2-2	
		Strigigenalis crassimarginata	1-2	
	KR-849	*Petigurus cullisoni*	1-0	
9	KR-827	*Petigurus cullisoni*	0-1-1	
		Strigigenalis crassimarginata	0-1	
	KR-823	*Petigurus cullisoni*	0-0-1	
		Punka verecunda	1?-2	
	KR-816	*Isoteloides peri*	1-1-1	
	KR-809	*Petigurus cullisoni*	1-3-3	
		Punka verecunda	1-1	
		Lutesvillia sp. 1	1-0	
		Strigigenalis crassimarginata	2-0	
	KR-805	*Bathyurellus inflatus*	0-1	
		Jeffersonia sp. 2	1-0	
		Petigurus cullisoni	0-0-4	
		Petigurus sp. 1	1-0	
		Punka verecunda	0-2-1	
		Strigigenalis insentis	1-0-1	
		Strigigenalis crassimarginata	0-1-2	
	KR-796	*Petigurus cullisoni*	0-0-1	
	KR-770	*Ischyrotoma* sp. 1	1-0	
		Ischyrotoma sila	4-0	
		Jeffersonia sp. 2	2-0	
		Petigurus cullisoni	4-0-4	
8	KR-741	*Bolbocephalus* cf. *B. convexus*	0-1	
		Punka verecunda	0-2-1	
		Strigigenalis sp. 1	1-0	
	KR-735	*Strigigenalis implexa*	1-1-1	
		Petigurus cullisoni	2-0	
		Strigigenalis sp. 1	1-0	
	KR-714	*Strigigenalis implexa*	0-1	
	KR-708	*Isoteloides peri*	0-1	
		Strigigenalis implexa	0-0-1	
	KR-685	*Punka verecunda*	0-1	
	KR-684	*Punka verecunda*	0-3	
	KR-681	*Petigurus cullisoni*	1-0	
		Punka verecunda	1-2	
	KR-677	*Petigurus* sp. 1	1-0	
	KR-671	*Bathyurellus*? sp. 1	0-3	
		Ischyrotoma sila	1-0	
		Strigigenalis implexa	0-0-1	

*Components a-b, cranidia-pygidia, or a-b-c, cranidia-pygidia-librigenae, where appropriate, with "(Hy.)" indicating associated hypostomes.

(continued on next page)

Unit no.	Collection	Taxon	Components*	Zone
8 (cont'd.)		*Speyeris hami*	1-0-2	*Petigurus cullisoni* Zone
		Punka verecunda	1-0	
	KR-653	*Speyeris hami*	0-1	
	KR-638	*Strigigenalis implexa*	0-1	
		Speyeris hami	0-0-1	
		Strigigenalis sp. 1	0-1	
	KR-636	*Strigigenalis implexa*	0-0-2	
		Strigigenalis sp. 1	1-0	
	KR-631	*Bathyurellus inflatus*	1-0	
		Speyeris hami	0-0-1	
	KR-623	*Strigigenalis implexa*	0-1	
		Petigurus cullisoni	0-0-1	
		Speyeris hami	2-0	
	KR-610	*Bathyurellus inflatus*	1-0	*Benthamaspis rhochmotis* Zone
		Benthamaspis rhochmotis	0-1	
		Strigigenalis implexa	1-0-3	
		Speyeris hami	1-0	
7	KR-571	*Lutesvillia bispinosa*	0-1	
		Strigigenalis implexa	0-0-1	
	KR-568	*Lutesvillia bispinosa*	1-1	
		Punka akoura	0-0-1	
		Punka verecunda	1-3	
	KR-564	*Lutesvillia bispinosa*	1-1	
		Punka akoura	1-0	
		Punka verecunda	1-7	
	KR-563	*Strigigenalis implexa*	0-1	
	KR-556	*Ischyrotoma sila*	1-0	
		Punka verecunda	0-1	
		Strigigenalis implexa	1-1-1	
		Petigurus sp.	1-0-1	
6	KR-538	*Strigigenalis implexa*	0-1	
		Strigigenalis derbyi	0-2	
	KR-520	*Bathyurellus arbucklensis*	0-0-1	
		Punka verecunda	0-2	
5	KR-489	*Benthamaspis rhochmotis*	0-3	
		Ischyrotoma sila	1-1	
		Punka verecunda	1-0	
	KR-483	*Benthamaspis rhochmotis*	0-1	
	KR-481	*Benthamaspis rhochmotis*	1-3	
		Gelasinocephalus whittingtoni	3-0	
	KR-458	*Strigigenalis derbyi*	1-0-1	
	KR-451	*Punka akoura*	0-0-1	
		Strigigenalis derbyi	0-1	
	KR-441	*Ischyrotoma sila*	1?-0	
	KR-437	*Bathyurellus arbucklensis*	0-2-1	
		Benthamaspis rhochmotis	1-1	
		Bolbocephalus sp.	0-1	
		Gelasinocephalus pustulosus	1-0	
		Gelasinocephalus whittingtoni	1-0	
		Jeffersonia granosa	2-1	
		Lutesvillia bispinosa	0-3	
		Ranasasus colossus	2-3-3	

(continued on next page)

Unit no.	Collection	Taxon	Components*	Zone
5 (cont'd.)	KR-431	*Ischyrotoma sila*	1-0	*Jeffersonia granosa* Zone
		Punka akoura	1-0	
	KR-429	*Punka akoura*	1-1	
		Punka sp. 1	1-0	
	KR-420	*Jeffersonia granosa*	1-0-1	
	KR-411	*Punka akoura*	1-0	
	KR-409	*Chapmania carterensis*	0-0-1	
	KR-399	*Jeffersonia granosa*	0-1	
		Chapmania oklahomensis	0-1	
		Ischyrotoma sila	1-0	
		Lutesvillia bispinosa	0-1	
	KR-339	*Jeffersonia granosa*	1-0	
4	KR-331	*Bolbocephalus myktos*	0-1-1	
		Jeffersonia granosa	2-0	
		Lutesvillia bispinosa	0-1	
	KR-325	*Jeffersonia granosa*	1-0	
	KR-319	*Chapmania oklahomensis*	1-1	
		Ischyrotoma sila	0-1	
	KR-313	*Lutesvillia bispinosa*	0-0-1	
	KR-312	*Bolbocephalus myktos*	0-1	
	KR-305	*Chapmania oklahomensis*	0-1	
		Chapmania sp. 1	0-1	
		Jeffersonia granosa	5-2-4	
	KR-301	*Jeffersonia granosa*	1-1	
	KR-254	*Jeffersonia granosa*	1-0	
		Cullisonia producta	0-1	
	KR-253	*Benthamaspis* cf. *B. mediacrista*	1-0	*Ranasasus brevicephalus* Zone
	KR-243	*Bolbocephalus myktos*	2-0	
	KR-152	*Chapmania taylori*	0-2	
	KR-151	*Chapmania taylori*	0-2	
		Bolbocephalus jeffersonensis	1-3	
		Bolbocephalus myktos	0-0-1	
		Bolbocephalus sp. 1	1-0	
		Ranasasus brevicephalus	1-0	
3	KR-143	*Bolbocephalus myktos*	0-0-1	
		Cullisonia producta	0-1	
		Jeffersonia sp. 1	1-0	
	KR-132	*Bolbocephalus jeffersonensis*	0-0-1	
		Chapmania taylori	0-1	
		Cullisonia producta	2-0	
		Ranasasus brevicephalus	0-0-1	
	KR-128	*Chapmania taylori*	1-0	
		Cullisonia producta	0-0-1	
	KR-120	*Ranasasus brevicephalus*	1-0	
	KR-119	*Cullisonia producta*	0-0-2	
		Ranasasus brevicephalus	1-0	
	KR-117	*Ranasasus brevicephalus*	0-1	
	KR-109	*Bolbocephalus myktos*	0-1	
		Cullisonia producta	0-0-1	
	KR-108	*Chapmania taylori*	0-1	
		Cullisonia producta	0-0-1	
	KR-103	*Ranasasus brevicephalus*	1-0	
	KR-96	*Ranasasus brevicephalus*	1-0	
	KR-94	*Ranasasus brevicephalus*	2-0	

(continued on next page)

Unit no.	Collection	Taxon	Components*	Zone
3 *(cont'd.)*	KR-84	*Cullisonia producta*	0-1	*Ranasasus brevicephalus* Zone
	KR-83	*Chapmania taylori*	0-1	
	KR-82	*Chapmania taylori*	0-0-1	
2	KR-76	*Chapmania taylori*	4-9-2	
		Ranasasus brevicephalus	1-3	
	KR-75	*Bolbocephalus jeffersonensis*	0-1	
		Chapmania taylori	2-2-2	
		Cullisonia producta	2-0-1	
		Ranasasus brevicephalus	0-1	
	KR-75A	*Chapmania taylori*	5-3-2	
		Cullisonia producta	2-0	
		Ranasasus brevicephalus	1-1	
	KR-73	*Chapmania taylori*	0-1-1	
	KR-66	*Bolbocephalus jeffersonensis*	2-3-1	
		Chapmania taylori	0-1	
1	KR-04	Genus and species indet., fragmentary		Unassigned

Plates

(Plates 1–3, in pocket)

Plate 4

ISOTELOIDES Raymond, *BATHYURELLUS* Billings

Figure		*Page*
1–9	***Isoteloides peri* Fortey.** *1*, Stereopair; small cranidium, palpebral view, testate, ×5.1 (UMC 16801), from I-757. *2*, Large fragmentary cranidium, palpebral view, exfoliated, ×1.1 (UMC 16802), from I-1045. *3*, Large fragmentary cranidium, palpebral view, exfoliated, with muscle scars and medial glabellar node, ×2.1 (UMC 16803), from I-757. *4*, Large pygidium, dorsal view, partially exfoliated, ×1.7 (UMC 16804), from I-771. *5*, *7*, Articulated exoskeleton, testate, (UMC 16805), from I-1066; *5*, palpebral view, ×3.4; *7*, lateral view showing distal ends of thoracic segments, ×3.9. *6*, Stereopair; medium-sized pygidium, dorsal view, partially exfoliated showing contrast in axial rings on testate and exfoliated surfaces, ×3.1 (UMC 16806), from I-771. *8*, Small librigena, dorsal view, testate, ×3.9 (UMC 16807), from I-1066. *9*, Small hypostome, testate, ×5.5 (UMC 16808), from I-809.	22
10	***Isoteloides*? sp. 1.** Large hypostome, partially exfoliated, ×4.2 (UMC 16809), from I-486.	23
11	***Bathyurellus*? sp. 1.** Stereopair; large pygidium with fine terrace lines, dorsal view, testate, ×2.5 (UMC 16810), from KR-671.	55

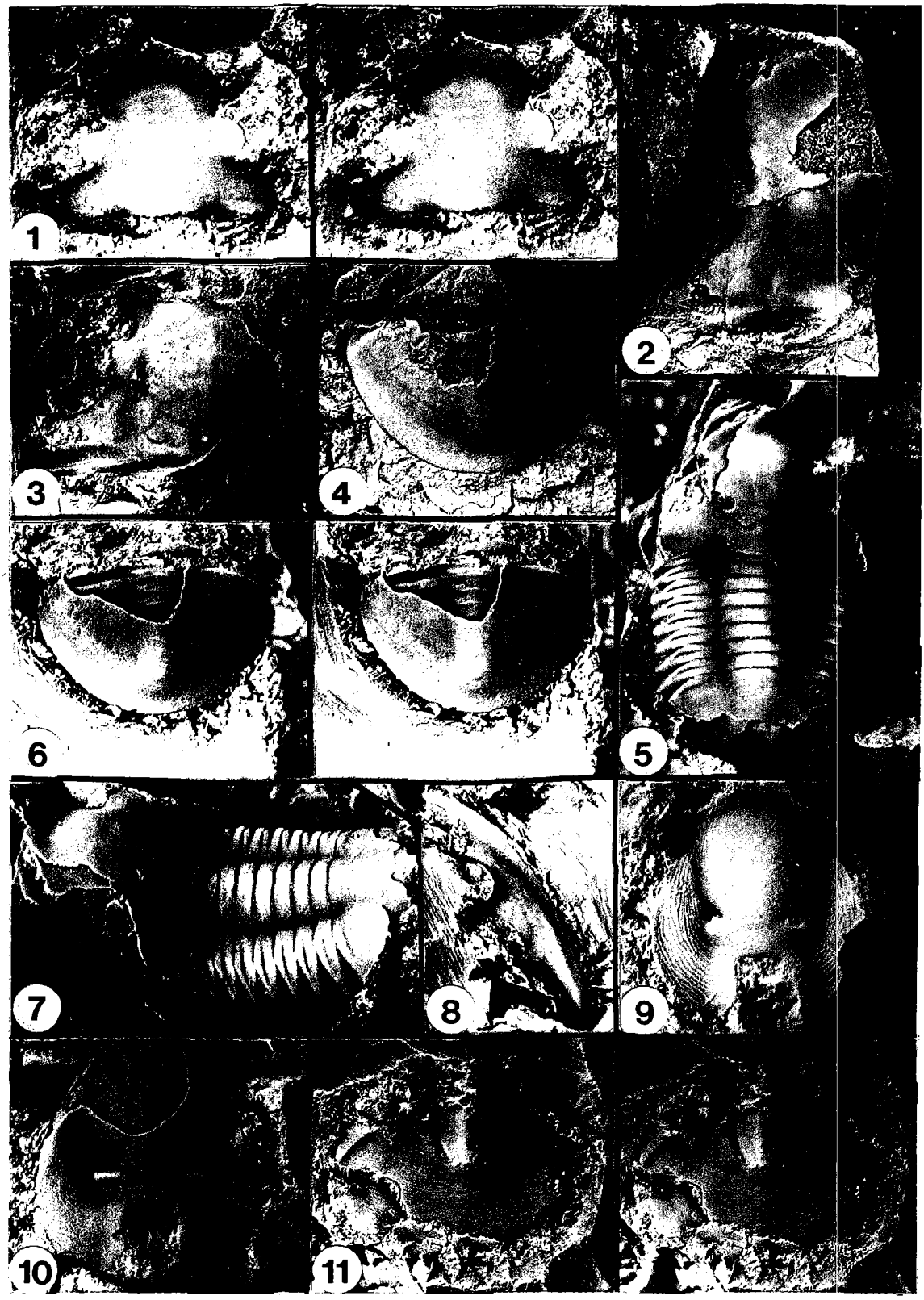

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Plate 5

BOLBOCEPHALUS Whitfield

Figure		*Page*
1–8	***Bolbocephalus jeffersonensis* Cullison.** *1–3*, Large fragmentary cranidium, exfoliated (UMC 16933), from KR-66; *1*, stereopair; palpebral view, ×2.8; *2*, lateral view, ×2.7; *3*, anterior view, ×2.7. *4*, Large cranidium, dorsal view, internal mold on chert nodule, ×2.1, topotype (UMC16934), from locality 72.50 of Cullison (1944), northwest of Rolla, Missouri. *5*, Large pygidium, dorsal view, exfoliated, ×2.7 (UMC 16935), from KR-66. *6*, Medium-sized librigena, lateral view, partially exfoliated, ×4.3 (UMC 16936), from KR-66. *7*, Stereopair; medium pygidium with mildly inflated pleural fields, dorsal view, internal mold on chert nodule, ×2.3 (UMC 16937), from locality 5 mi north of Rolla, Missouri. *8*, Small pygidium, dorsal view, exfoliated, ×4.7 (UMC 16938), from KR-66.	23
9–13	***Bolbocephalus* sp. 1.** *9–11*, Medium cranidium, internal mold on chert nodule (UMC 16941), from locality 75.27 of Cullison (1944); *9*, stereopair showing inflated palpebral and posterior fixigenae, ×2.3; *10*, oblique anterior view, ×2.8; *11*, lateral view, ×1.9. *12, 13*, Small cranidium, largely exfoliated (UMC 16942), from KR-151; *12*, palpebral view showing palpebral and posterior fixigenae, ×6.0. *13*, oblique anterior view, ×5.1.	28

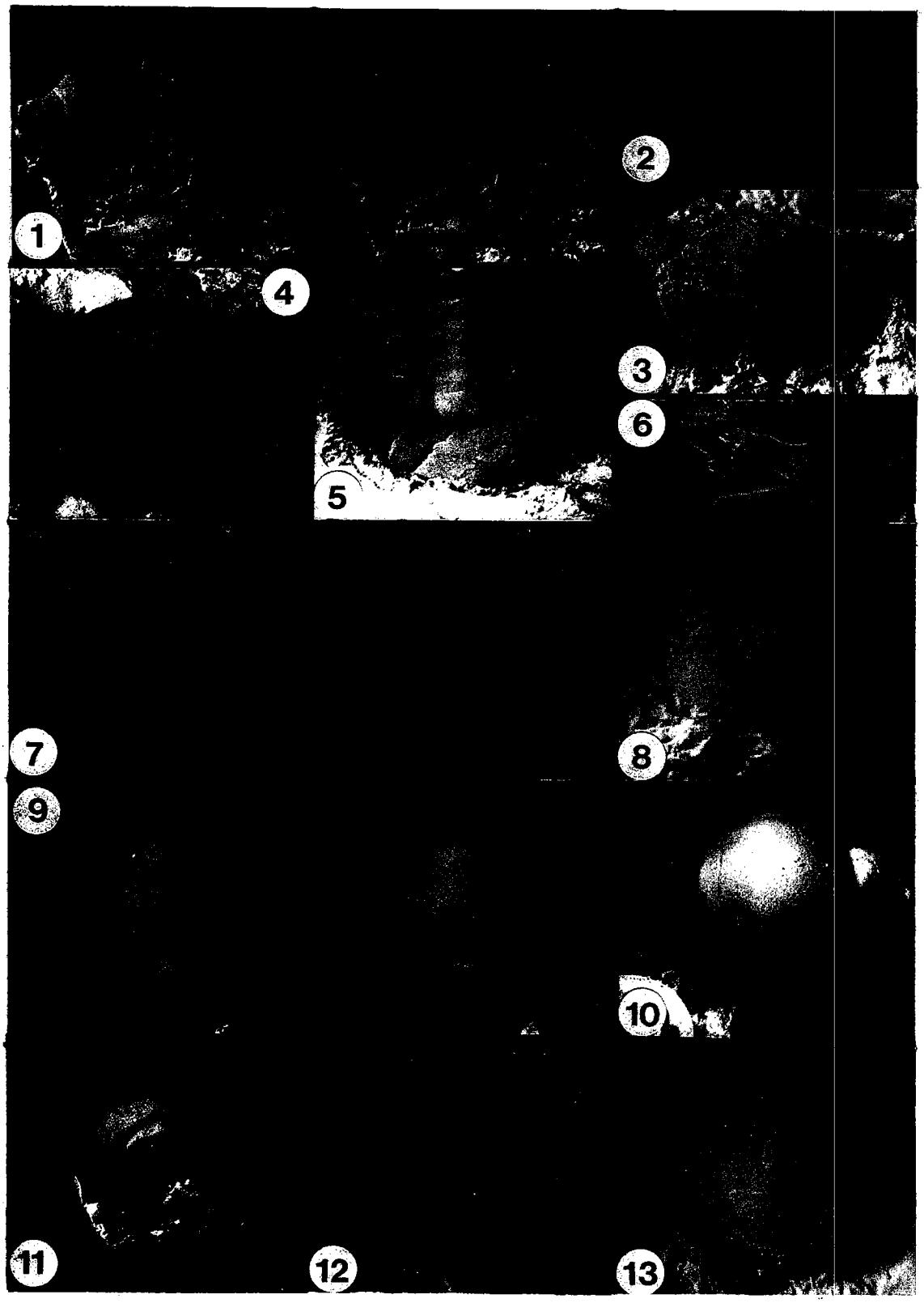
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Plate 6

BOLBOCEPHALUS Whitfield

Figure *Page*

1–9 ***Bolbocephalus stitti*** **n. sp.** *1, 2,* Large cranidium, exfoliated (UMC 16923, holotype), from I-1135; *1,* stereopair, palpebral view, ×2.3; *2,* lateral view, ×1.4. *3, 4,* Large pygidium, exfoliated (UMC 16924, paratype), from I-1270; *3,* posterior view, ×1.9; *4,* stereopair; dorsal view, ×1.7. *5,* Large cranidium, anterior view showing short frontal area, palpebral view, exfoliated, ×3.5 (UMC 16925, paratype), from I-1080. *6,* Small cranidium, dorsal view, testate, ×6.6 (UMC 16926, paratype), from I-1468. *7,* Medium pygidium, dorsal view, testate, ×2.5 (UMC 16927, paratype), from I-1255. *8,* Fragmentary medium librigena, dorsal view, exfoliated with coarse ridges along margin, ×2.7 (UMC 16928, paratype), from I-1079. *9,* Medium librigena, dorsal view, partially exfoliated, oblique view, ×4.3 (UMC 16929, paratype), from I-1269. 25

10–15 ***Bolbocephalus myktos*** **n. sp.** *10–12,* Large cranidium, exfoliated (UMC 16930, holotype), from KR-243; *10,* stereopair; palpebral view, showing deep pits on posterior fixigenae, ×1.8; *11,* lateral view, ×1.7; *12,* Anterior view showing subparallel anterior facial sutures and broad anterior fixigenae, ×1.4. *13, 14,* Large pygidium, dorsal view, exfoliated (UMC 16931, paratype), from KR-109; *13,* stereopair, ×2.8; *14,* enlargement showing pitted prosopon, ×6.5. *15,* Medium librigena, dorsal view, exfoliated, showing pits, ×2.2, (paratype, UMC 16932), from KR-143. 27

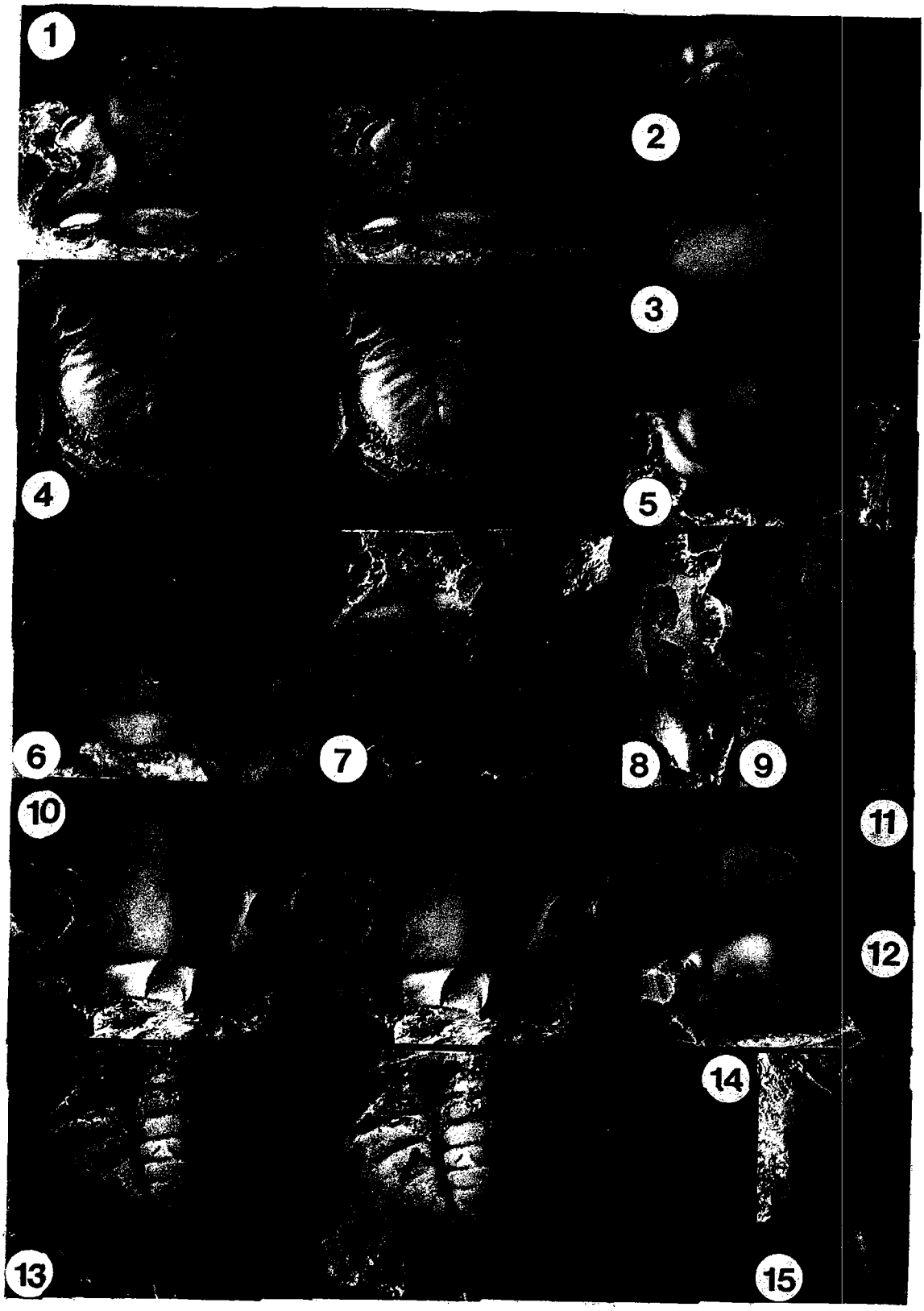
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Plate 7

BOLBOCEPHALUS Whitfield

Figure		*Page*
1, 2	***Bolbocephalus* cf. *B. convexus* (Billings).** *1*, Large cranidium, palpebral view, exfoliated, ×2.0 (UMC 16943), from I-841. *2*, Large pygidium, dorsal view, exfoliated, ×2.0 (UMC 16944), from KR-741.	25
3, 4	***Bolbocephalus* sp. 2.** Small pygidium, testate with tubercles on axial rings and granules on pleural fields and border (UMC 16945), from I-499. *3*, Dorsal view, ×5.0. *4*, Oblique posterior view, ×5.3.	28
5, 6, 9	***Bolbocephalus* sp. 3.** Small cranidium, partially exfoliated (UMC 16946), from I-1440. *5*, Palpebral view showing low transverse convexity, ×3.5. *6*, Oblique anterior view, ×3.0. *9*, Enlarged view of anterior fixigenae showing terrace lines on testate surface, ×8.3.	29
7, 8, 10–17	***Bolbocephalus* spp.** *7*, Large cranidium, palpebral view, exfoliated, ×2.8 (UMC 16947), from I-846. *8*, Medium cranidium, palpebral view, testate, ×2.3 (UMC 16948), from I-1135. *10*, Medium pygidium, dorsal view, exfoliated?, ×1.6 (UMC 16949), from I-486. *11, 12*, Medium fragmentary cranidium, exfoliated, (UMC 16950), from I-1468; *11*, palpebral view, ×2.2;. *12*, oblique anterior view, ×1.9. *13*, Large pygidium, dorsal view, latex cast of external mold, ×1.3 (UMC 16951), from KR-437. *14, 15*, Large fragmentary pygidium, exfoliated (UMC 16952), from I-762; *14*, dorsal view, ×1.1; *15*, posterior view with moderate dorsal arch on margin, ×1.4. *16, 17*, Large fragmentary pygidium, exfoliated (UMC 16953), from I-630; *16*, posterior view with slight dorsal arch on margin, ×1.0; *17*, dorsal view, ×1.1.	29

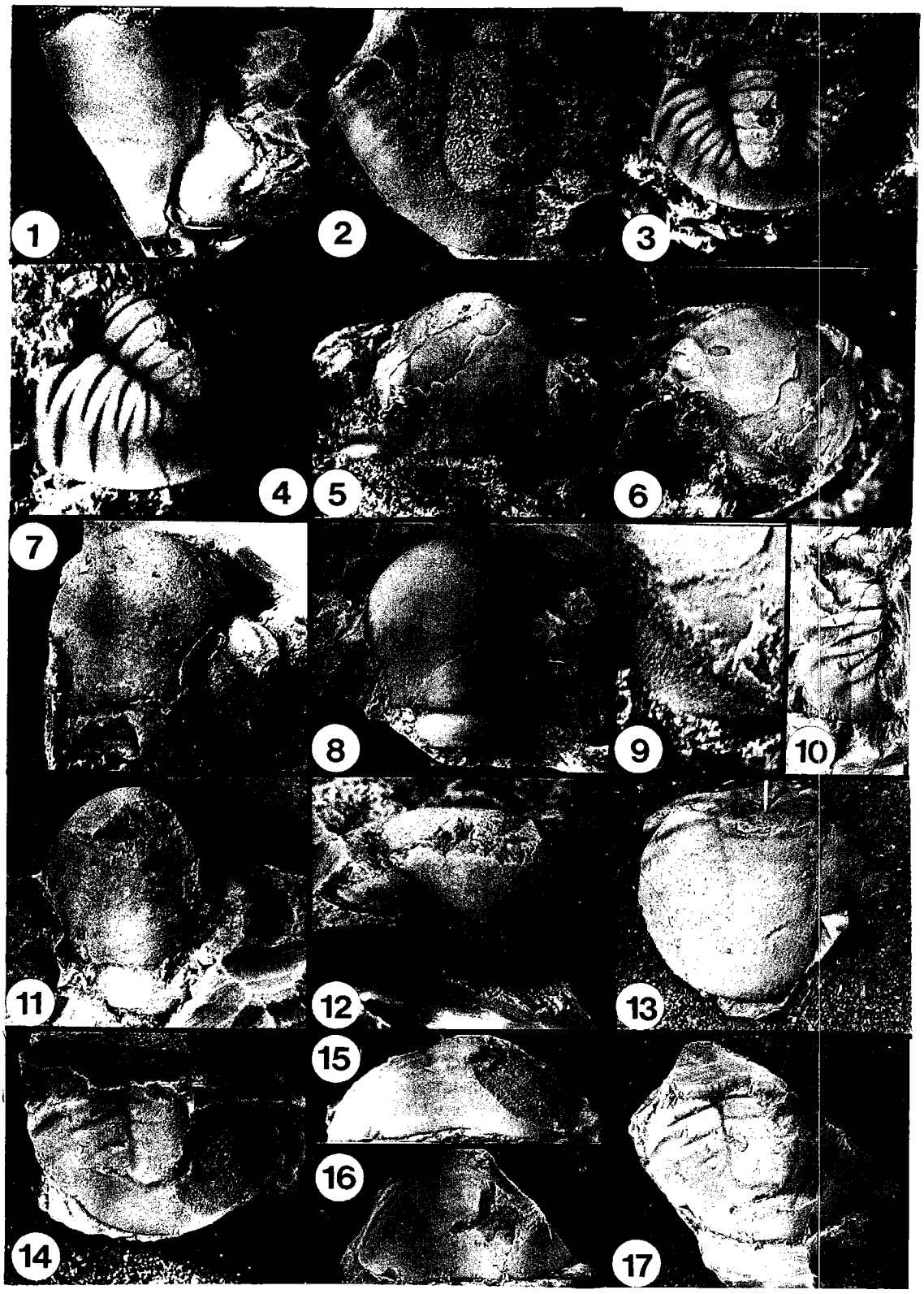
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Plate 8

CULLISONIA n. gen. and *JEFFERSONIA* Poulsen

Figure		*Page*
1–5	***Cullisonia producta*** **(Cullison).** *1*, Stereopair; large cranidium with slightly declined preglabellar field, exfoliated, ×3.0 (UMC 16977), from KR-75. *2*, Large cranidium, exfoliated, ×2.1 (UMC 16978), from KR-75. *3*, Stereopair; large pygidium with prominent axis and horizontal border, exfoliated, ×2.1 (UMC 16979), from KR-143. *4, 5*, Medium librigena, testate (UMC 16980), from KR-128; *4*, lateral view, ×2.6; *5*, dorsal view, ×2.2.	30
6–8	***Jeffersonia jenni*** **Cullison.** *6, 7*, Medium librigena, testate, ×2.6 UMC 16981), from I-1474; *6*, dorsal view; *7*, lateral view. *8*, Small fragmentary cranidium, anterior view showing prominent recurved, cord-like anterior border, testate, ×6.2 (UMC 16982), from I-1475	35
9, 10, 13–17	***Jeffersonia ulrichi*** **n. sp.** *9, 10*, Small cranidium, testate (UMC 16983, holotype), with medium cranidium (UMC 16984, paratype) in anterior oblique view at right, from I-556; *9*, stereopair; palpebral view, ×2.7; *10*, enlargement of holotype, ×4.4. *13, 14*. Small pygidium, testate (UMC 16987, paratype), from I-499; *13*, stereopair; dorsal view, ×3.6; *14*, lateral view showing ventrally drawn post-axial border, ×4.0. *15*, Small pygidium, dorsal view, testate, ×4.3 (UMC 16988, paratype) with small librigena, lateral view, exfoliated (UMC 16989, paratype), from I-556. *16*, Small librigena, dorsal view, testate, ×2.9 (UMC 16990, paratype), from I-556. *17*, Small librigena, dorsal view, testate with thin ridges on genal spine, ×3.2 (UMC 16991, paratype), from I-556.	36
11, 12	***Jeffersonia*** **sp. 3.** *11*, Small cranidium, palpebral view, testate, ×5.5 (UMC 16985), from I-631. *12*, Small cranidium with anterior border missing, palpebral view, testate, ×5.4, (UMC 16986), from I-631.	38
18–21	***Jeffersonia*** **sp. 2.** *18*, Stereopair; palpebral view. Small cranidium with axially recurved anterior border furrow, testate, ×6.4 (UMC 16992), from I-897. *19*, Small fragmentary cranidium with axially recurved anterior border furrow, palpebral view, testate, ×5.1 (UMC 16993), from I-841. *20, 21*, Small librigena, testate (UMC 16994), from I-883; *20*, lateral view, ×4.3; *21*, dorsal view, ×4.5.	38

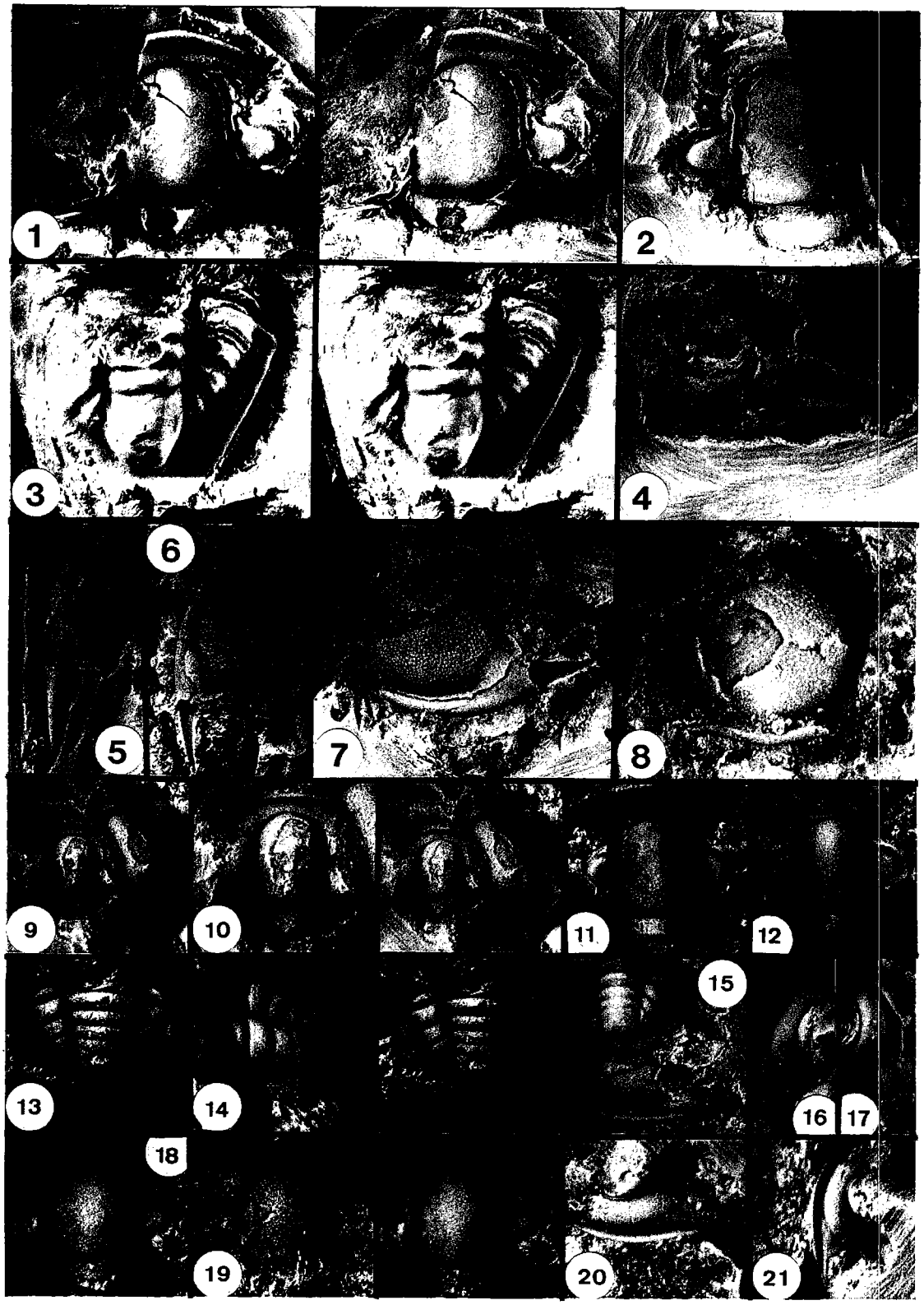
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Plate 9

GELASINOCEPHALUS n. gen.

Figure		*Page*
1–13	***Gelasinocephalus whittingtoni* n. sp.** *1, 2,* Medium cranidium, exfoliated (UMC 16954, holotype), from KR-481; *1,* stereopair, palpebral view, ×2.4; *2,* anterior view with pronounced anterior arch, ×2.5. *3,* Medium cranidium, palpebral view, exfoliated, ×2.4 (UMC 16955, paratype), from KR-481. ***4, 5,*** Small weathered cranidium, exfoliated (UMC 16956, paratype), from I-499;. *4,* palpebral view, ×4.4; *5,* oblique anterior view showing anterior arch and weakly impressed glabellar furrow opposite anterior end of palpebral lobe, ×4.3. ***6–9,*** Medium pygidium, exfoliated, ×2.9 (UMC 16957, paratype), from I-521; *6,* stereopair, dorsal view; *7,* oblique lateral view emphasizing ventrally extended posterior margin; *8,* posterior view; *9,* ventral view showing strongly concave doublure, with two fragmentary cranidia of *G. whittingtoni.* ***10, 11,*** Small pygidium, exfoliated (UMC 16958, paratype), from I-521; *10,* palpebral view with pits on post-axial border, ×5.7; *11,* oblique lateral view, ×6.7. ***12, 13,*** Medium librigena, exfoliated (UMC 16959, paratype), from I-546; *12,* lateral view with ridges on border and pits on genal fields, ×2.4; *13,* dorsal view, ×2.2.	31

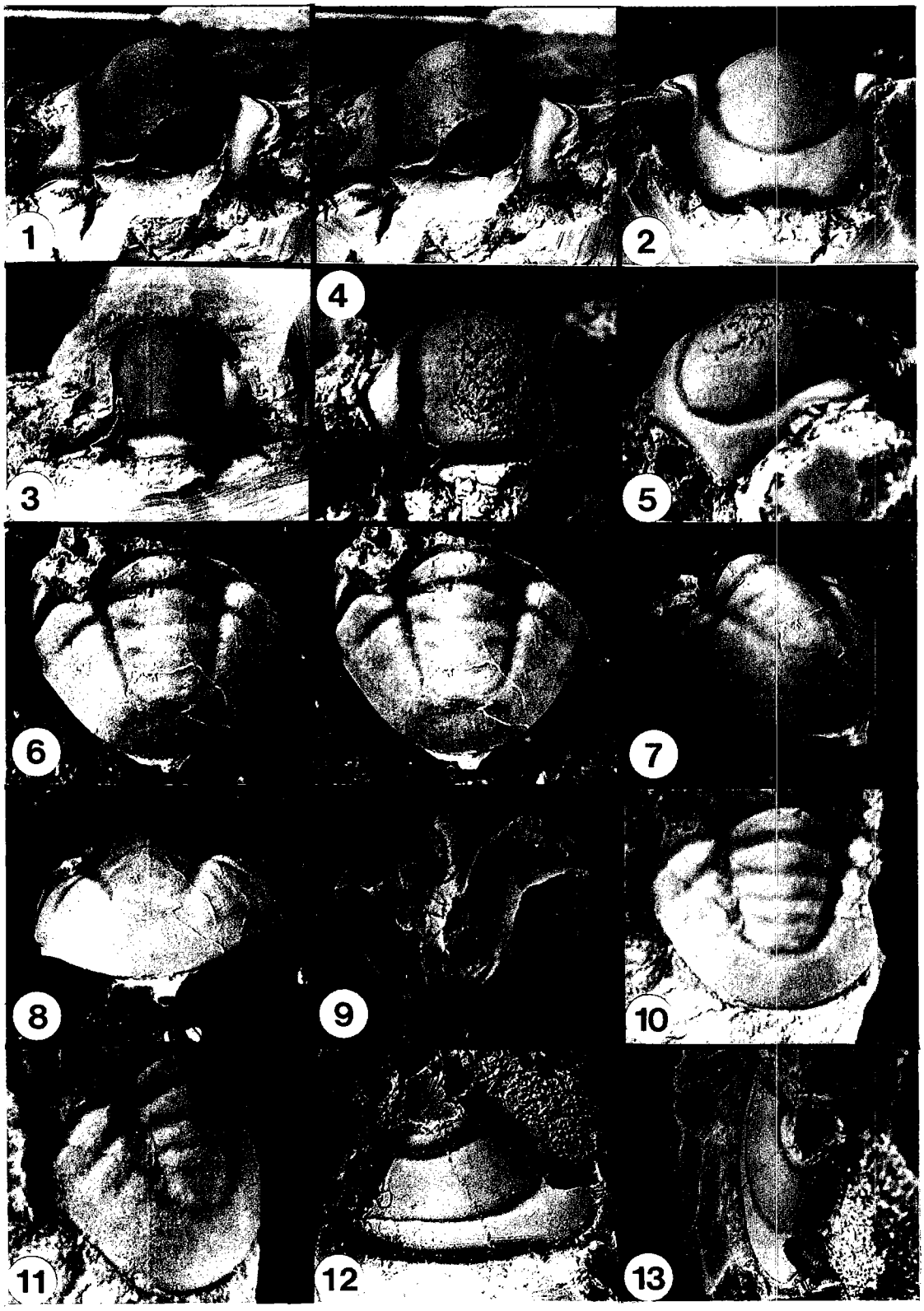
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Plate 10

GELASINOCEPHALUS n. gen. and *PETIGURUS* Raymond

Figure		*Page*
1–7	***Gelasinocephalus pustulosus* n. sp.** *1, 2,* Medium cranidium, largely exfoliated with pustules on both exfoliated and testate surfaces (UMC 16960, holotype), from I-521; *1,* stereopair, palpebral view, ×3.6; *2,* anterior view showing anterior arch and coarse ridges on testate border, ×5.0. *3–5,* Medium cranidium, largely exfoliated (UMC 16961, paratype), from I-521; *3,* palpebral view, ×5.1; *4,* anterior view, ×4.5; *5,* lateral view, ×5.0. *6,* Medium cranidium, palpebral view, largely exfoliated, ×2.9 (UMC 16962, paratype), from KR-437. *7,* Medium librigena, testate with pustules on genal field and coarse ridges on border, oblique lateral view, ×4.2 (UMC 16963, paratype), from I-521.	32
8–13	***Petigurus* sp. 1.** *8,* Medium librigena, dorsal view, testate with mixture of granules and ridges on border, ×4.8, (UMC 16964), from KR-556. *9–11,* Medium cranidium, largely exfoliated (UMC 16965), from KR-677; *9,* Stereopair; palpebral view, ×2.4; *10,* lateral view, ×3.1; *11,* anterior view, ×2.8. *12, 13.* Medium cranidium, largely testate, ×2.5, (UMC 16966), from I-546; *12,* palpebral view; *13,* oblique anterior view.	40

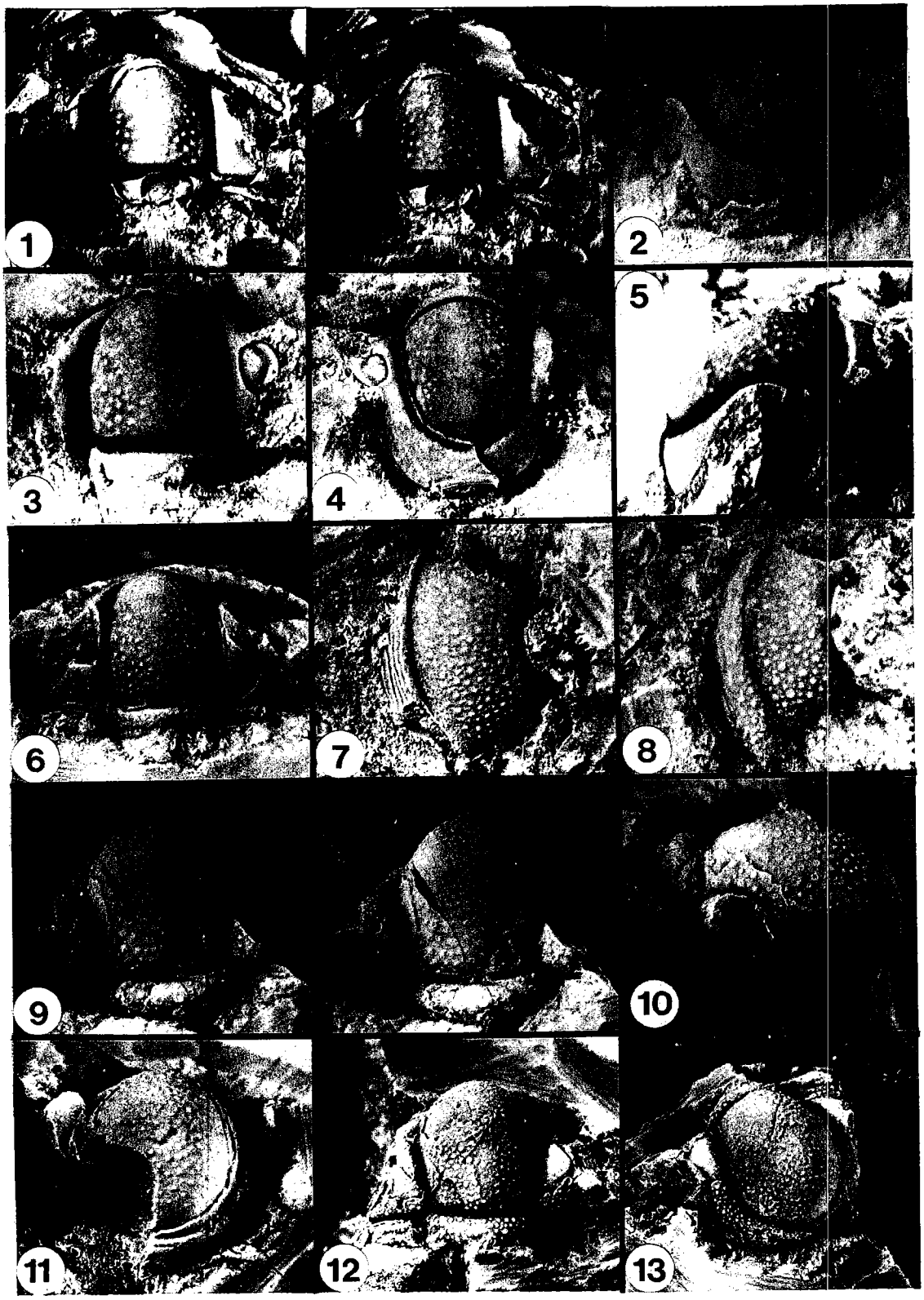
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Plate 11

JEFFERSONIA Poulsen

Figure		*Page*
1–11	***Jeffersonia granosa*** **Cullison.** ***1, 2,*** Large cranidium, exfoliated (UMC 16967), from KR-305; *1,* stereopair; palpebral view, ×2.3; *2,* anterior view, ×2.5. ***3,*** Medium cranidium, palpebral view, testate with coarse tubercles on glabella, ×3.8 (UMC 16968), from I-430. ***4, 5,*** Medium cranidium, exfoliated (UMC 16969), from KR-305; *4,* palpebral view, ×4.7; *5,* anterior view, ×5. ***6,*** Medium cranidium, anterior view showing dorsal arch (UMC 16970), from KR-420. *7,* Medium pygidium with bases of broken axial spines on axial rings, dorsal view, exfoliated, ×4.4 (UMC 16971), from KR-301. ***8,*** Medium pygidium showing ventral extension of post-axial border, oblique posterior view, exfoliated with pits on pleural ribs and border, ×3.5 (UMC 16972), from KR-305. ***9,*** Stereopair; small pygidium, dorsal view, testate, ×4.4 (UMC 16973), from I-430. ***10,*** Medium librigena, dorsal view, exfoliated with prominent ridge separating lateral and posterior border furrows, ×4.2 (UMC 16974), from I-434. ***11,*** Medium librigena, lateral view, partially exfoliated, ×4.2 (UMC 16975), from I-430.	34
12	***Jeffersonia*** **sp. 1.** Stereopair; medium cranidium, dorsal view, exfoliated with fine granules and moderately impressed glabellar furrows, ×2.7 (UMC 16976), from KR-143.	37

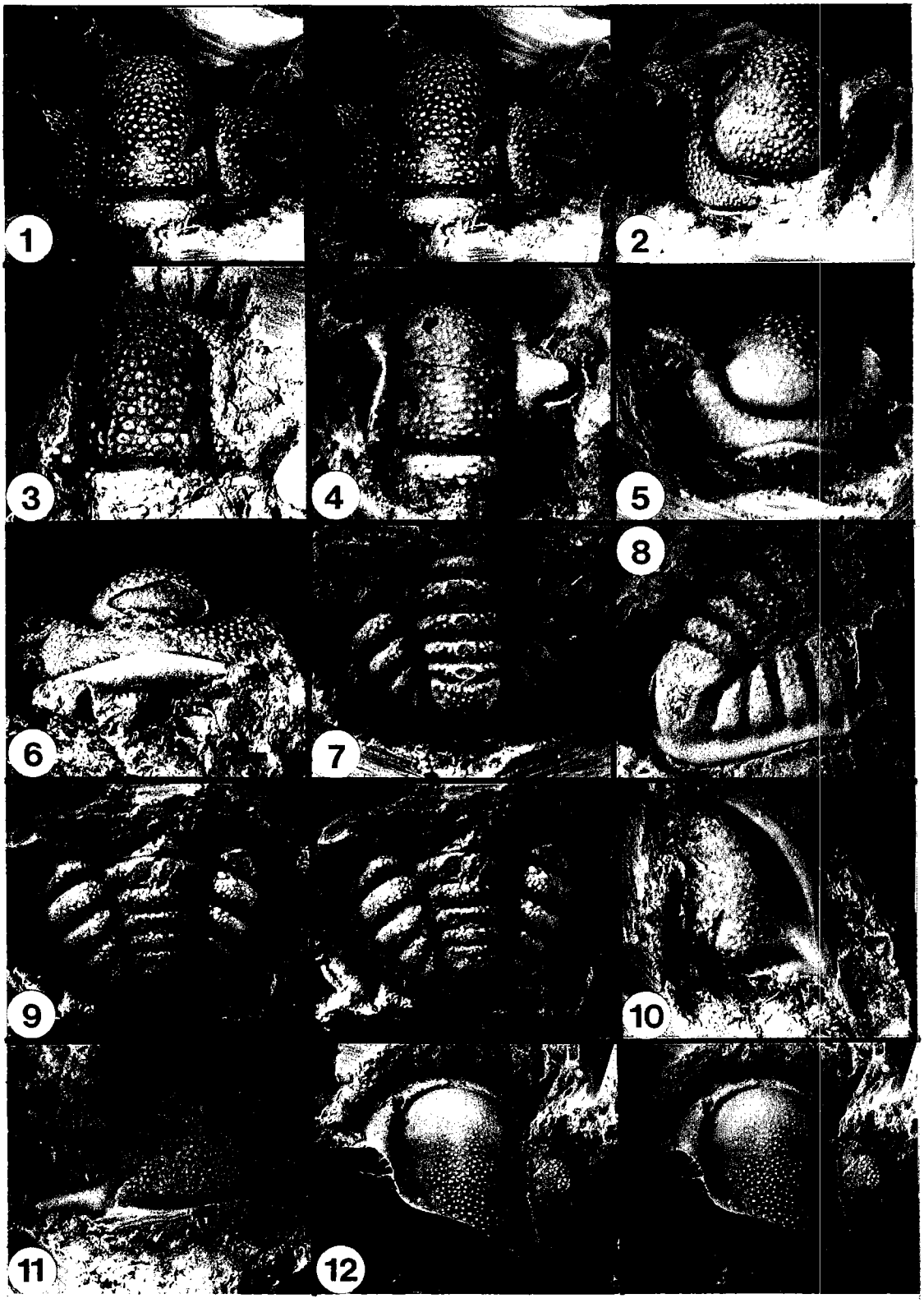
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Plate 12

PETIGURUS Raymond

Figure		*Page*
1–14	***Petigurus cullisoni* n. sp.** *1–3*, Medium cranidium, largely exfoliated (UMC 16995, holotype), from I-738; *1*, stereopair; palpebral view, ×2.1; *2*, lateral view, ×2.4; *3*, anterior view, ×2.2. *4*, Medium cranidium, anterior view, largely exfoliated with testate anterior border and fixigena preserved on right, ×2.5 (UMC 16996, paratype), from I-762. *5*, Medium cranidium, dorsal view, largely exfoliated, ×2.1 (UMC 16997, paratype), from I-1127. *6, 7*, Medium cranidium, largely exfoliated (UMC 16998, paratype), from I-1009; *6*, palpebral view with faint eye ridge and occipital ring present, ×2.3; *7*, anterior view, ×2.7. *8*, Large fragmentary cranidium, anterior oblique view, testate with thin exoskeleton wrinkled along axial furrow, ×4.0 (UMC 16999, paratype), from I-1009. *9, 10*, Large fragmentary pygidium, exfoliated (UMC 17000, paratype), from I-1105; *9*, stereopair; dorsal view, ×1.6; *10*, posterior view showing steeply declined border, ×1.4. *11*, Large pygidium, dorsal view, testate with pustules, ×2.0 (UMC 17001, paratype), from KR-809. *12*, Medium fragmentary pygidium, lateral oblique view, testate showing lateral border, ×2.7 (UMC 17002, paratype), from I-1009. *13*, Medium librigena, dorsal oblique view, testate, ×2.4 (UMC 17003, paratype), from I-952. *14*, Medium librigena with short genal spine, dorsal view, exfoliated, ×2.2 (UMC 17004, paratype), from KR-796.	38

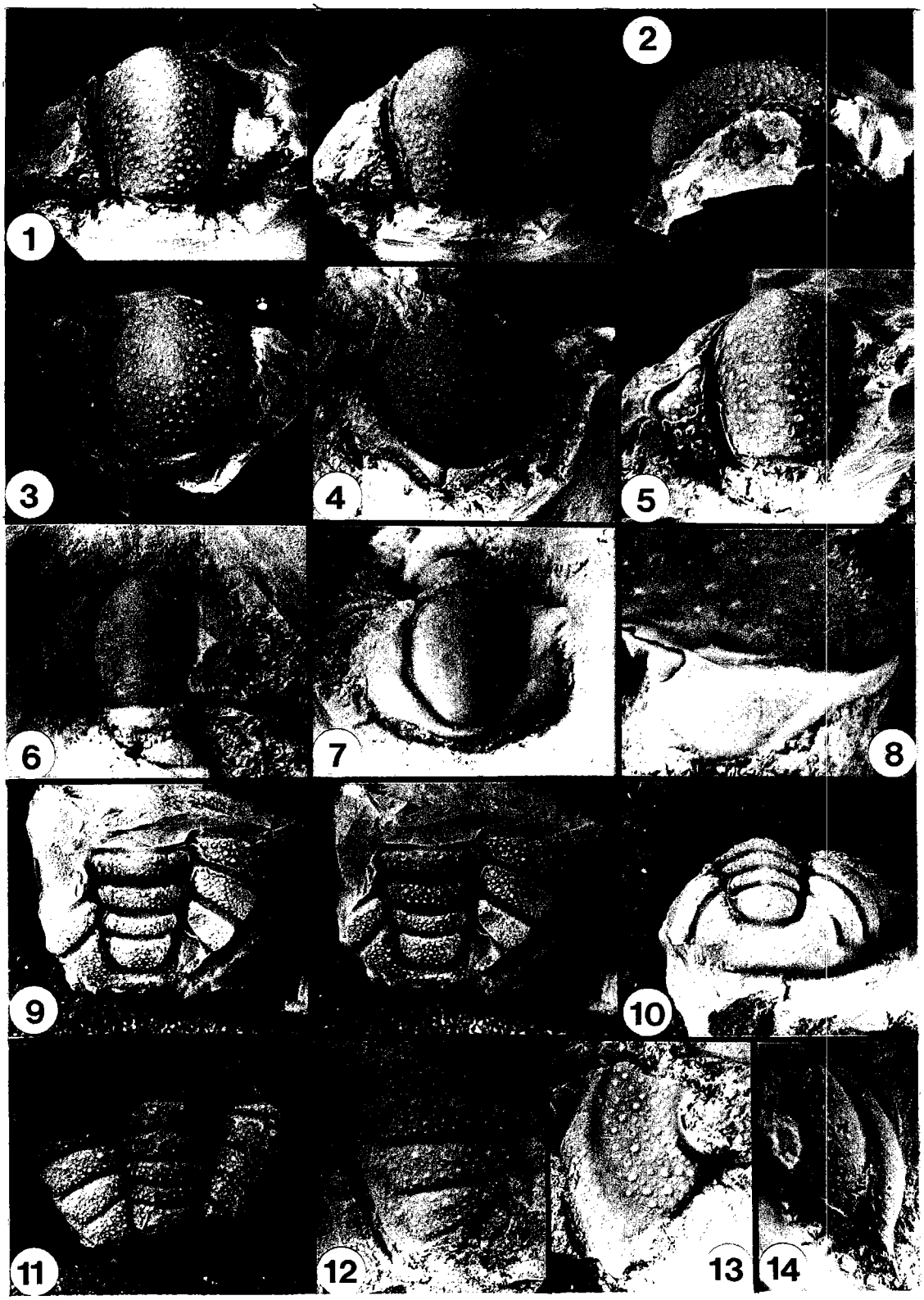
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Plate 13

RANASASUS Cullison

Figure		*Page*
1–8	***Ranasasus brevicephalus* Cullison.** *1*, Stereopair; medium cranidium showing slight transverse convexity, palpebral view, exfoliated and weathered, ×3.6 (UMC 17005), from KR-76. *2*, Medium cranidium, palpebral view, exfoliated showing faintly impressed axial furrows and faint keel, ×5.1 (UMC 17006), from KR-75A. *3*, Medium cranidium, palpebral view, testate showing effacement of cranidial furrows, ×4.1 (UMC 17007), from KR-120. *4*, Medium cranidium, anterior view, testate showing anterior border and vaguely impressed preglabellar furrow, ×4.6 (UMC 17008), from KR-103. *5*, Medium librigena, lateral view, exfoliated, ×5.2 (UMC 17009), from KR-132. *6*, Medium pygidium, dorsal view, testate showing effacement of pygidial furrows, ×4.9 (UMC 17010), from I-44. *7*, Stereopair; medium pygidium showing slightly convex axis, dorsal view, exfoliated with weakly impressed ring and pleural furrows, ×5.3 (UMC 17011), from KR-75. *8*, Medium pygidium, dorsal view, exfoliated, broken to show concave doublure on right side, ×4.0 (UMC 17012), from KR-76.	40
9	***Ranasasus* sp. 1.** Stereopair; large pygidium, dorsal view, partially exfoliated, ×1.8 (UMC 17013), from I-1127.	43
10, 11	***Ranasasus conicus* Cullison.** Medium cranidium showing conical anterior outline, exfoliated and weathered, ×4.5 (UMC 17014), from I-119. *10*, Stereopair; palpebral view. *11*, Anterior view.	42

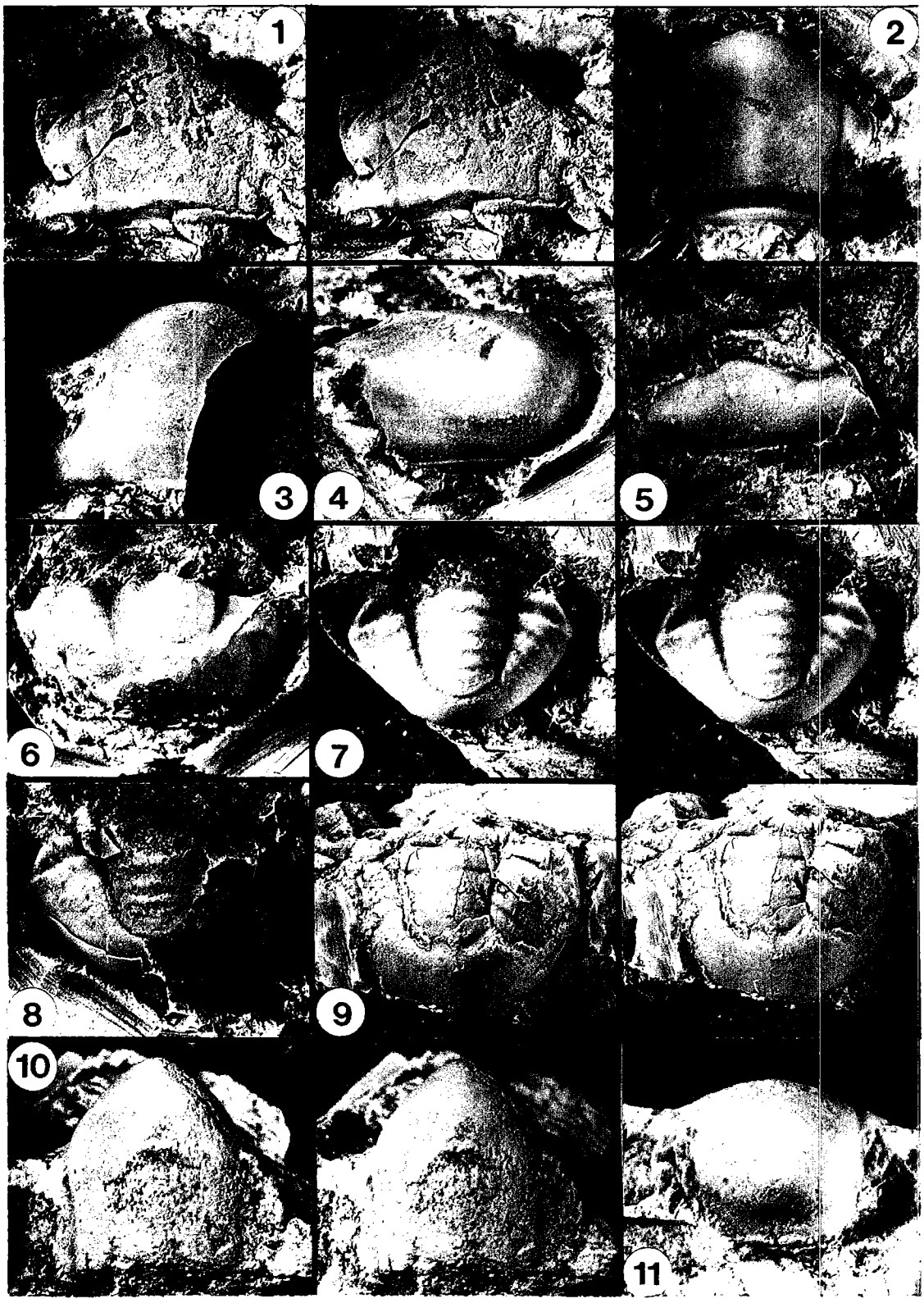
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Plate 14

RANASASUS Cullison and *SPEYERIS* n. gen.

Figure		*Page*
1–7	***Ranasasus colossus* n. sp.** *1*, Stereopair; small cranidium, palpebral view, exfoliated, ×8.2 (UMC 17015, holotype), from KR-437. *2, 3*, Large fragmentary cranidium, anterior view, exfoliated (UMC 17016, paratype), from KR-437; *2*, showing confluence of anterior border and preglabellar furrows, ×1.0; *3*, enlargement showing anterior terrace lines, ×2.1. *4, 5*, Large librigena, exfoliated, ×1.4 (UMC 17017, paratype), from KR-437; *4*, dorsal view; *5*, lateral view showing rounded genal spine. *6*, Large librigena, lateral view, exfoliated showing lateral and posterior border furrows, ×1.6 (UMC 17018, paratype), from KR-437. *7*, Stereopair; large fragmentary pygidium showing terminal axial piece flush with border and pleural fields, dorsal view, exfoliated, ×2.0 (UMC 17019, paratype), from KR-437.	42
8	***Ranasasus* sp. 1.** Large pygidium, dorsal view, exfoliated, ×1.7 (UMC 17020), from I-1210.	43
9–13	***Speyeris hami* n. sp.** *9, 10*, Large fragmentary pygidium, exfoliated showing prosopon on pleural ribs (UMC 17021, paratype), from KR-653; *9*, stereopair, dorsal view, ×2.1; *10*, lateral oblique view, latex mold showing border, ×2.0. *11, 12*, Large librigena, partially exfoliated showing prosopon (UMC 17022, paratype), from KR-638; *11*, lateral view, ×1.2; *12*, dorsal view, ×1.0. *13*, Cranidial fragment of preoccular area and frontal lobe of glabella, anterior oblique view, partially exfoliated, ×3.1 (UMC 17023), from I-1009.	51

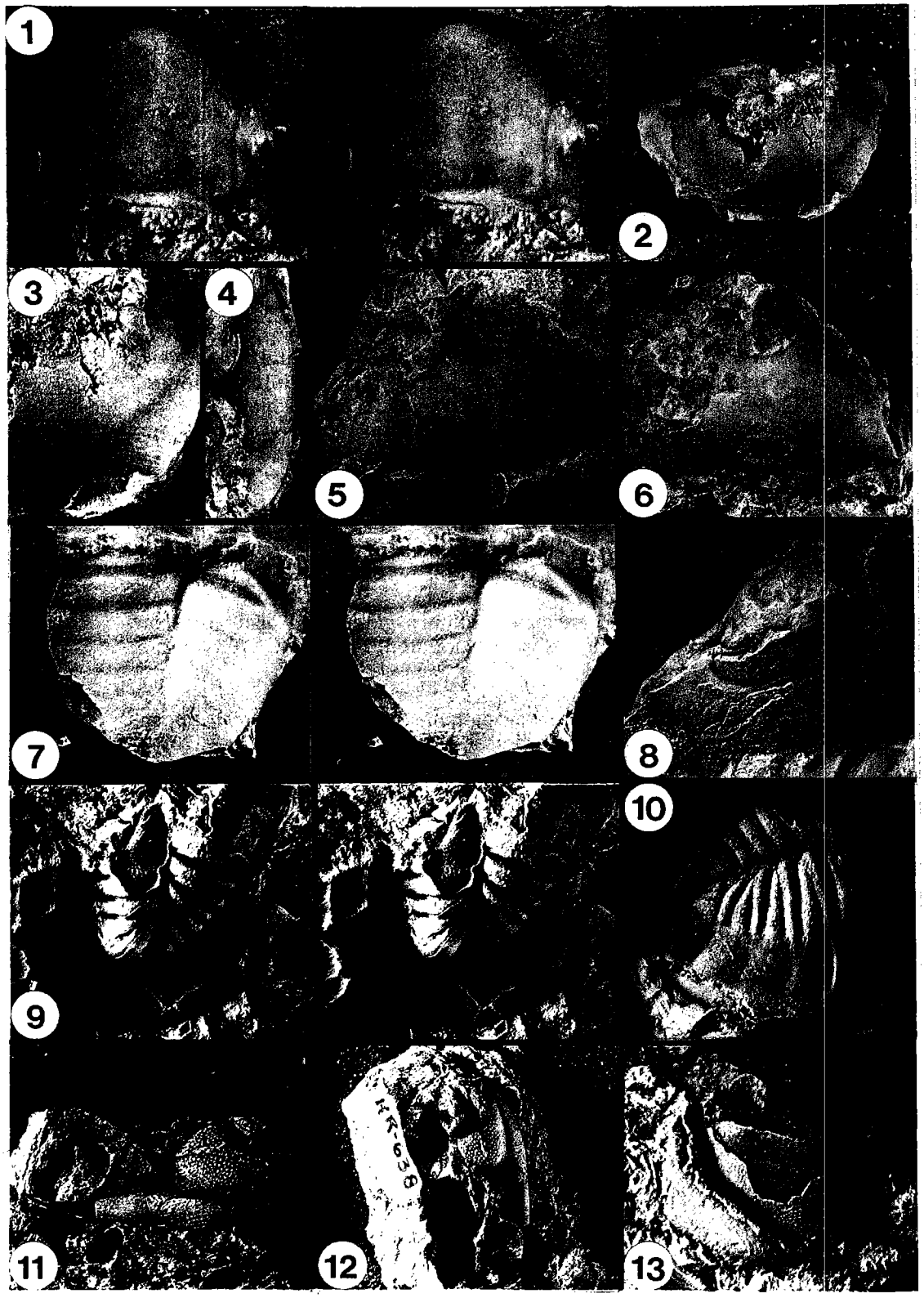
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Plate 15

STRIGIGENALIS Whittington and Ross

Figure		*Page*
1–8	***Strigigenalis caudata*** **(Billings).** *1*, Meraspid pygidium, dorsal view, testate, ×10.7 (UMC 17024), from I-1227. *2, 3*, Medium cranidium, largely testate, ×4.2 (UMC 17025), from I-1227; *2*, stereopair; palpebral view; *3*, anterior view. *4*, Medium cranidium, palpebral view, testate, ×5.8 (UMC 17026), from I-1227. *5*, Medium pygidium, testate, ×4.0 (UMC 17027), from I-1227. *6*, Stereopair; medium pygidium, dorsal view, partially exfoliated showing pitted prosopon, ×5.1 (UMC 17028), from I-1227. *7*, Medium pygidium, dorsal view, testate, ×5.5 (UMC 17029), from I-1227. *8*, Fragmentary medium pygidium, dorsal view, testate, ×6.5 (UMC 17030), from I-1227.	44
9	***Strigigenalis*** **sp. 2.** Stereopair; medium pygidium with distinct keel on post-axial border, dorsal view, exfoliated, ×4.6 (UMC 17031), from I-1444.	50
10, 11	***Strigigenalis?*** **sp. 3.** *10*, Stereopair; medium pygidium lacking post-axial spine due to breakage, dorsal view, exfoliated, ×4.9 (UMC 17032), from I-1468. *11*, Medium fragmentary pygidium, lateral oblique view, exfoliated, ×5.2 (UMC 17033), from I-1468.	50

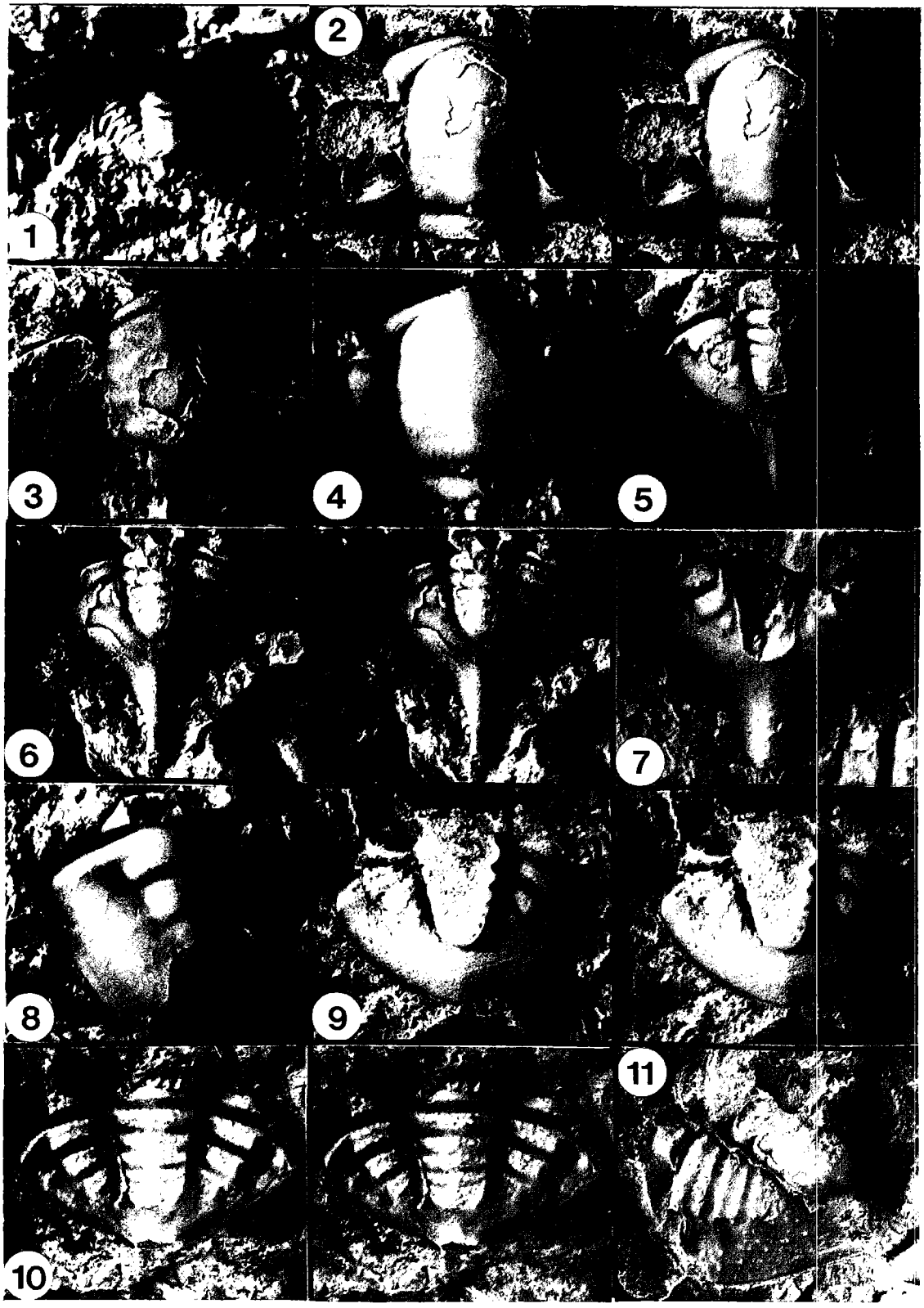
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Plate 16

STRIGIGENALIS Whittington and Ross

Figure		*Page*
1–12	***Strigigenalis crassimarginata*** (Cullison). ***1, 2***, Medium cranidium, largely testate (UMC 17034), from KR-809; *1*, stereopair; palpebral view, ×3.5; *2*, anterior view with coarse ridges as prosopon, ×4.5. ***3***, Small cranidium, palpebral view, testate, ×5.1 (UMC 17035), from KR-860. ***4***, Medium cranidium, palpebral view, partially testate with prosopon preserved on occipital ring and posterior fixigenae, ×4.4 (UMC 17036), from I-940. ***5***, Medium pygidium with short post-axial lappet, dorsal view, exfoliated along axis, ×2.7 (UMC 17037), from I-1064, with medium pygidium of *Strigigenalis insentis*, partially exfoliated (UMC 17057) at right. ***6***, Small pygidium with short post-axial lappet, dorsal view, testate, ×4.4 (UMC 17038), from I-1159. ***7***, Stereopair; small pygidium with moderate post-axial lappet, dorsal view, testate, ×7.2 (UMC 17039), from KR-860. ***8***, Medium pygidium with narrow (tr.) post-axial lappet and prosopon on pleural ribs, dorsal view, ×5.1 (UMC 17040), from I-1185. ***9***, Stereopair of two specimens; at left, dorsal view, medium pygidium (UMC 17041) with short post-axial spine, and triangular post-axial lappet; at right posterior oblique view (UMC 18000), demonstrating range of variability of this feature; specimens exfoliated with pitted prosopon, ×2.6, from I-1185. ***10***, Medium pygidium with triangular post-axial lappet, dorsal view, exfoliated, ×4.8 (UMC 17042), from I-1185. ***11***, Small pygidium with short post-axial spine, dorsal view, testate, ×6.2 (UMC 17043), from I-1227. ***12***, Medium pygidium, lacking post-axial spine due to breakage, dorsal view, testate with coarse prosopon on axis and pleural ribs, ×5.9, from I-1227.	44

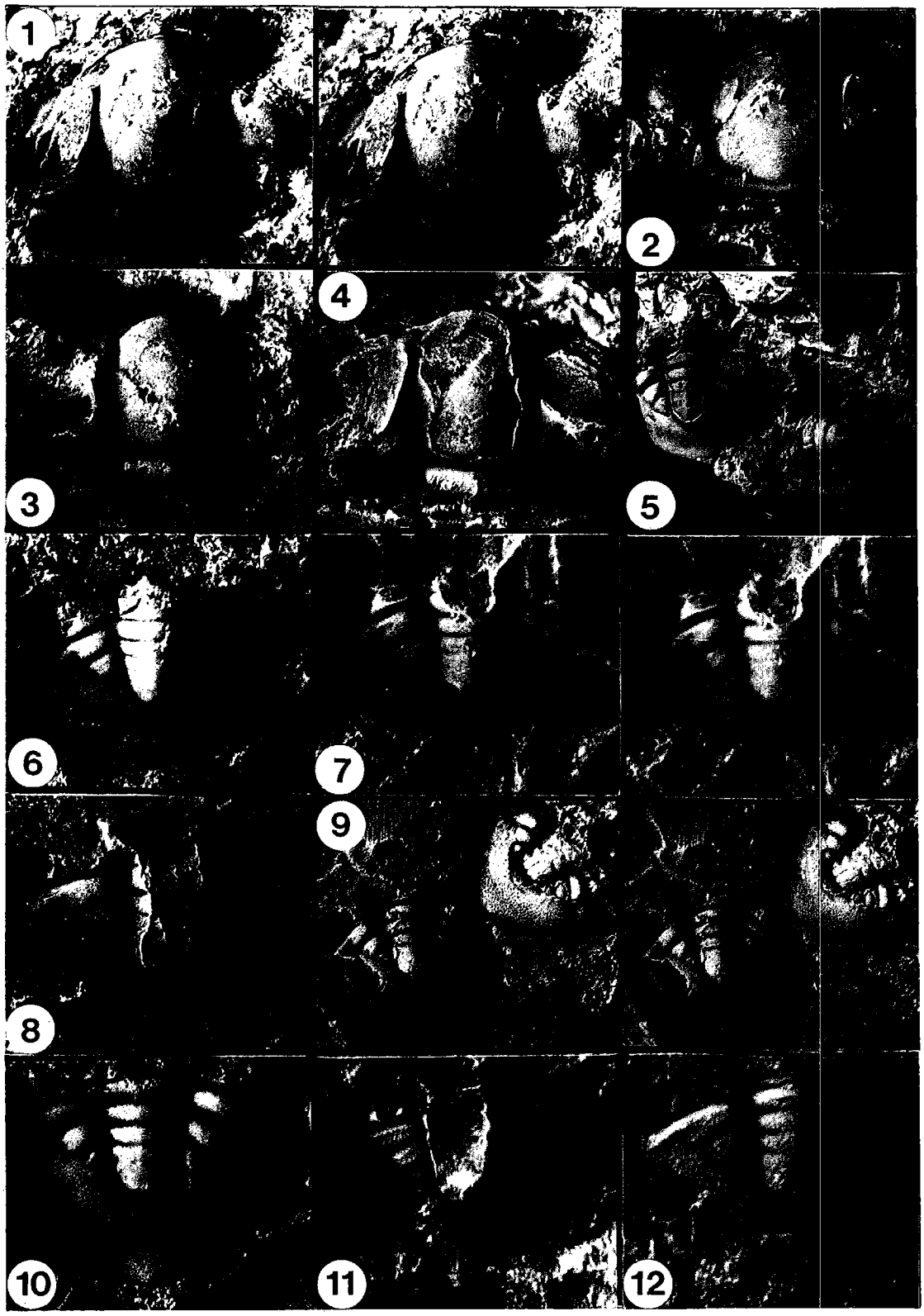
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Plate 17

STRIGIGENALIS Whittington and Ross

Figure		*Page*
1–3	***Strigigenalis crassimarginata*** **(Cullison).** *1*, Medium librigena, dorsal view, testate with coarse ridges, ×4.1 (UMC 17045), from I-893. *2*, Medium librigena, lateral view, testate with coarse ridges, ×4.1 (UMC 17046), from I-1143. *3*, Small librigena, dorsal view, exfoliated, ×5.6 (UMC 17047), from I-1113.	44
4–13	***Strigigenalis derbyi*** **n. sp.** *4, 5*, Medium cranidium, testate with fine granular prosopon on glabella (UMC 17048, holotype), from I-525; *4*, stereopair; palpebral view, ×4.0; *5*, anterior view, ×4.5. *6*, Large cranidium, palpebral view, exfoliated, ×2.7 (UMC 17049, paratype), from I-521. *7*, Stereopair; medium pygidium, dorsal view, testate ×3.9 (UMC 17050, paratype), from I-476. *8*, Large pygidium, dorsal view, testate, ×5.9 (UMC 17051, paratype), from I-503. *9*, Large pygidium, dorsal view, testate with granular prosopon on axis and pleural ribs, ×3.3 (UMC 17052, paratype), from I-525. *10*, Small, crushed pygidium, dorsal view, testate, ×6.0 (UMC 17053, paratype), from I-527. *11*, Large pygidium, dorsal view, exfoliated with pitted prosopon, ×3.9 (UMC 17054, paratype), from KR-451. *12*, Large librigena, lateral view, testate with granules on genal field and short ridges on posterior border, ×3.1 (UMC 17055, paratype), from I-503. *13*, Small librigena, dorsal view, exfoliated with pitted prosopon, ×4.8 (UMC 17056, paratype), from I-527.	46

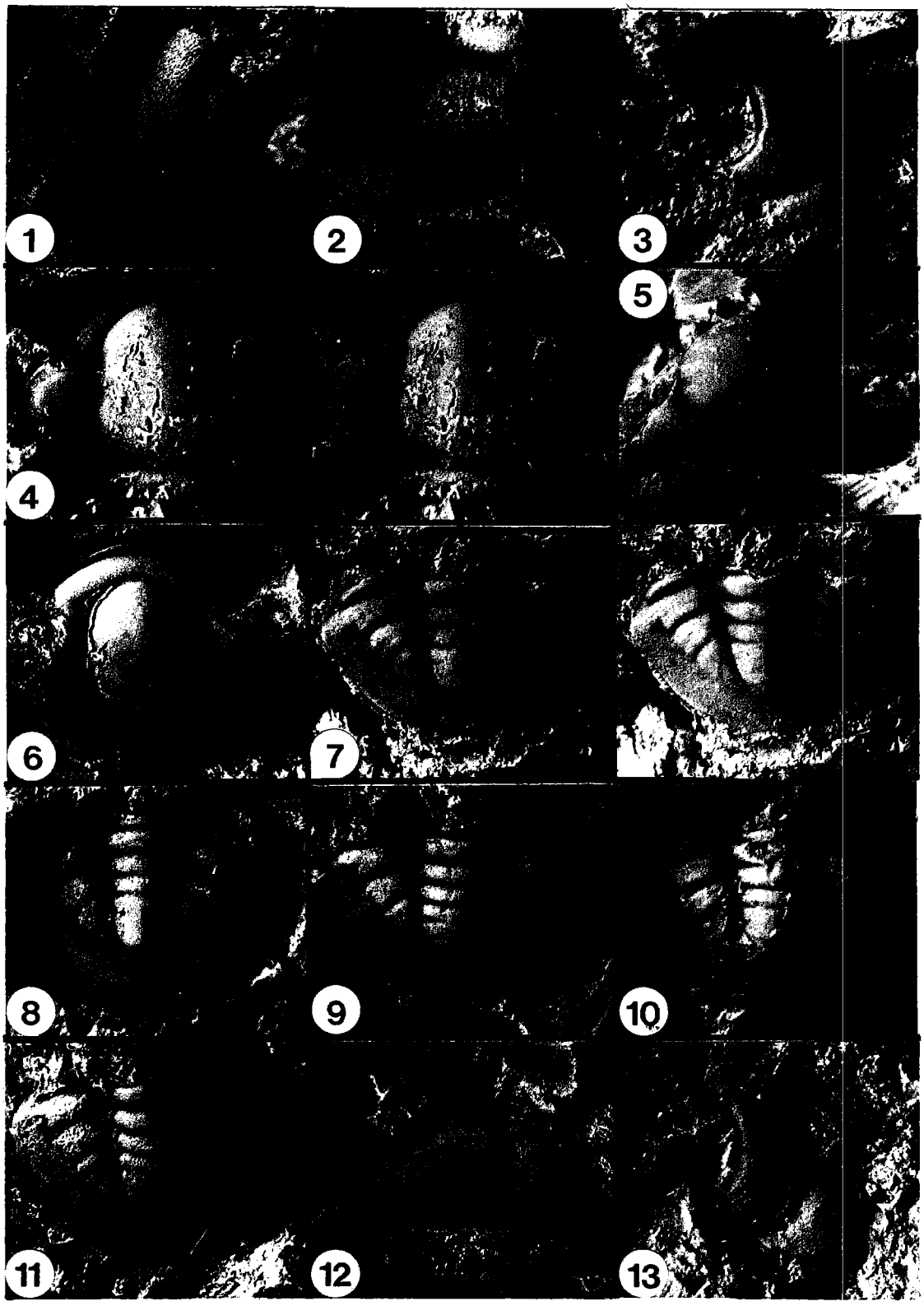
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Plate 18

STRIGIGENALIS Whittington and Ross

Figure		*Page*
1–12	***Strigigenalis implexa* n. sp.** *1, 2,* Medium cranidium, testate, ×3.5 (UMC 16882, holotype), from I-666; *1,* stereopair; palpebral view; *2,* anterior view. *3,* Medium cranidium showing lateral shoulder on occipital ring, palpebral view, testate with granulose prosopon on glabella, ×4.8 (UMC 16883, paratype), from I-691. *4,* Medium fragmentary cranidium, palpebral view, testate with granulose prosopon concentrated along flanks of glabella, ×4.6 (UMC 16884, paratype), from I-650. *5,* Small pygidium with concave post-axial border, dorsal view, testate, ×5.5 (UMC 16885, paratype), from I-650. *6, 7,* Medium pygidium, largely exfoliated with faint post-axial ridge (UMC 16886, paratype), from I-650; *6,* stereopair; dorsal view, ×2.7; *7,* lateral view, ×2.9. *8,* Medium fragmentary pygidium, dorsal view, testate with granules restricted to axial rings and pleural ribs, ×3.2 (UMC 16887, paratype), from KR-638. *9,* Medium fragmentary pygidium showing doublure, dorsal view, testate with coarser granulose prosopon, ×4.4 (UMC 16888, paratype), from I-650. *10,* Medium librigena, dorsal view, testate with coarse ridges on genal spine, ×3.0 (UMC 16889, paratype), from I-711. *11, 12,* Medium librigena, largely testate with fine ridges on genal field, ×2.3 (UMC 16890, paratype), from KR-610; *11,* dorsal view; *12,* lateral view showing well-elevated lateral border as marginal rim.	47
13	***Strigigenalis* cf. *S. knighti* (Boyce).** Medium fragmentary librigena showing angulation in posterior border furrow, lateral-oblique view, exfoliated, ×4.1 (UMC 16891), from I-1272.	46

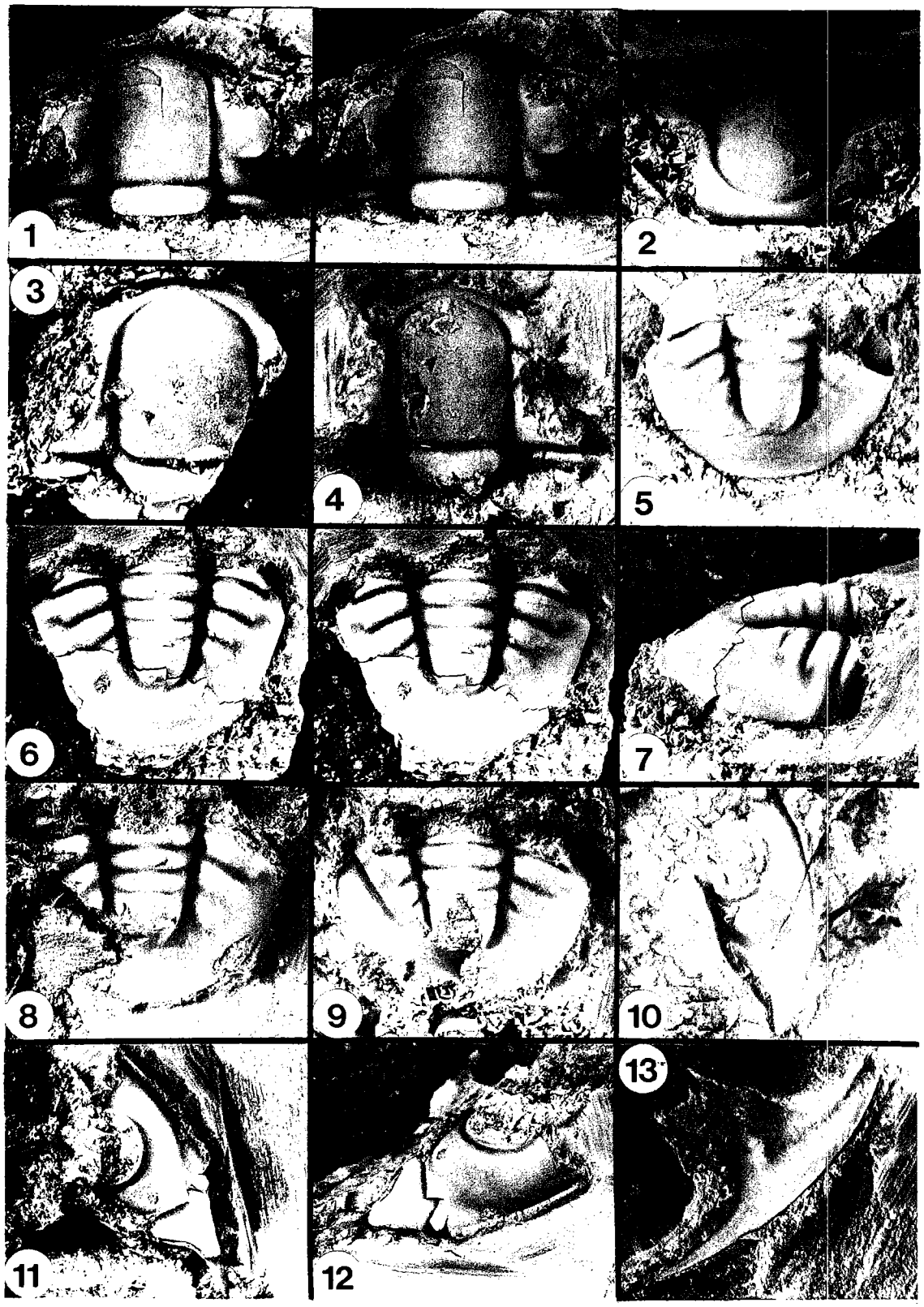
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Plate 19

STRIGIGENALIS Whittington and Ross

Figure		*Page*
1–10	***Strigigenalis insentis* n. sp.** *1.* Stereopair; medium cranidium, palpebral view, testate with fine granules, ×7.5 (UMC 17075, holotype), from I-1064. *2,* Medium cranidium, palpebral view, exfoliated, ×5.7 (UMC 17076, paratype), from I-1064. ***3, 4,*** Medium cranidium, partially exfoliated (UMC 17077, paratype), from I-108; *3,* palpebral view, ×5.0; *4,* anterior view, ×4.8. *5,* Medium pygidium, palpebral view, partially exfoliated, ×5.0 (UMC 17078, paratype), from I-1064. *6,* Stereopair; medium pygidium, dorsal view, partially exfoliated with granules on axis and smooth border (UMC 17079, paratype), from I-1064. *7,* Large fragmentary pygidium, dorsal view, exfoliated, paratype, ×4.4 (UMC 17080), from I-1064. *8,* Large librigena, dorsal view, partially exfoliated, ×2.8 (UMC 17081, paratype), from I-1146. *9,* Medium librigena, lateral view, partially exfoliated, ×2.8 (UMC 17082, paratype), from I-1064. *10,* Medium librigena, lateral view, testate, showing coarse ridges on border, ×5.0 (UMC 17083 paratype,), from I-1064.	48
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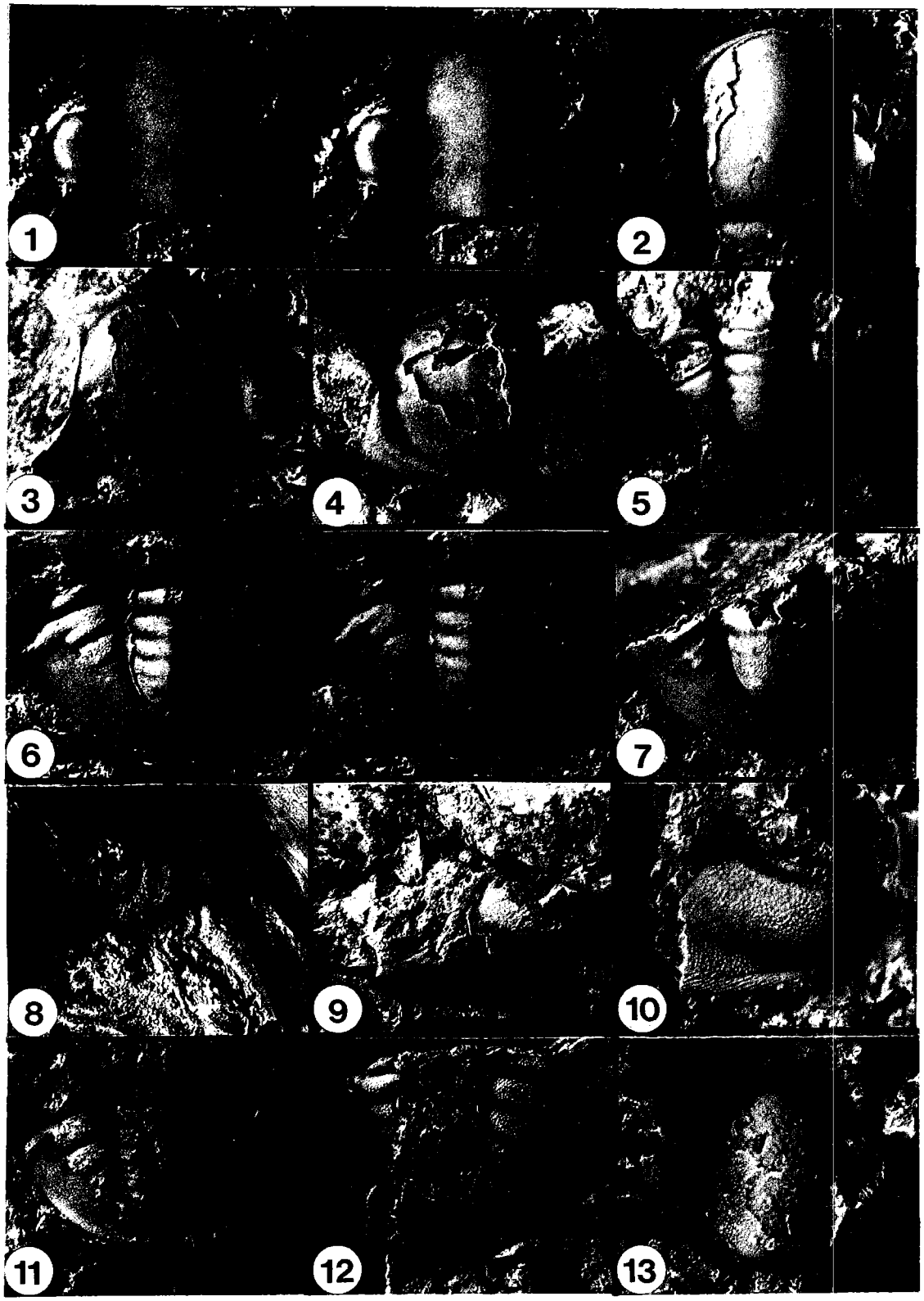
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Plate 20

BATHYURELLUS Billings

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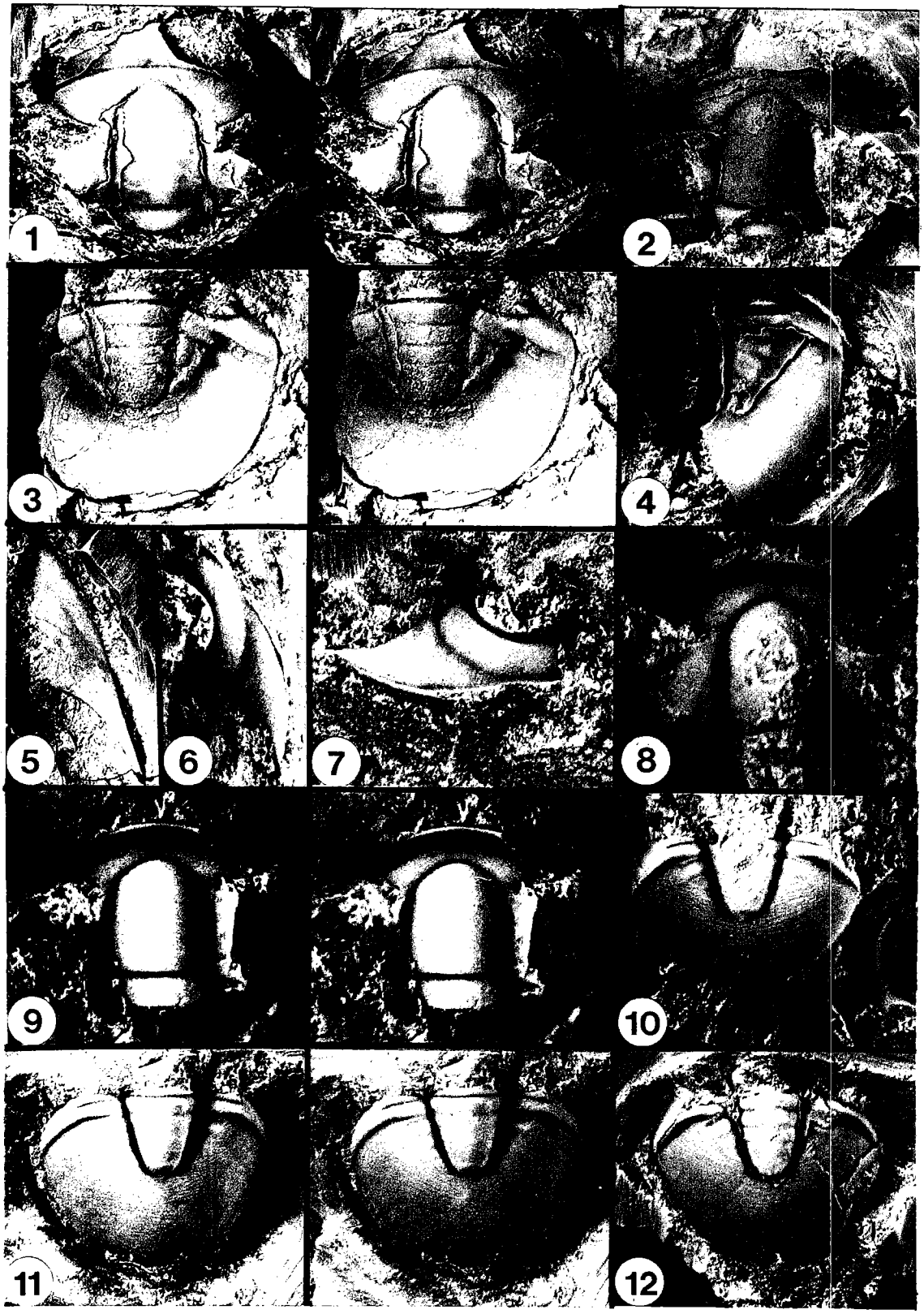
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Plate 21

BENTHAMASPIS Poulsen

Figure		*Page*
1–4	***Benthamaspis onomeris* n. sp.** *1*, Stereopair; medium cranidium, palpebral view, partially exfoliated, ×5.3 (UMC 16822, holotype), from I-1064. *2*, Small cranidium, palpebral view, testate, ×10.0 (UMC 16823, paratype), from I-1064. *3*, Stereopair; medium pygidium, dorsal view, testate with terrace lines and faint post-axial ridge, ×5.3 (UMC 16824, paratype), from I-1227. *4*, Medium pygidium, dorsal view, testate, ×5.3 (UMC 16825, paratype), from I-996.	57
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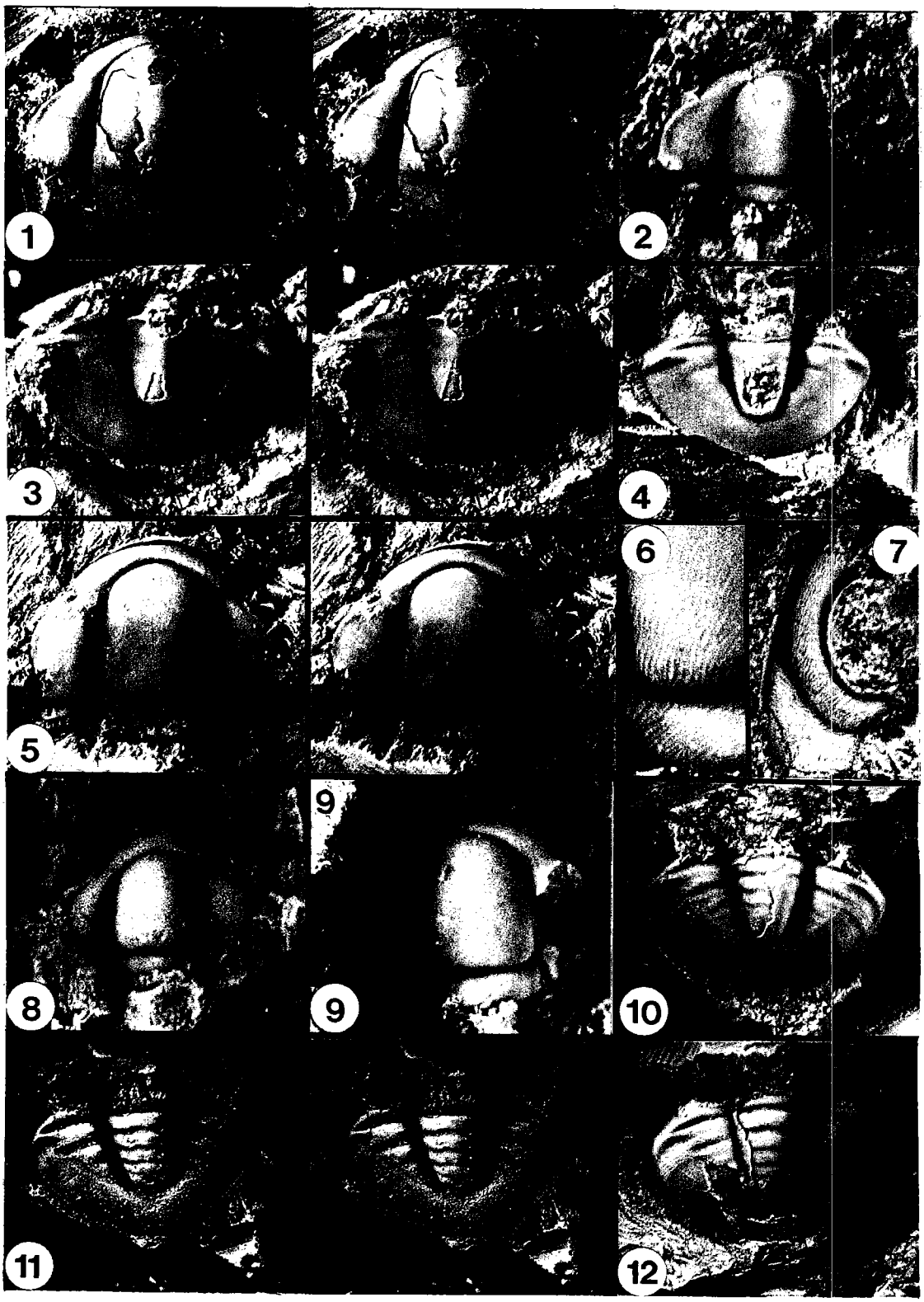
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Plate 22

BENTHAMASPIS Poulsen and *CHAPMANIA* n. gen.

Figure		*Page*
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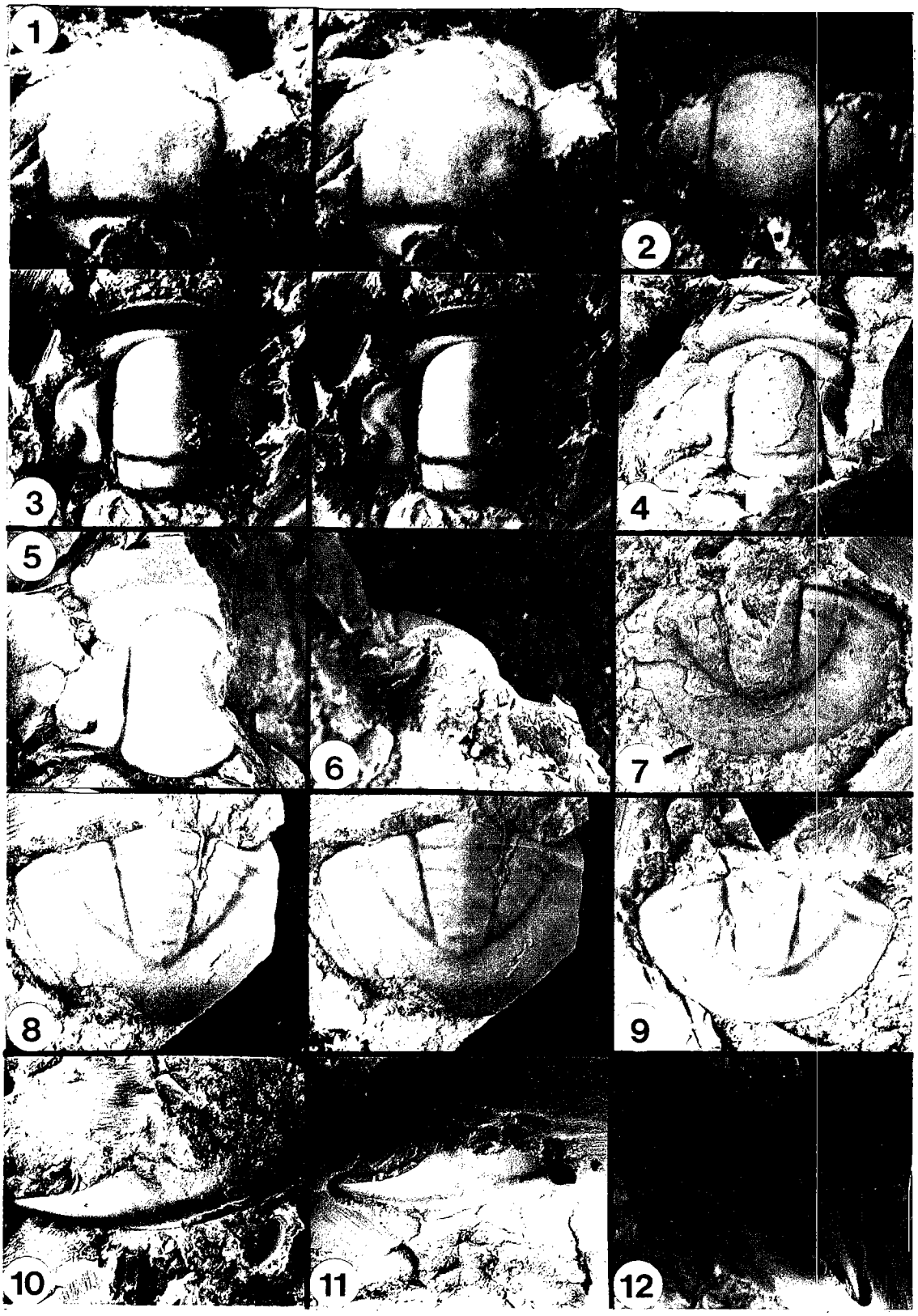
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Plate 23

CHAPMANIA n. gen.

Figure		*Page*
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10	***Chapmania* sp. 1.** Stereopair; medium pygidium, dorsal view, exfoliated with paired muscle scars on axial rings, ×2.4 (UMC 16868), from KR-305.	64

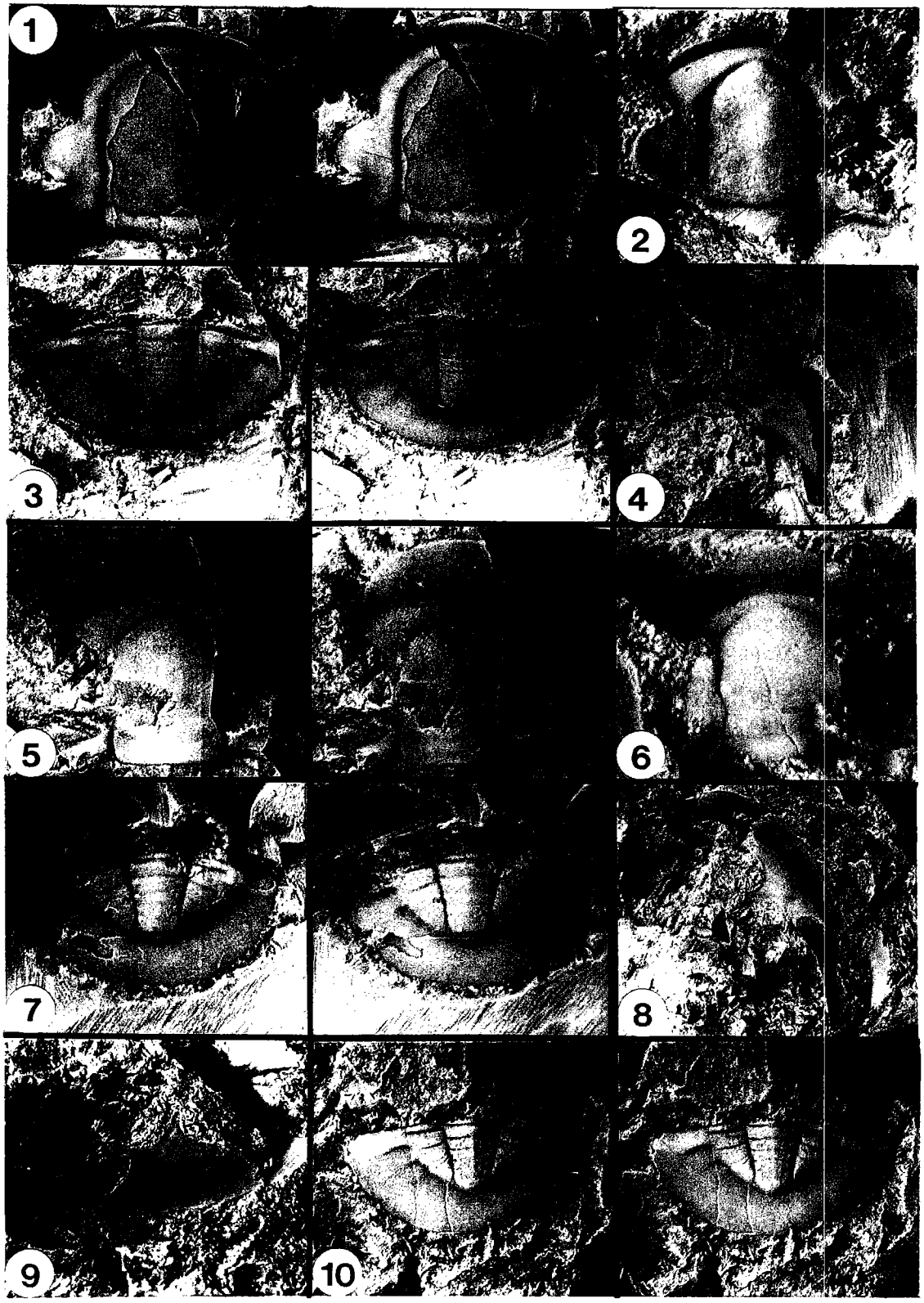
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Plate 24

LUTESVILLIA Cullison

Figure		*Page*
1–13	***Lutesvillia bispinosa* Cullison.** *1*, Stereopair; medium cranidium with recurved anterior border furrow, palpebral view, testate, ×3.6 (UMC 16869), from I-623. *2*, Medium cranidium, palpebral view, testate, ×3.8 (UMC 16870), from KR-571. *3*, Crushed medium cranidium, palpebral view, testate, ×2.2 (UMC 16871), from I-623. *4*, Small cranidium, palpebral view, testate, ×6.2 (UMC 16872), from I-398. *5*, Small pygidium, dorsal view, testate, ×5.0 (UMC 16873), from I-556. *6*, Stereopair; medium pygidium with deformed right pygidial spine, dorsal view, exfoliated with deep pits on border and pleural fields, ×3.0 (UMC 16874), from KR-437. *7*, Large pygidium, dorsal view, exfoliated, ×1.9 (UMC 16875), from I-314. *8, 9*, Large librigena, testate (UMC 16876), from I-396; *8*, dorsal view, ×1.8; *9*, lateral view, ×1.6. *10, 11*, Large librigena, testate (UMC 16877), from I-398; *10*, lateral view, ×2.0; *11*, dorsal view, ×1.9. *12*, Medium pygidium, dorsal view, partially exfoliated, ×4.8 (UMC 16878), from I-596. *13*, Fragmentary medium pygidium, ventral view showing doublure, testate, ×5.6 (UMC 16879), from I-451.	65
14	***Lutesvillia* sp. 1.** Stereopair; medium cranidium, palpebral view, testate, ×2.6, (UMC 16881), from KR-809.	66

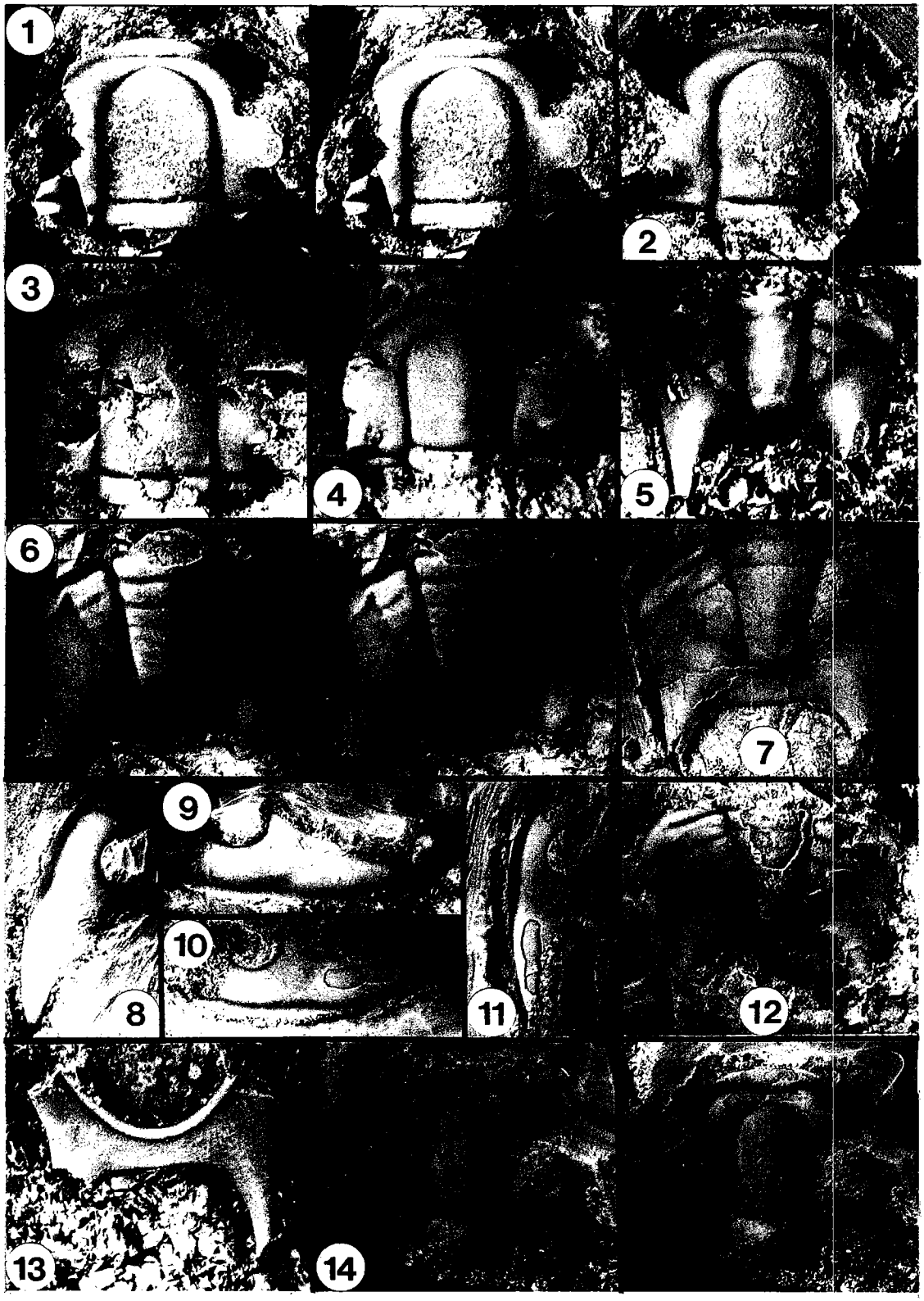
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Plate 25

PUNKA Fortey and *SPEYERIS* n. gen.

Figure		*Page*
1–7	***Punka akoura*** **n. sp.** *1*, Stereopair; medium cranidium, palpebral view, exfoliated, ×2.5 (UMC 16892, paratype), from I-499. *2*, Medium fragmentary cranidium showing complete frontal area, palpebral view, exfoliated, ×2.3 (UMC 16893, paratype), from KR-411. *3*, Stereopair; large encrusted pygidium, dorsal view, showing well-impressed interpleural furrows on border, testate, ×1.4 (UMC 16894, holotype), from KR-429. *4*, Large fragmentary pygidium, dorsal view, showing portion of axis, testate, ×1.6 (UMC 16895, paratype), from I-486. *5*, Medium fragmentary pygidium, dorsal view, testate, ×2.1 (UMC 16896, paratype), from I-696. *6, 7*, Large librigena, testate (UMC 16897, paratype), from I-523; *6*, ventral view, showing anterior extension of doublure, ×1.4; *7*, lateral view, ×1.1	66
8–12	***Speyeris hami*** **n. sp.** *8–11*, Large cranidium, exfoliated (UMC 16899, holotype), from KR-610; *8*, stereopair, palpebral view. ×1.3; *9*, lateral view, ×1.5; *10*, anterior view, showing frontal area, ×1.5; *11*, enlargement of left palpebral lobe showing distinctive prosopon, ×3.6. *12*, Large fragmentary cranidium, palpebral view, exfoliated, ×1.7 (UMC 16900), from KR-623.	51

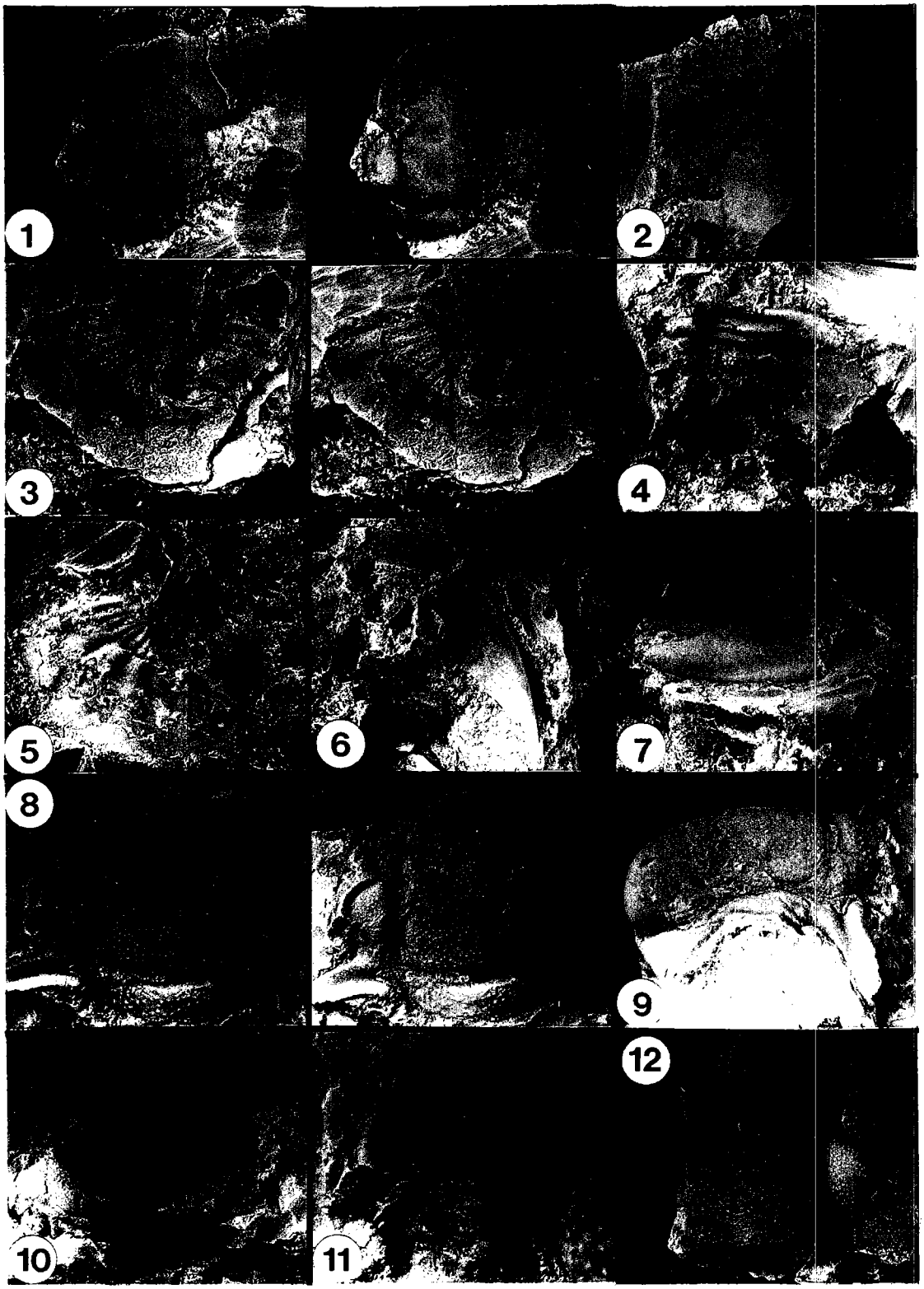
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Plate 26

PUNKA Fortey

Figure		*Page*
1–11	***Punka verecunda* n. sp.** *1*, Stereopair; large fragmentary cranidium, palpebral view, largely exfoliated, ×2.1 (UMC 16901, holotype), from KR-681. *2*, Medium cranidium showing left palpebral lobe, palpebral view, exfoliated, ×2.8 (UMC 16902, paratype), from KR-671. *3*, Medium fragmentary cranidium, palpebral view, exfoliated, showing postocular area, ×3.0 (UMC 16903, paratype), from I-762. *4*, Stereopair; large pygidium, dorsal view, exfoliated, showing pitted prosopon, ×2.0 (UMC 16904, paratype), from KR-681. *5*, Large fragmentary pygidium, dorsal view, exfoliated, showing paired muscle scars on axis, ×2.2 (UMC 16905, paratype), from I-738. *6*, Medium pygidium, dorsal view, exfoliated, showing interpleural furrows on border, ×2.7 (UMC 16906, paratype), from KR-823. *7*, Small pygidium, dorsal view, testate, ×5.4 (UMC 16907, paratype), from I-996. *8*, Medium fragmentary pygidium, ventral view of doublure, testate, ×1.7 (UMC 16908, paratype), from KR-684. *9*, *10*, Large fragmentary librigena, testate (UMC 16909, paratype), from KR-741; *9*, dorsal view, ×1.6; *10*, lateral view, showing genal caecae on genal field, ×1.8. *11*, Medium librigena, lateral view, testate, ×3.2 (UMC 16910, paratype), from I-1034.	68
12, 13	***Punka* sp. 1.** *12*, Stereopair, medium fragmentary cranidium, palpebral view, testate, ×2.6 (UMC 16911), from I-471. *13*. Medium fragmentary cranidium, palpebral view, testate, ×3.0 (UMC 16912), from I-471.	69

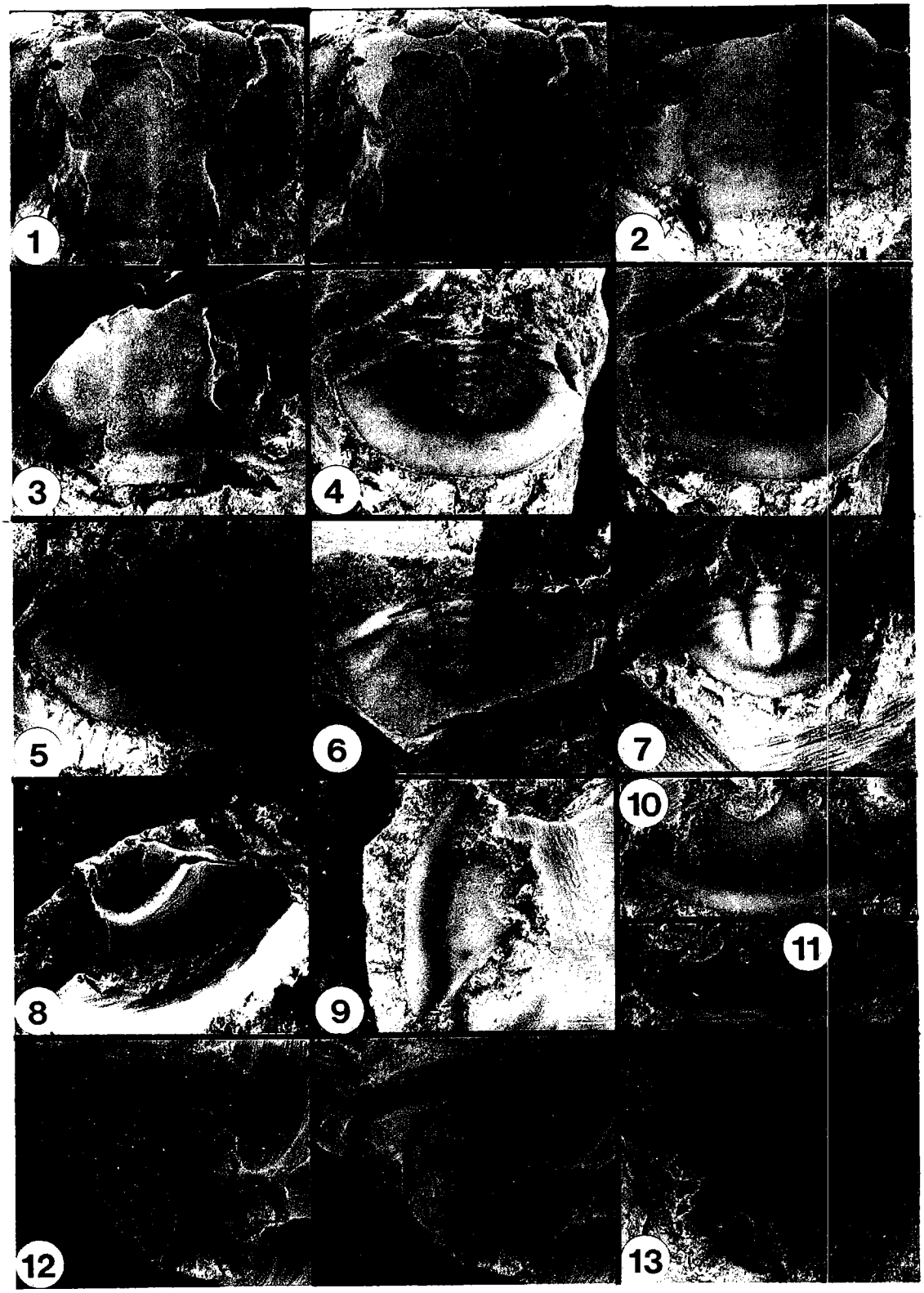
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Plate 27

RANDAYNIA Boyce

Figure		*Page*
1–7	***Randaynia leatherburyi* n. sp.** *1, 2,* Medium cranidium, partially exfoliated with faint axial and preglabellar furrows (UMC 16913, holotype), from KR-901; *1,* stereopair; specimen with narrow anterior border at upper left, palpebral view, ×3.1; *2,* anterior view, ×3.4. *3,* Weathered medium cranidium with postocular area, palpebral view, exfoliated, ×2.6 (UMC 16914) , paratype, from KR-901. *4,* Stereopair; medium pygidium, dorsal view, exfoliated, ×3.6 (UMC 16915, paratype), from KR-901. *5,* Large pygidium, dorsal view, exfoliated, ×3.6 (UMC 16916, paratype), from KR-901. *6, 7,* Medium librigena, exfoliated (UMC 16917, paratype), from KR-901; *6,* lateral view with narrow lateral border, ×3.4; *7,* enlargement showing genal caecae, ×6.7.	70
8–12	***Randaynia* sp. 1.** *8,* Small pygidium with paired axial tubercles, dorsal view, testate, ×8.0 (UMC 16918), from I-1369. *9,* Stereopair; medium pygidium, dorsal view, partially exfoliated with terrace lines on border, ×4.7, (UMC 16919), from I-1369. *10,* Small pygidium, dorsal view, testate, ×5.7, (UMC 16920), from I-1369. *11,* Fragmentary medium cranidium, palpebral view, exfoliated, ×6.0 (UMC 16921), from I-1369. *12,* Fragmentary medium librigena, lateral oblique view, exfoliated, ×7.0, (UMC 16922), from I-1369	71

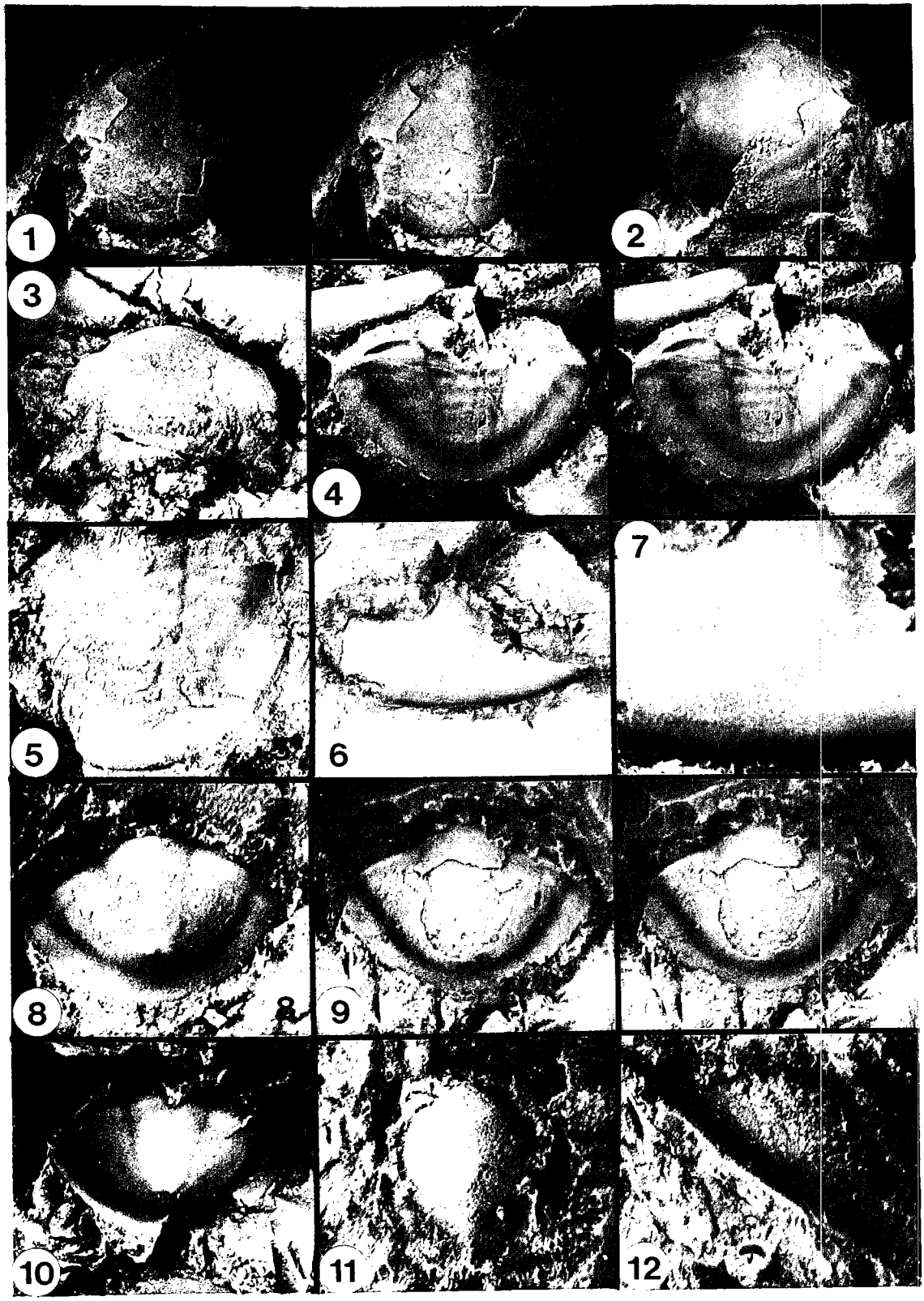
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Plate 28

ISCHYROTOMA Raymond, *DIMEROPYGIELLA* Ross, and *ROLLIA* Cullison

Figure — *Page*

1–10 ***Ischyrotoma sila*** **n. sp.** ***1, 2,*** Medium cranidium, partially testate showing granular prosopon (UMC 17085, holotype), from I-371; *1,* stereopair, palpebral view, ×2.3; *2,* anterior view showing mildly inflated anterior border, ×3.4. ***3,*** Small librigena, lateral oblique view, testate, note notch-like posterior border furrow and small lateral node at genal angle, ×5.3 (UMC 17086, paratype), from I-525. ***4, 5,*** Small cranidium, exfoliated (UMC 17087, paratype), from I-371; *4,* palpebral view showing vague glabellar furrows, ×4.4; *5,* anterior view showing sharply curved, weakly impressed anterior border furrow, ×4.7. ***6, 7,*** Small librigena with eye retained, testate (UMC 17088, paratype), from I-503; *6,* lateral view, ×3.7; *7,* dorsal view, ×4.0. ***8, 9,*** Small pygidium with one node on terminal axial piece missing, testate (UMC 17089, paratype), from I-631; *8,* dorsal view, ×7.5; *9,* posterior view, note low dorsal arch in posterior margin and moderately declined pleural fields, ×6.3. ***10,*** Small pygidium, oblique posterior view, testate, 7.0 (UMC 17090, paratype), from I-631. — 73

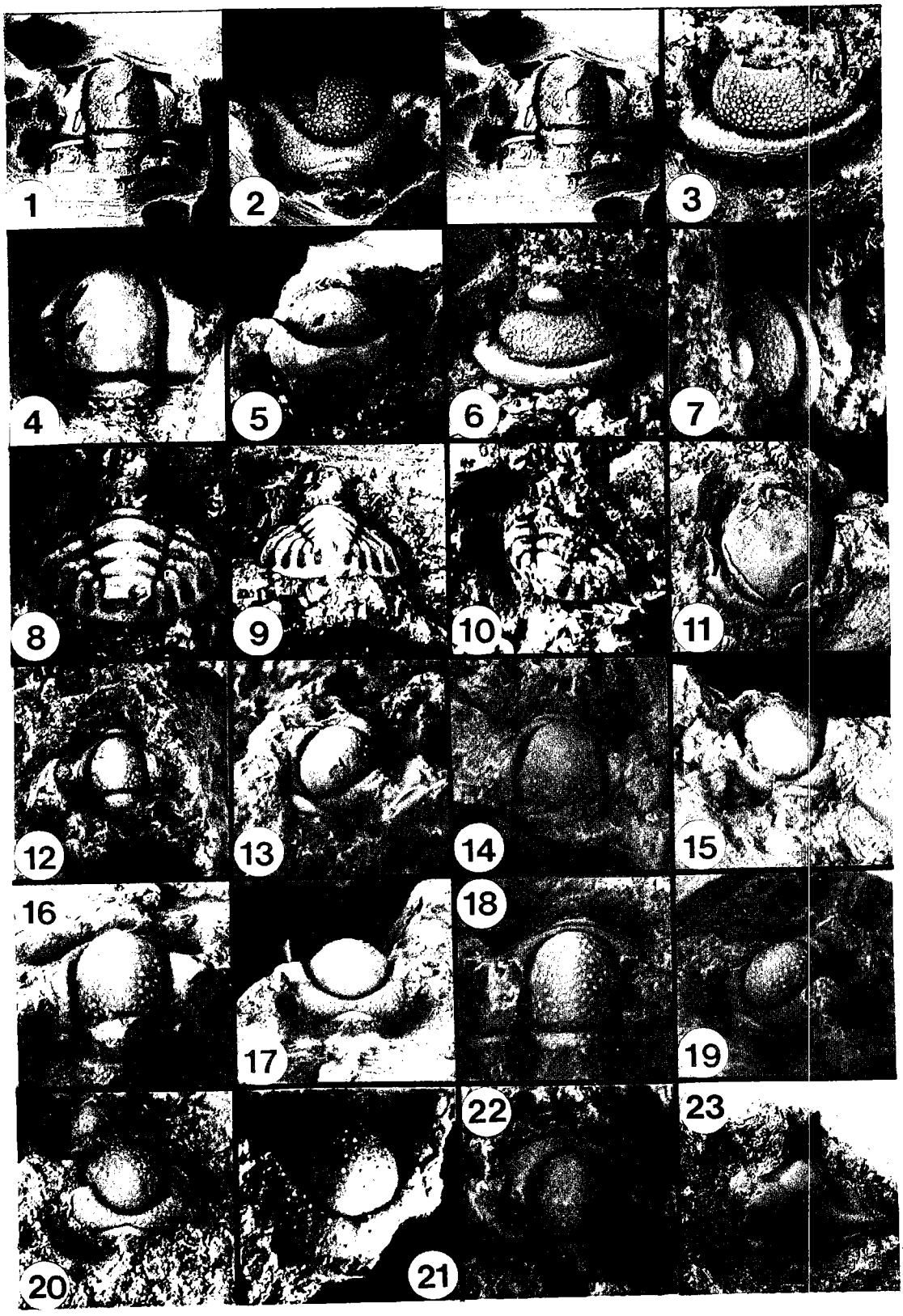
11–13 ***Dimeropygiella*** **sp. 1.** ***11,*** Medium fragmentary cranidium showing short preglabellar field, anterior oblique view, largely exfoliated, ×4.5 (UMC 17091), from I-1212. ***12, 13,*** Small cranidium showing protrusive, tubular, anterior border, testate (UMC 17092), from I-1227; *12,* palpebral view, ×5.2; *13,* anterior oblique view showing laterally tapering anterior border, ×7.2. — 72

14, 15 ***Ischyrotoma*** **sp.** ***14, 15,*** Small cranidium, testate (UMC 17093), from I-1064; *14,* palpebral view, ×4.5; *15,* anterior view, ×4.3. — 72

16–20 ***Ischyrotoma*** **sp. 1.** ***16, 17,*** Small cranidium, testate (UMC 17094), from I-849; *16,* palpebral view of quadrate glabella with glabellar furrows as granule-free patches, ×5.1; *17,* anterior view showing crease separating preocular and palpebral areas at anterior corner of palpebral lobes, ×6.0. ***18, 19,*** Small cranidium missing palpebral lobes, testate (UMC 17095), from KR-770; *18,* palpebral view showing short (exsag.) postocular area, ×7.3; *19,* anterior oblique view, ×5.8. ***20,*** Small fragmentary cranidium, anterior view, testate, ×7.8 (UMC 17096), from I-846. — 74

21 ***Ischyrotoma abrupta*** **(Cullison).** ***21,*** Small cranidium, anterior oblique view, internal mold, ×10.3 (UMC 17097), from road cut along Missouri
Highway 63, 6 mi north of Rolla, Missouri. — 74

22, 23 ***Rollia goodwini*** **Cullison.** ***22,*** Small cranidium, palpebral view, exfoliated with granules on glabella, ×7.3 (UMC 17098), from I-268. ***23,*** Medium librigena, lateral view, partially exfoliated, ×1.7 (UMC 17099), from I-268. — 75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