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PTYCHOPARIID TRILOBITES OF THE LOWER-MIDDLE CAMBRIAN BOUNDARY INTERVAL, PIOCHE SHALE, SOUTHEASTERN NEVADA

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ABSTRACT—Twelve ptychopariid species assigned to five genera occur in the Lower-Middle Cambrian boundary interval, Pioche Shale, eastern Nevada. New taxa include one genus, *Eokochaspis,* and seven species, *Eokochaspis nodosa, E. delamarensis, E. metalaspis, E. longspina, Kochina*? *walcotti, Mexicella antelopea,* and *M. robusta.* Two new biozones, the *Eokochaspis nodosa* and overlying *Amecephalus arrojosensis* Biozones, are proposed between the Lower Cambrian *Olenellus* Biozone and the Middle Cambrian *Plagiura-Poliella* Biozone. In addition, the three remaining informal shale members of the Pioche Shale are formally named.

INTRODUCTION

A LOW DIVERSITY assemblage of ptychopariid trilobites occur in the Lower-Middle Cambrian boundary interval, Pioche Shale, eastern Nevada (Figs. 1, 2). Ptychopariids from the youngest portion of the *Olenellus* Biozone include *Crassifimbra walcotti* (Resser, 1937; reillustrated here) and *Eokochaspis metalaspis* n. gen. and sp. These trilobites are associated with abundant and diverse assemblages of olenellid trilobites (Palmer, 1957, 1998), the common corynexochid *Zacanthopsis* spp. (Palmer 1998), and very rare specimens of *Bathynotus holopygus* (Hall, 1859; Palmer 1998) and *Oryctocephalites palmeri* Sundberg and McCollum (1997).

Ptychopariids assigned to the basal Middle Cambrian *Eokochaspis nodosa* Biozone (new) include *Eokochaspis nodosa* n. gen. and sp., *E. piochensis* (Palmer, in Palmer and Halley, 1979), *E. delamarensis* n. gen. and sp., *E. longspina* n. gen. and sp., *Mexicella antelopea* n. sp., and *Amecephalus* sp. A. Corynexochids are very rare within this assemblage and are represented by *Oryctocephalites rasettii* Sundberg and McCollum (1997) and a few hypostomata. In addition to the trilobites, inarticulate brachiopods, hyolithids, spicules of *Protospongia,* and lightly scleritized forms such as *Anomalocaris, Canadaspis,* and *Tuzoia* are present in this biozone.

Ptychopariids from the overlying *Amecephalus arrojosensis* Biozone (new) include *Amecephalus arrojosensis* (Lochman, 1952), *Kochina*? *walcotti* n. sp., and *Mexicella robusta* n. sp. Corynexochids are also rare in this biozone and are only represented by a few hypostomata.

LITHOSTRATIGRAPHY

The current lithostratigraphic scheme in the Pioche Shale consists of six members, some formal and others informal. Merriam (1964, table 2) adopted the local mining nomenclature, proposing informal A- through D-shale members in descending order, with two formal member designations, the Susan Duster Limestone Member separating the B-shale from the C-shale, and the Combined Metals Member separating the C-shale from the D-shale (Fig. 3). Eddy and McCollum (1998), in their study of the *Albertella* Biozone faunas, designated the formal Grassy Spring Member to replace most of the informal A-shale member of Merriam (1964).

In keeping with the scheme of formalizing the informal members of the Pioche Shale, we designate three new members: the Log Cabin Member, the Comet Shale Member, and the Delamar Member (Fig. 3). Although the name Comet Shale had previously been used in an attempt to replace the Middle Cambrian portion of the Pioche Shale by Mason (*in* Grabau, 1936) and Deiss (1938), their suggested usage was never adequately defined or adopted. The Comet Shale Member is used here to define a more restricted lithostratigraphic interval, which happens to coincide with the basal Middle Cambrian.

The Delamar Member replaces the informal D-shale member of Merriam (1964) and includes the basal 85–90 m clastic interval of the Pioche Shale. The stratotype for the Delamar Member is within the Delamar Mountains, approximately one kilometer northwest of Oak Spring, on the Chokecherry Mountain 7.5-minute quadrangle, Nevada. This member contains a Lower Cambrian fauna characterized by *Bristolia, Olenellus,* and *Peachella.*

The lower contact of the Delamar Member is placed at the top of the massive quartz arenites of the Zabriskie Quartzite. A fining upward sequence occurs in the lower half of this clastic member, beginning with 15–20 m of interbedded thin quartz arenites and bioturbated siltstones, followed by bioturbated siltstones and siltshales and culminating in a 8 to 10 m intervals of fissile shale. The upper, coarsening up sequence begins at about 60 m, and consists of a siltshale with very thin, discontinuous, silty, bioclastic limy beds, overlain by bioturbated siltstones and sandstones. The upper member contact is drawn at the top of a regionally karsted surface of calcareous sandstone that had formerly been included as the basal subunit of the Combined Metals Member by Merriam (1964).

Merriam (1964, table 3) had previously subdivided the 21 m thick Combined Metals Member into five subunits in the reference section, which is west of Pioche Divide in the Pioche Hills (formerly Ely Range). Merriam's subunit 1 is reassigned to the top of the Delamar Member, since it is part of a gradational, coarsening up sequence, and its karsted upper surface suggests a regional unconformity. The other subunits of Merriam (1964) can be recognized to the south, but not to the west in the Highland Range, where the Combined Metals Member is primarily a medium bedded limestone with no intervening clastic interval.

The lower contact of the Combined Metals Member is defined at the base of a meter thick, silty oncolitic limestone, which overlies the karsted, calcareous sandstone at the top of the underlying Delamar Member. The upper contact of the Combined Metals Member of Merriam (1964) was placed at the top of a nodular limestone and interbedded shale interval which contains the youngest faunas of the Lower Cambrian *Olenellus* Biozone. This interval is easily recognized in the Highland and Chief Ranges, but becomes more shale-rich in the Delamar Mountains.

The Comet Shale Member replaces the C-shale member of Merriam (1964). The stratotype is 0.5 km east of the Comet Mine on the west side of the Highland Range, within the Highland Peak 7.5-minute quadrangle, Nevada. The Comet Shale

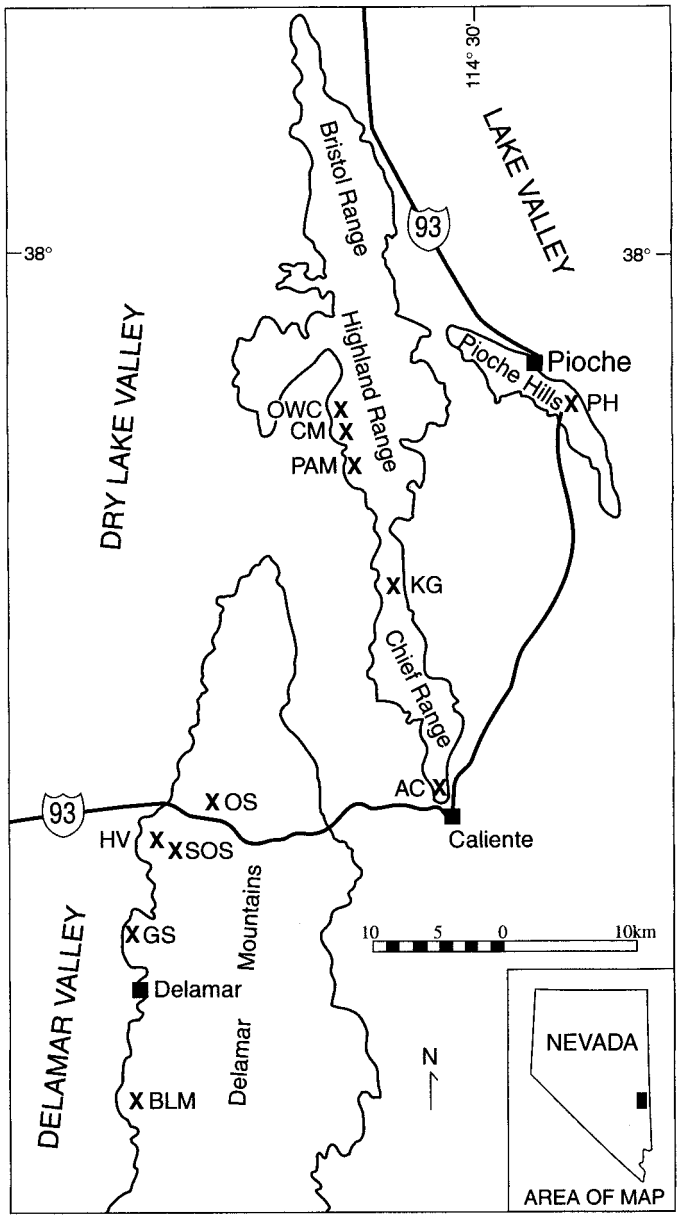

FIGURE 1—Location of the stratigraphic sections and faunas of the Comet Shale Member, Pioche Shale in Lincoln County, Nevada. The stratotype sections for the *Eokochaspis nodosa* Biozone and the Comet Shale Member are at One Wheel Canyon (OWC). Sections: AC = Antelope Canyon, BLM = Big Lime Mountain, CM = Comet Mine, GS = Grassy Spring, HV = Hidden Valley, KG = Klondike Gap; PAM = Pan American Mine, PH = Pioche Hills, OS = Oak Springs, and OWC = One Wheel Canyon and Log Cabin Mine, SOS = Seven Oak Spring.

Member is a remarkably uniform fissile shale, with one to three thin, silty ribbon limestones in its lower third, and one or more bioclastic limestones above 32 m. The member reaches its maximum thickness of 34 m in the type section, but thins to 17 m at Antelope Canyon, Chief Range (Fig. 2), just north of Caliente. The regional thinning is due to an erosional unconformity at the top of this member, prior to the deposition of the overlying Susan Duster Limestone Member. Most of the ptychopariid trilobites described in this report are from this member.

The contact between the Comet Shale Member and the underlying Combined Metals Member is here drawn at the base of a 70-cm thick, silty ribbon limestone, containing abundant silicified *Eokochaspis nodosa.* This limestone layer maintains a consistent thickness, lithology, and faunal content throughout its geographic extent, from the Highland and Chief Ranges southward through the Delamar Mountain sections. The regional extent and uniform character of this limestone suggests that it has chronostratigraphic significance in the local outcrop area of the Pioche Shale in eastern Nevada.

The Log Cabin Member replaces the B-shale member of Merriam (1964). The stratotype is 0.5 km southeast of the Log Cabin Mine on the west side of the Highland Range, within the Highland Peak 7.5-minute quadrangle, Nevada. The Log Cabin Member is predominantly a bioturbated siltstone to sandstone, with thin limestone intervals. The member ranges from 80 m in the Highland Range to approximately 50 m in the Pioche Hills to the east. The thinning is due to an erosional unconformity at the top of the member prior to the deposition of the Grassy Spring Member of Eddy and McCollum (1998). The member contains a kochaspid trilobite fauna (sensu Palmer and Halley, 1979), which is presently under study by the authors.

BIOSTRATIGRAPHY

The Lower and Middle Cambrian ptychopariid trilobites discussed here occur in the Combined Metals Member, Comet Shale Member, and basal portion of the Susan Duster Limestone Member, Pioche Shale. The Lower Cambrian *Olenellus* Biozone in the Combined Metals Member contains *Crassifimbra walcotti* and *Eokochaspis metalaspis.* Charles D. Walcott collected specimens later referred to as *C. walcotti* from the Highland Range on 22 September 1885, although neither the fauna nor the horizon has ever been relocated. Palmer (1958) described the ontogenetic stages of a silicified ptychopariid trilobite that he considered conspecific with *C. walcotti* from the upper portion of the Combined Metals Member, although we refer Palmer's specimens to *E. metalaspis.*

Two ptychopariid trilobite assemblages occur in an intermediate position between the Lower Cambrian *Olenellus* Biozone and the early Middle Cambrian *Plagiura-Poliella* Biozone in the southern Great Basin (Figs. 2, 3). The earlier assemblage is dominated by species of the new genus *Eokochaspis,* and the overlying assemblage includes species of *Amecephalus, Kochina*?, and *Mexicella.* Two new biozones, the *Eokochaspis nodosa* and *Amecephalus arrojosensis* biozones, are proposed for these geographically widespread trilobite assemblages (Sundberg and McCollum, 1999).

The *Eokochaspis nodosa* Biozone is a lineage zone defined on the first occurrence of *Eokochaspis nodosa* from the 70 cm thick, silty ribbon limestone at the base of the Comet Shale Member. This species appears to have been derived from the underlying *E. metalaspis* (see species description). Trilobites restricted to this biozone include *Eokochaspis nodosa, E. piochensis, E.* cf. *piochensis, E. longspina, E. delamarensis, Mexicella antelopea, Amecephalus* sp. A, and *Oryctocephalites rasettii* (Fig. 2). The authors have collected elements of this fauna from the Pyramid Shale Member of the Carrara Formation in the Death Valley region and in the basal shale member of the Emigrant Formation, western Nevada (Sundberg and McCollum, 1999).

The *Amecephalus arrojosensis* Biozone is an interval zone defined on the first occurrence of that species approximately nine meters above the base of the Emigrant Formation, northeast of Split Mountain, Clayton Ridge, Esmeralda County, Nevada (Sundberg and McCollum, 1999). In the Pioche Shale, this biozone is characterized by *Amecephalus arrojosensis, Mexicella robusta,* and *Kochina*? *walcotti* (Fig. 2). The geographic range of this biozone includes that of the underlying biozone, and

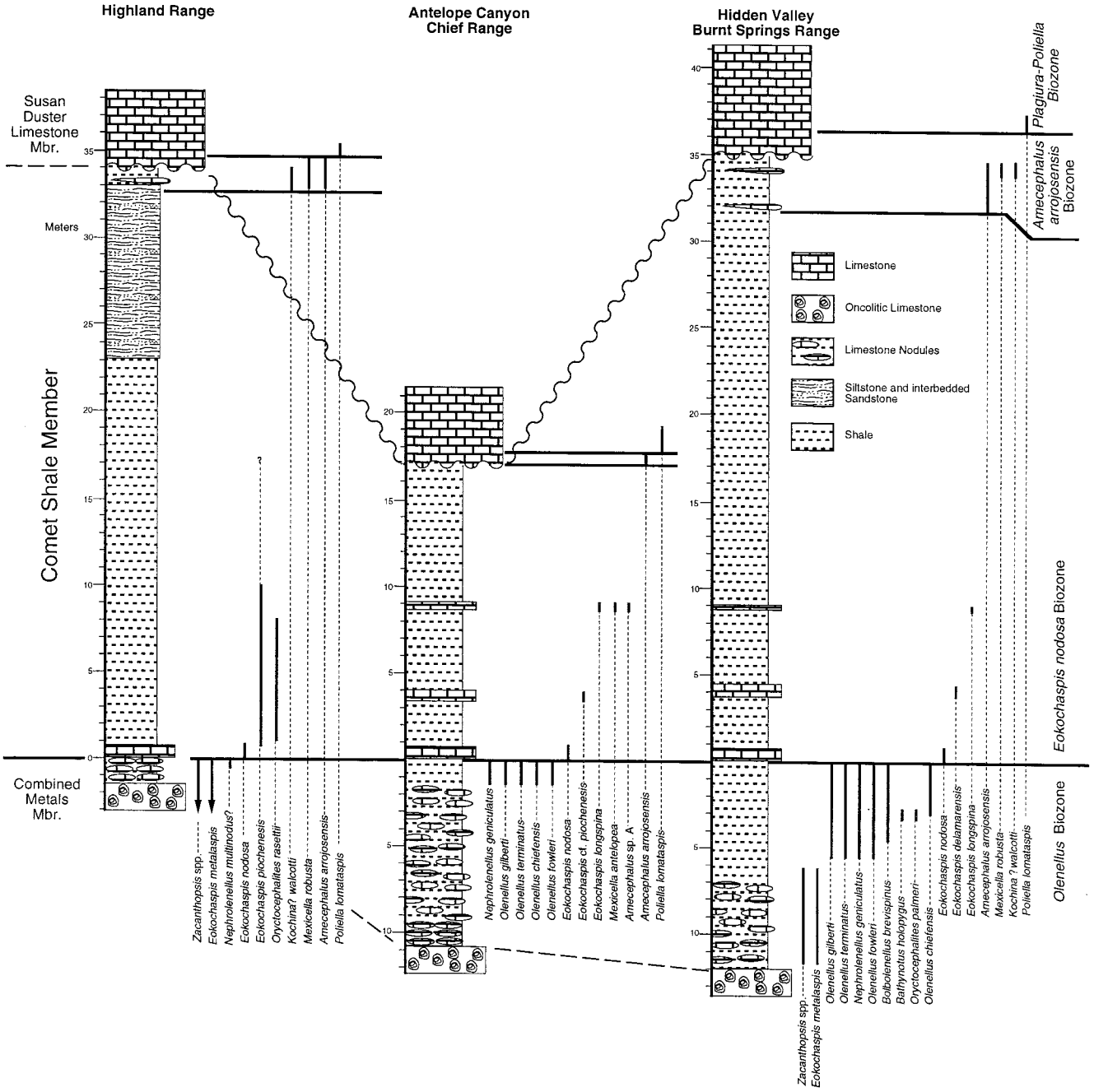

FIGURE 2—Representative lithostratigraphic and biostratigraphic section of the Comet Shale Member, Pioche Shale and the *Eokochaspis nodosa* Biozone in Lincoln County, Nevada. For the Combined Metals Member, only that portion extending down to the first oncolitic unit is represented. Lower Cambrian trilobites listed for Hidden Valley are from the nearby section at Oak Springs Summit illustrated by Palmer (1998, fig. 4).

Amecephalus arrojosensis was originally reported from the Arrojos Formation near Caborca, Mexico (Cooper and Arellano, 1952; Lochman, 1952).

The base of the *Amecephalus arrojosensis* Biozone is 30 m above the base of the Comet Shale Member, and the upper boundary is placed within the basal 0.7 to 1.0 m of the Susan Duster Limestone Member at the first occurrence of *Poliella lomataspis* Palmer (*in* Palmer and Halley, 1979), which occurs at the base of the overlying *Plagiura-Poliella* Biozone. A regional unconformity, on which the Susan Duster Limestone Member was deposited, has locally removed the central portion of this biozone. This unconformity progressively removes section eastward, and may explain why the cratonal sections do not record the ptychopariid faunas assigned to these two basal Middle Cambrian biozones (McCollum, 1999).

ABBREVIATIONS AND MEASUREMENTS

The type specimens are deposited in the U.S. National Museum of Natural History (USNM). Measurements used are illustrated in Figure 4. Terminology and abbreviations are derived from Shaw (1957), Whittington et al. (1997), and Sundberg and

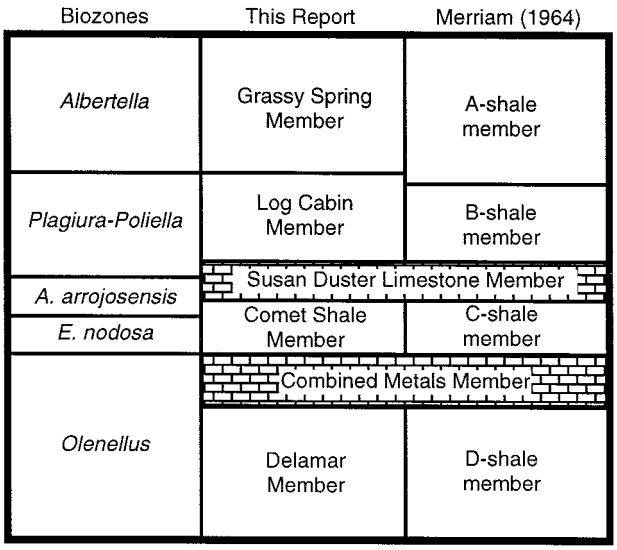

FIGURE 3—New stratigraphic nomeclature used in this report compared to that of Merriam (1964) and the stratigraphic position of biozone boundaries (Eddy and McCollum, 1997; Palmer, 1998; this report).

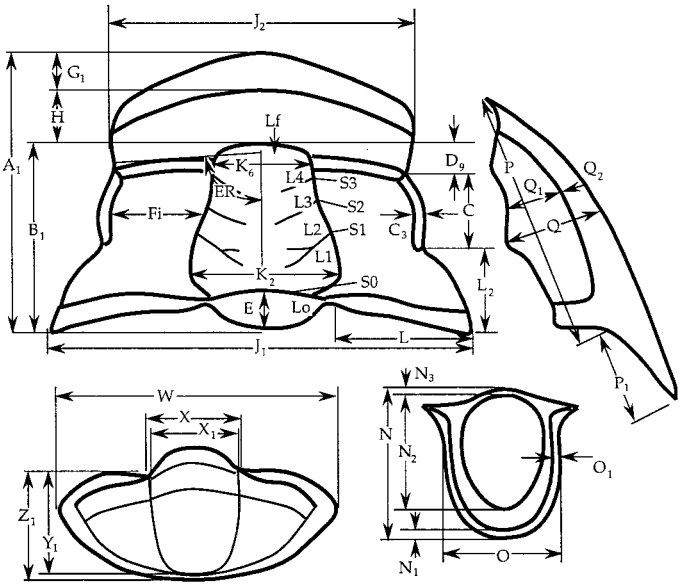

FIGURE 4—Measurements and lobe and furrow labels used in the trilobite descriptions.

McCollum (1997). Sagittal (sag.) and exsagittal (exsag.) measures are referred to as lengths and transverse (trans.) measures are referred to as widths. The values within the parentheses in some descriptions are based on either limestone or shale specimens. If the type material is preserved in shale, then the measure of the limestone specimens will be given in parentheses, and vice versa. Measures are given as averages plus one standard deviation when five or more specimens are measured. Ranges of percentages are given if two to four specimens are measured and these ranges are rounded off to the nearest five percent (e.g., 54 percent would be listed as 55 percent). The term approximately is given when only one specimen was measured or if two to four specimens were measured, but their range rounded to a single 5 percentage (e.g., 54 to 57 percent is listed as approximately 55 percent). Under material examined, illustrated specimens are listed by their USMN numbers and unfigured specimens are listed by the number of cranidia, librigenae, hypostomata, and pygidia inspected from each locality.

All photographed specimens are coated with colloidal graphite and ammonium chloride sublimate.

SYSTEMATIC PALEONTOLOGY

Class TRILOBITA Walch, 1771
Order PTYCHOPARIIDA Swinnerton, 1915
Suborder PTYCHOPARIINA Richter, 1933
Superfamily PTYCHOPARIACEA Matthew, 1887
Family UNKNOWN

Familial assignment of the taxa described below is left open until a phylogenetic analysis can be completed. *Amecephalus* Walcott, 1924; *Kochina* Resser, 1935; and *Mexicella* Lochman, 1948, were previously assigned to Alokistocaridae Resser, 1939 (Harrington et al., 1959); but this family has recently been redefined in which these taxa were not included (Sundberg, 1999). *Eokochaspis*, as the name implies, are similar to the kochaspids, a slightly younger, informal group discussed by Palmer (*in* Palmer and Halley, 1979). Taxa assigned to the kochaspids by Palmer are presently being studied by the authors. As a result of the unknown familial status of these genera, extended diagnosis are provided to differentiate them from other kochaspids, taxa previously assigned to Alokistocaridae, and Ptychopariidae Matthew 1887.

Genus AMECEPHALUS Walcott, 1924

Type species.—*Amecephalus piochensis* (Walcott, 1886)

Emended diagnosis.—Cranidia with an anterior border slightly tapered distally, no medial inbend, poorly defined anterior border furrow. Glabella moderately elongated, strongly tapered from S0 to S2 then slightly tapered, S1 and S2 bifurcated; axial furrows deepest posteriorly. S0 moderately shallow. Posterior area of fixigena strap-like with sharp termination, border widens distally; border furrow extends to suture. Anterior branches of facial sutures slightly to strongly divergent to midlength (exsag.) of anterior border; posterior branches strongly divergent to posterior border furrow, then nearly parallel. Librigena spine flattened, broad-based. Pygidium suboval, micropygous; axis with one or two axial rings; poorly developed anterior pleural band; anterolateral corners rounded, opposite anterior half of the axis; posterior margin with median notch arched in posterior view; doublure absent behind axis.

Discussion.—The relationship between *Amecephalus* and *Alokistocare* Lorenz, 1906, has had a confusing history (see Sundberg, 1999). Various authors have either differentiated between the two genera or regarded *Amecephalus* as a junior synonym (see Rasetti, 1951; Palmer, 1954; Harrington et al., 1959; Fritz, 1968; Palmer and Halley, 1979). Part of the problem is that the type species *Alokistocare subcoronatum* (Hall and Whitfield, 1877) was poorly known and poorly illustrated. However, *Amecephalus* differs from *Alokistocare* in having a poorly developed occipital ring and furrow, poorly defined anterior border furrow, strap-like posterior area of the fixigena, and a pygidium with poorly defined anterior pleural bands that do not project from the border area (Sundberg, 1999).

Strotocephalus Resser, 1935, is synonymous to *Amecephalus.*

Amecephalus ranges from the *Eokochaspis nodosa* Biozone to *Glossopleura* Biozone.

AMECEPHALUS ARROJOSENSIS (Lochman, 1952)
Figure 5.1–5.13

Strotocephalus arrojosensis LOCHMAN, 1952, p. 157–158, pl. 21, figs. 29–34.

Emended diagnosis.—Cranidium with frontal area subequally

divided (anterior border 60 ± 5 percent cranidial length). Anterior branches of the facial sutures slightly divergent. Posterior area of fixigena short (width 73 ± 7 percent glabellar length). Glabellar furrows very shallow. Surface granular. Interborder furrow shallow. Pygidium with oval outline, axis has two to three axial rings, border area well developed.

Emended description.—Cranidium moderate size, length 8.7 ± 2.5 mm (n = 11); subquadrate, length 68 ± 5 percent width; moderately low convexity (sag. and trans.), height 19 ± 6 percent width; anterior margin moderately and evenly curved, width (J_1) 73 ± 5 percent cranidial width (J_2); posterior margin, excluding occipital ring, straight. Anterior branches of facial sutures slightly divergent to anterior border, convergent to anterior margin; posterior branches strongly divergent to posterior border furrow then directed nearly posteriorly. Glabella moderately elongated, strongly tapered, width at anterior end 73 ± 4 percent glabellar width (K_2); low convexity (sag. and trans.); frontal lobe bluntly rounded; length 65 ± 2 percent and width 50 ± 2 percent cranidial length; width 34 ± 2 percent cranidial width. Axial furrow shallow, deeper posteriorly, slightly convex in outline and moderately convergent from S0 to S2 then slightly convergent; preglabellar furrow shallow, uniform depth, narrow, slightly curved. Lateral glabellar furrows very shallow, S1 bifurcated and directed posteriorly, S2 directed laterally, S3 and S4 directed slightly anteriorly. Occipital ring very slightly elevated above glabella, slightly convex, length 21 ± 2 percent glabellar length; small occipital node; posterior margin convex posteriorly; doublure approximately 30 percent of occipital ring length medially. S0 straight and shallow depth, shallowest medially. Frontal area unequally divided; length 34 ± 2 percent cranidial length. Preglabellar field slightly convex, moderately downsloping, length 40 ± 5 percent frontal area length. Anterior border concave, slightly upsloping, very slightly tapering laterally, margin evenly curved, length 20 ± 2 percent cranidial length, 60 ± 5 percent frontal area length. Anterior border furrow evenly curved, narrow, much shallower than axial furrows; no interborder furrow. Fixigena slightly convex, level, anterior area moderately downsloping, width 67 ± 5 percent glabellar width (K_2). Palpebral lobe level, narrow and long, width 23 ± 3 percent lobe length, length 48 ± 4 percent glabellar length; anterior margin located about opposite of L4, 18 ± 4 percent glabellar length behind glabellar anterior margin; palpebral furrow shallow. Ocular ridge weak, straight, directed slightly to moderately posterolaterally from glabella at 77 ± 4 degrees to axis (progressively more posterolaterally in larger specimens). Posterior area of fixigena strap-like, downsloping, sharply terminated; length 40 ± 3 percent glabellar width, 31 ± 3 percent glabellar length; width 73 ± 7 percent glabella length. Posterior border slightly convex, expanding distally; border furrow moderate depth, shallowing laterally, straight, not expanding.

Hypostoma small, length 1.8 ± 0.3 mm (n = 5); suboval, moderately convex (sag. and trans.); anterior margin moderately curved; lateral margins straight, slightly convergent; posterior margin strongly curved; length 140 ± 5 percent width. Middle body moderately convex (sag. and trans.); suboval; macula not evident; unequally divided into very poorly differentiated anterior and posterior lobes; anterior lobe moderately convex, length 73 ± 4 percent of hypostomal length; posterior lobe moderately convex, length 13 ± 6 percent of hypostomal length; furrow very shallow to absent. Anterior border weakly convex, narrow, 9 ± 2 percent of hypostomal length; prominent, pointed anterior wings, directed laterally and dorsally; border furrow shallow and narrow. Lateral borders moderately defined, convex, narrow, 11 ± 1 percent of hypostomal width; border furrows very shallow. Posterior wings pointed, directed dorsally. Posterior border weakly convex, narrow, 5 ± 1 percent hypostomal length; border furrow narrow, very shallow.

Rostral plate nearly as wide as anterior margin, length approximately 20 percent width, arched, ''V'' shaped in cross-section, lateral sutures concave, posterior margin with slight point at axial line. Transverse terrace lines present on anterior margin.

Librigena moderate size, length 7.5 to 4.5 mm (n = 4); moderately wide, width 45 to 55 percent length without spine; lateral margin moderately curved. Anterior part of dorsal surface developed as very short projection. Genal field very slightly convex, width 20 to 40 percent librigenal width. Border very slightly concave, uniform width, width 30 to 40 percent librigenal width; lateral border furrow very shallow and poorly defined; posterior border furrow very short, very shallow; intraborder furrow very shallow in lateral border and projects into genal spine. Genal spine broad based, short, approximately 50 percent librigenal length. Doublure wide, as wide as lateral border, wider posteriorly than border, ''V'' shaped in cross-section.

Pygidium small, length 2.6 ± 0.8 mm (n = 11); suboval, length 47 ± 4 percent width; margin smooth, anterior margin next to axis project laterally, distal portion moderately curved posterolaterally, anterolateral corners rounded, adjacent to axial midlength; lateral margins moderately curved; small median notch; moderately convex (sag. and trans.). Axis very slightly tapered, width at midlength 97 ± 3 percent anterior width, anterior width 40 ± 3 percent pygidial width; length 94 ± 3 percent pygidial length, no postaxial ridge; 2 to 3 axial rings, strongly convex; terminal axial piece large, posteriorly rounded; axial furrow shallow, uniform depth; axial ring furrows very shallow, slightly deeper laterally. Pleural regions moderately defined, exsagittally elongate; slightly convex, downsloping; anterior pleural furrow narrow width and moderate depth, extending to border, curved slightly posterolaterally; 1 or 2 additional pleural furrows, very shallow or absent; interpleural furrows very faint or not visible; first anterior pleural band moderately well developed, others very weakly convex, posterior pleural bands very poorly developed. Border narrow, wider at anterolateral corners, sloping upwards; absent at anterior notch; border furrow very shallow. Doublure widest at anterolateral corners, thinning towards posterior margin, absent medially.

Exoskeleton smooth except for fine granules on the posterior end of the glabella, medial portion of the occipital ring, and on the pygidium. Granules are better developed on smaller specimens.

Material examined.—USNM 493126, 493132–493134 and 5 cranidia, 2 librigenae, 4 hypostomata, and 2 pygidia from USNM locality 41215; USNM 493127–493131 and 3 cranidia and 5 pygidia and from USNM locality 41441; USNM 493135

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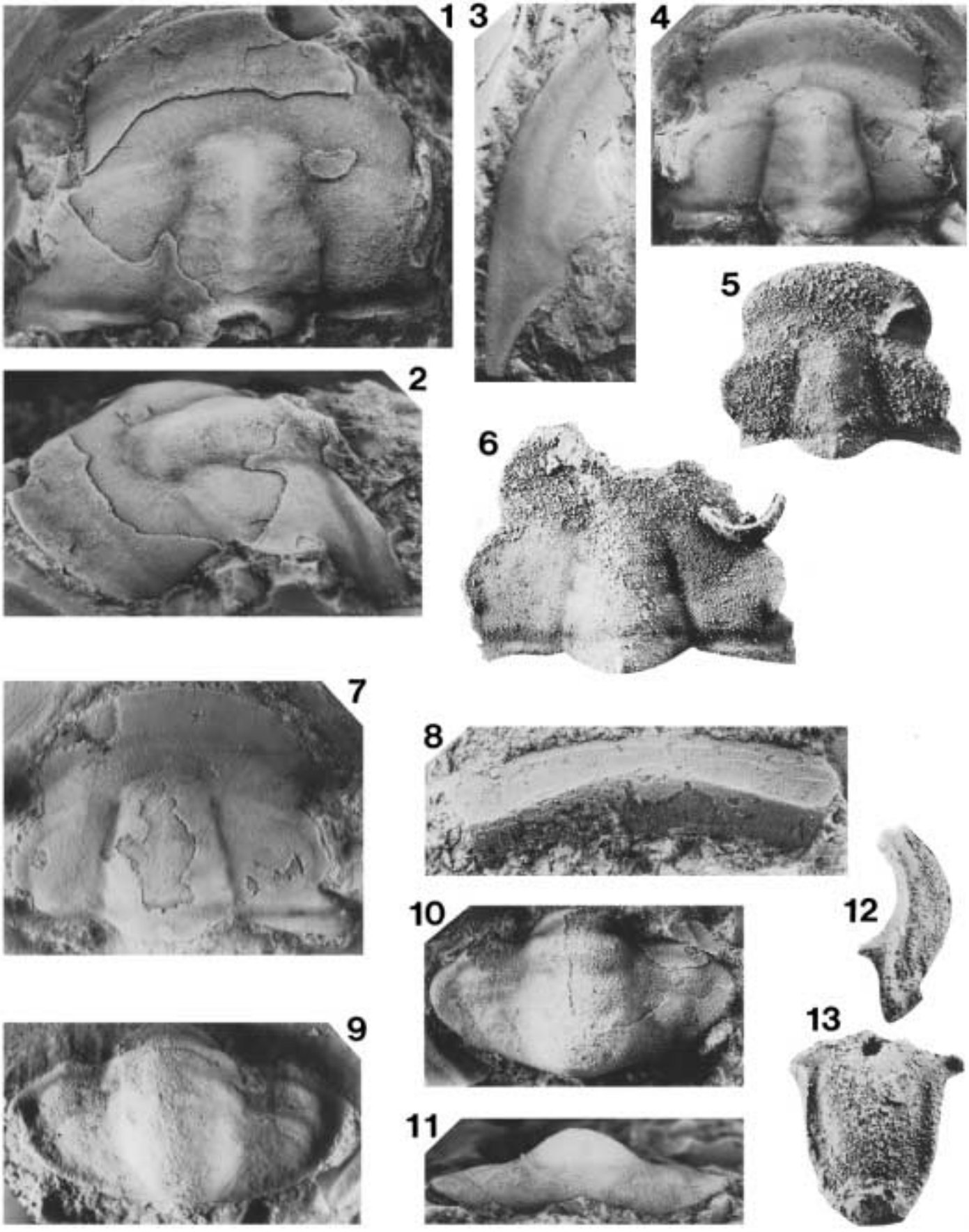
FIGURE *5—1–13, Amecephalus arrojosensis* (Lochman, 1952); *1, 2,* large, mostly exfoliated cranidium (USNM 493133) from USNM locality 41215, ×4.5; *3,* librigena (USNM 493135) from USNM locality 41212, ×10.0; *4,* smaller cranidium (USNM 493132) from USNM locality 41215, ×6.0; *5,* silicified cranidium (USNM 493128) from USNM locality 41441, ×10.0; *6,* silicified cranidium (USNM 493127) from USNM locality 41441, ×10.0; *7,* cranidium (USNM 493131) from USNM locality 41441, ×6.0; *8,* rostral plate (USNM 493130) from USNM locality 41441, ×11.5; *9,* pygidium (USNM 493126) from USNM locality 41215, ×10.0; *10, 11,* dorsal and posterior view of a pygidium (USNM 493134) from USNM locality 41215, ×7.0; *12, 13,* lateral and ventral view of a silicified hypostoma (USNM 493129) from USNM locality 41441, ×16.0.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and 1 cranidium, 1 librigena, and 2 pygidia from USNM locality 41212.

Occurrence.—*Amecephalus arrojosensis* Biozone, Comet Shale and Susan Duster Limestone members (Palmer *in* Merrian, 1964), Pioche Shale, eastern Nevada. USNM localities 41212, 41215, 41431, 41440, 41441, and 41451. Arrojos Formation, Caborca, Mexico (Lochman 1952).

Discussion.—There is no reason to separate these Pioche Shale specimens from those reported from the basal Arrojos Formation, Proveedora Hills, near Caborca, Mexico (Lochman, 1952; Cooper and Arellano, 1952). *Amecephalus arrojosensis* differs from *A. agnesensis* (Walcott, 1912b) in having a subequally divided frontal area, granular surface, and oval pygidium with only two axial segments and well developed border area. *Amecephalus arrojosensis* differs from *A. cleora* (Walcott, 1917) in having a subequally divided frontal area, less divergent anterior branch of the facial sutures, shorter posterior area of fixigena, shallower glabellar furrows, granular surface, and shallower interborder furrow. *Amecephalus arrojosensis* differs from *A. piochensis* in having a subequally divided frontal area, less divergent anterior branch of the facial sutures, shorter posterior area of fixigena, shallower interborder furrow, granular surface, and oval pygidium. *Amecephalus arrojosensis* differs from *A. gordonensis* (Resser, 1935) in having a subequally divided and shorter frontal area, slightly divergent anterior branch of the facial sutures, granular surface, and flat anterior border.

AMECEPHALUS sp. A
Figure 6.1, 6.2

Description.—Cranidium moderate to large size, length 5.6 to 10.0 mm (n = 3); subquadrate, length 70 to 75 percent width; moderately low convexity (sag. and trans.), height 20 to 25 percent width; anterior margin moderately and evenly curved, width (J_2) 70 to 90 percent cranidial width (J_1); posterior margin, excluding occipital ring, straight. Anterior branches of facial sutures slightly divergent to midlength (exsag.) of anterior border, convergent to anterior margin; posterior branches strongly divergent to posterior border furrow then directed nearly posteriorly. Glabella elongated, width approximately 35 percent cranidial width; moderately tapered, width at anterior end 65 to 80 percent glabellar width (K_2); low convexity (sag. and trans.); frontal lobe moderately rounded; length approximately 70 percent and width 50 to 55 percent cranidial length. Axial furrow shallow, slightly deeper posteriorly, convex in outline and moderately convergent from S0 to S2 then slightly convergent; preglabellar furrow very shallow, uniform depth, narrow, curved. Lateral glabellar furrows very shallow to absent, S1 bifurcated directed posteriorly, S2 directed laterally, S3 and S4 directed slightly anteriorly. Occipital ring very slightly elevated above glabella, slightly convex, length 15 to 20 percent glabellar length; small occipital node; posterior margin convex posteriorly. S0 straight and shallow depth, shallowest medially. Frontal area unequally divided; length approximately 30 percent cranidial length. Preglabellar field slightly convex, moderately downsloping, length 35 to 40 percent frontal area length. Anterior border concave, slightly upsloping, very slightly tapering laterally, margin evenly curved, length approximately 18 percent cranidial length, 60 to 65 percent frontal area length. Anterior border furrow evenly curved, narrow, very shallow, shallower than axial furrows; slight, elongated swelling anterior or furrow. Fixigena slightly convex, level to slightly downsloping, anterior area moderately downsloping, width 55 to 70 percent glabellar width (K2). Palpebral lobe level, narrow and moderately long, width approximately 20 percent lobe length, length 35 to 40 percent glabellar length; anterior margin located about opposite of S3, 20 to 25 percent glabellar length behind glabellar anterior margin; palpebral furrow very shallow. Ocular ridge very weak, straight, directed slightly posterolaterally from glabella at approximately 75 degrees to axis. Posterior area of fixigena straplike, downsloping, sharply terminated; length 45 to 50 percent glabellar width, 30 to 40 percent glabellar length; width 65 to 70 percent glabella length. Posterior border moderately convex, expanding distally; border furrow moderate depth, shallowing laterally, straight, not expanding.

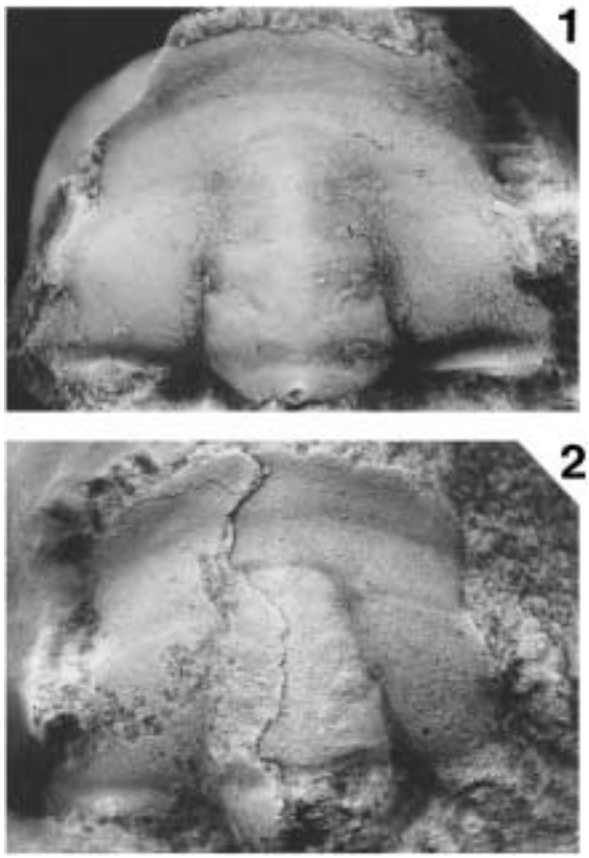

FIGURE *6—1, 2, Amecephalus* sp. A from USNM locality 41439; *1,* testate cranidium (USNM 493137), ×5; *2,* partially exfoliated cranidium (USNM 493136), ×5.

Material examined.—USNM 493136–493137 and 1 cranidium from USNM locality 41439.

Occurrence.—*Eokochaspis nodosa* Biozone, Comet Shale Member, Pioche Shale, Nevada. USNM locality 41439.

Discussion.—*Amecephalus* sp. A is known from only a few cranidia from the third ribbon limestone in Hidden Valley. The nomenclature is left open until more specimens are found. *Amecephalus* sp. A differs from *Amecephalus arrojosensis* in its longer glabella, shorter frontal area, slightly convergent facial sutures, elongated swelling in the anterior border, and shorter palpebral lobes.

Genus EOKOCHASPIS new genus

Type species.—*Eokochaspis nodosa* new species

Diagnosis.—Cranidia with subtrapezoidal outline and an anterior border slightly tapered distally, slightly to moderately curved, with a weak medial inbend present in some specimens. Glabella moderately elongated, strongly tapered from S0 to S2 then slightly tapered, S1 and S2 bifurcated, axial furrows deepest

posteriorly. S0 moderately deep. Posterior area of fixigena triangular with sharp termination, border widens distally, and border furrow extends to suture. Anterior branches of facial sutures parallel to slightly divergent to midlength (exsag.) of anterior border; posterior branches moderately divergent to posterior border furrow, then nearly parallel. Librigena spine mostly flattened, broad-based. Pygidium suboval, micropygous; axis with one or two axial rings; anterolateral corners rounded opposite anterior half of the axis; posterior margin with median notch arched in posterior view; doublure absent behind axis.

Etymology.—*Eo* = early, refers to the lower stratigraphic occurrence of these kochaspids.

Discussion.—Determining the taxonomic relationships of *Eokochaspis* to other Lower and Middle Cambrian ptychopariids is difficult because almost all previously named ptychopariids are based solely on isolated cranidia (see Rasetti, 1951, 1955). Associated librigenae, thoracic segments, and pygidia are needed to determine the taxonomic affiliation. In addition, some of these ptychopariids show large amount of variation in cranidial features commonly used for generic and specific identification. For example, *Ptychoparella* sp. A discussed by Blaker and Peel (1997) encompasses the morphological range of *Syspacephalus* Resser, 1938; *Elrathina* Resser, 1937, *Eoptychoparia* Rasetti, 1955; and *Ptychoparella* Poulsen, 1927. Caution must be used in constructing new genera for these simple ptychopariids and all associated sclerites should be used. Previously established genera known only from cranidia should probably have their name restricted to the type species until additional parts of their exoskeleton are known. However, it is useful to compare *Eokochaspis* to some of the other Lower and Middle Cambrian ptychopariids.

Based on the specimens illustrated by Rasetti (1955), *Eokochaspis* differs from the Lower Cambrian *Eoptychoparia* in having a more tapered glabella (GW2/GW1 = 71 to 74 ± 3 or 5 percent vs. 80 ± 5 percent, n = 9), bluntly rounded frontal lobe, axial furrows deeper posteriorly, and the anterior border furrow shallower and less curved. The difference in the tapering of the glabella is minor, but the primary difference is how the glabella tapers. The glabella of *Eoptychoparia* tapers evenly with straight axial furrows or a slight curvature inward as a result of the axial furrows converging slightly more rapidly to the S1. In *Eokochaspis*, the axial furrows converge rapidly to the S2 and then converge gradually. This stronger convergence of the axial furrows in *Eokochaspis* is more evident in larger specimens (4–8 mm in cranidial length).

Crassifimbra Lochman, 1947, is similar to *Eokochaspis*, and Palmer (1958) considered the type species *Crassifimbra walcotti* as conspecific with the silicified ptychopariids from the Combined Metals Limestone Member. These silicified ptychopariids are here assigned to a new species *Eokochaspis metalaspis*. The difference between the two species are outlined under the discussion of *E. metalaspis.* The two genera can be separated based on the higher relief of cranidial features, better defined cranidial furrows, and subtrapizoidal outline of the cranidium of *Eokochaspis.*

Shaw (1962, p. 335) placed *Crassifimbra* in synonymy with *Antagmus* Resser, 1936, based primarily on the medial position of the palpebral lobes and convergence of the anterior branch of the facial suture. *Crassifimbra walcotti* does not have convergent facial sutures from the palpebral lobes, but parallel sutures until the midlength (exsag.) of the anterior border and then convergent sutures, as seen in *Eokochaspis*. Shaw's mistaken identification of the suture's path is probably due to the poor illustrations of *C. walcotti* by Lochman (1947, figs. 1–3), the strong curvature of the anterior border, and the shorter length from the palpebral lobe to the anterior border (see Palmer, 1958).

Eokochaspis is also similar to *Antagmus*; however, species of *Antagmus* are only known from cranidia; thus, complete comparisons are not possible. In addition the type species, *A. typicalis* Resser, 1936, is represented by a single type specimen and a few topotype specimens. The type specimens in a poorly preserved, internal mold of an incomplete cranidium that is preserved in a partially friable, medium-grained, limonite-cemented sandstone. The topotype material consists of only cranidia that are even more poorly preserved and no associated parts. Thus, given the poor preservation and quality of the type and topotype material and the lack of associated body parts for the type species, *Antagmus* should be considered *nomina dubia* and the name restricted to the type species.

The cranidium of *Eokochaspis* is also similar to some species assigned to *Onchocephalus* Resser, 1937. The cranidium of *Onchocephalus maior* Rasetti, 1951, from the slightly higher *Plagiura-Kochaspis* Biozone of British Columbia, resembles those of *Eokochaspis* in its tapered glabella, palpebral lobe length, more triangular shape of the posterior portion of the fixigena and less tapered and curved anterior border. This species may belong to *Eokochaspis*, but it is difficult to be sure without an associated pygidium. The type species of *Onchocephalus* is the Lower Cambrian *O. thia* (Walcott, 1917); however, as discussed by Palmer (1958), the type material is either exfoliated or poorly preserved, making it difficult to determine the characteristics of the genus. The name *Onchocephalus* should be limited to the type material until better material is described. Other species presently assigned to *Onchocephalus* will need to be reanalyzed to determine their taxonomic affiliation. *Eokochaspis* differs from *Onchocephalus thia* illustrated by Rasetti (1951; although this specimen may not belong to *O. thia*) in having a more tapered glabella, more triangular posterior portion of the fixigena, shorter palpebral lobes, and less laterally tapered and curved anterior border (see Rasetti, 1951).

The cranidium of *Eokochaspis* is similar to *Kunmingaspis* Chang, 1964 (also see Chang et al. 1980), from the lower Middle Cambrian of China in its small palpebral lobe opposite L2, bluntly rounded frontal lobe, moderately deep glabellar furrows, and general outline. *Eokochaspis* differs from *Kunmingaspis* in its concave outline of the axial furrows and slightly convergent to parallel anterior branch of the facial suture. The librigena, thoracic segments, and pygidium of *Kunmingaspis* are unknown or poorly known.

EOKOCHASPIS NODOSA new species
Figure 7.1–7.20

Diagnosis.—Cranidium moderately convex; anterior margin moderately narrow (width 70 ± 7 percent cranidial width). Preglabellar area short (34 ± 6 percent frontal area length). Anterior border convex, furrow with faint median inbending, no medial swelling. Anterior branch of facial suture relatively long. Glabellar length 74 ± 2 percent cranidial length, convexity moderate, glabellar furrows well defined; occipital node large. Ocular ridge well defined. Posterior area of fixigena sharply terminated, directed slightly posteriorly; posterior border convex. Librigena with wide genal area, well defined border furrows, well defined border furrows, librigenal spine moderate length (38 ± 7 percent librigenal length), and recurved. Pygidium suboval, moderately arched, axis has 2 axial rings, plural bands moderately well defined, anterolateral corners moderately rounded, and median notch well developed. Granular ornamentation on glabella, fixigena, and pygidium.

Description.—Cranidium small to moderate size, length 5.2 ± 1.6 mm (n = 17); subtrapezoidal, length 70 ± 8 percent width; moderately convex (sag. and trans.), height 23 ± 5 percent width; anterior margin moderately and evenly curved in

smaller specimens, straighter in some larger specimens, width (J_2) 70 ± 7 percent cranidial width (J_1), arched dorsally; posterior margin, excluding occipital ring, curved slightly posterolaterally. Anterior branches of facial sutures very slightly convergent to midlength (exsag.) of anterior border, strongly convergent to anterior margin; posterior branches moderately divergent. Glabella elongated, strongly tapered, width at anterior end 73 ± 3 percent glabellar width (K_2); moderately convex (sag. and trans.); frontal lobe bluntly rounded; length 74 ± 2 percent and width 54 ± 4 percent cranidial length; width 38 ± 4 percent cranidial width. Axial furrow depth moderate and uniform, slightly convex in outline and moderately convergent from S0 to S2 then slightly convergent; preglabellar furrow moderately shallow, uniform depth, narrow, moderately curved. Lateral glabellar furrows moderate depth; S1 bifurcated and directed posteriorly, S2 directed laterally to slightly posterior, S3 and S4 directed moderately anteriorly. Occipital ring slightly elevated above glabella, moderately convex; large occipital node; length 19 ± 3 percent glabellar length; posterior margin convex posteriorly; doublure approximately 66 percent of occipital ring length. S0 curved anteriorly in smaller specimens, straighter in larger specimens, and moderate depth, deepest laterally. Frontal area subequally divided; length 26 ± 2 percent cranidial length. Preglabellar field very slightly convex, moderately downsloping, length 34 ± 6 percent frontal area length. Anterior border moderately convex, level, slightly tapering laterally, margin evenly curved to straighter laterally, straighter medially in larger specimens, faint median inbend, length 17 ± 2 percent cranidial length, 66 ± 6 percent frontal area length. Anterior border furrow evenly curved in smaller specimens, straighter in larger specimens, median inbend, moderate width, moderate depth, shallower medially, shallower than axial furrows. Fixigena slightly convex, level, anterior area moderately downsloping, width 54 ± 6 percent glabellar width (K2). Palpebral lobes slightly upturned, moderate width and moderately short to moderately long, width 34 ± 8 percent lobe length, length 30 ± 6 percent glabellar length; anterior margin located about opposite of S3 or L4, 20 ± 4 percent glabellar length behind glabellar anterior margin; palpebral furrow shallow. Ocular ridge moderately strong, straight to very slightly arched, directed slightly posterolaterally from glabella at 78 ± 4 degrees to axis. Posterior area of fixigena triangular, downsloping, sharply terminated; length 54 ± 6 percent glabellar width, 40 ± 4 percent glabellar length; width 60 ± 9 percent glabella length. Posterior border moderately convex to flattened distally, expanding distally; border furrow moderately deep, straight, not expanding.

Rostral plate nearly as wide as anterior margin, length approximately 20 percent width, arched, lateral sutures concave, posterior margin with slight point at axial line. Transverse terrace lines present on anterior margin.

Hypostoma small, length 2.3 ± 0.2 mm (n = 5); suboval, moderately convex (sag. and trans.); anterior margin moderately curved; lateral margins smooth, slightly convergent; posterior margin strongly curved; length 141 ± 6 percent width. Middle body moderately convex (sag. and trans.); suboval; macula not evident; unequally divided into very poorly differentiated anterior and posterior lobes; anterior lobe moderately convex, length 72 ± 4 percent of hypostomal length; posterior lobe moderately convex, length 20 ± 3 percent of hypostomal length; furrow very shallow to absent. Anterior border moderately defined, convex, narrow, 3 ± 1 percent of hypostomal length; prominent, pointed anterior wings, directed laterally and dorsally; border furrow shallow and narrow. Lateral borders moderately defined, convex, narrow, 10 ± 1 percent of hypostomal width; border furrows very shallow. Posterior wings pointed, directed dorsally. Posterior border poorly defined, weakly convex, narrow, 5 ± 1 percent hypostomal length; border furrow narrow, very shallow.

Librigena moderate size to small, length 4.0 ± 1.2 mm (n = 9); moderately wide, width 36 ± 6 percent length without spine; lateral margin moderately curved. Anterior portion of dorsal surface developed as short projection. Genal field slightly convex, width 39 ± 6 percent librigenal width, generally proportionally smaller in smaller specimens. Border convex, wider posteriorly, width 32 ± 5 percent librigenal width; lateral border furrow moderately shallow and uniform depth; posterior border furrow short, moderate and uniform depth. Librigenal spine moderate length, 38 ± 7 percent librigenal length, slightly recurved. Doublure as wide as lateral and posterior borders.

Thoracic pleura project horizontally to fulcrum, then downwardly to distal end, some distal sections slightly expanded; anterior and posterior pleural bands uniform length, curved slightly posterolaterally; posterior pleural band wider than anterior pleural band; pleural tips sightly posterolaterally directed, pointed; pleural furrow moderate depth, narrow, uniform width. Axial furrows well defined, moderate depth, slightly shallower next to anterior pleural band. Articulating surface not apparent.

Pygidium small, length 1.3 ± 0.4 mm (n = 10); suboval, length 34 ± 3 percent width; margin smooth, anterior margin moderately curved posterolaterally; anterolateral corners moderately rounded, adjacent to axial midlength; lateral margins slightly curved; median notch well developed, arched in posterior view; moderately convex (sag. and trans.). Axis slightly tapered, width at midlength 89 ± 4 percent anterior width, anterior width 38 ± 3 percent pygidial width; length 89 ± 3 percent pygidial length, no postaxial ridge; 2 axial rings, moderately convex; terminal axial piece moderate size, posteriorly rounded; axial furrow moderately shallow, deeper anteriorly; axial ring furrows moderate to shallow depth, deeper laterally. Pleural regions well defined, slightly exsagittally elongate; moderately convex, downsloping; anterior pleural furrow moderate width and depth, extending to border, curved moderately posterolaterally; 1 additional pleural furrow, shallow; interpleural furrows very shallow, not joining with pleural furrows; first anterior and posterior pleural bands well developed, second set weakly developed. Border narrow, wider at anterolateral corners, sloping downwards or level; absent at median notch next to terminal

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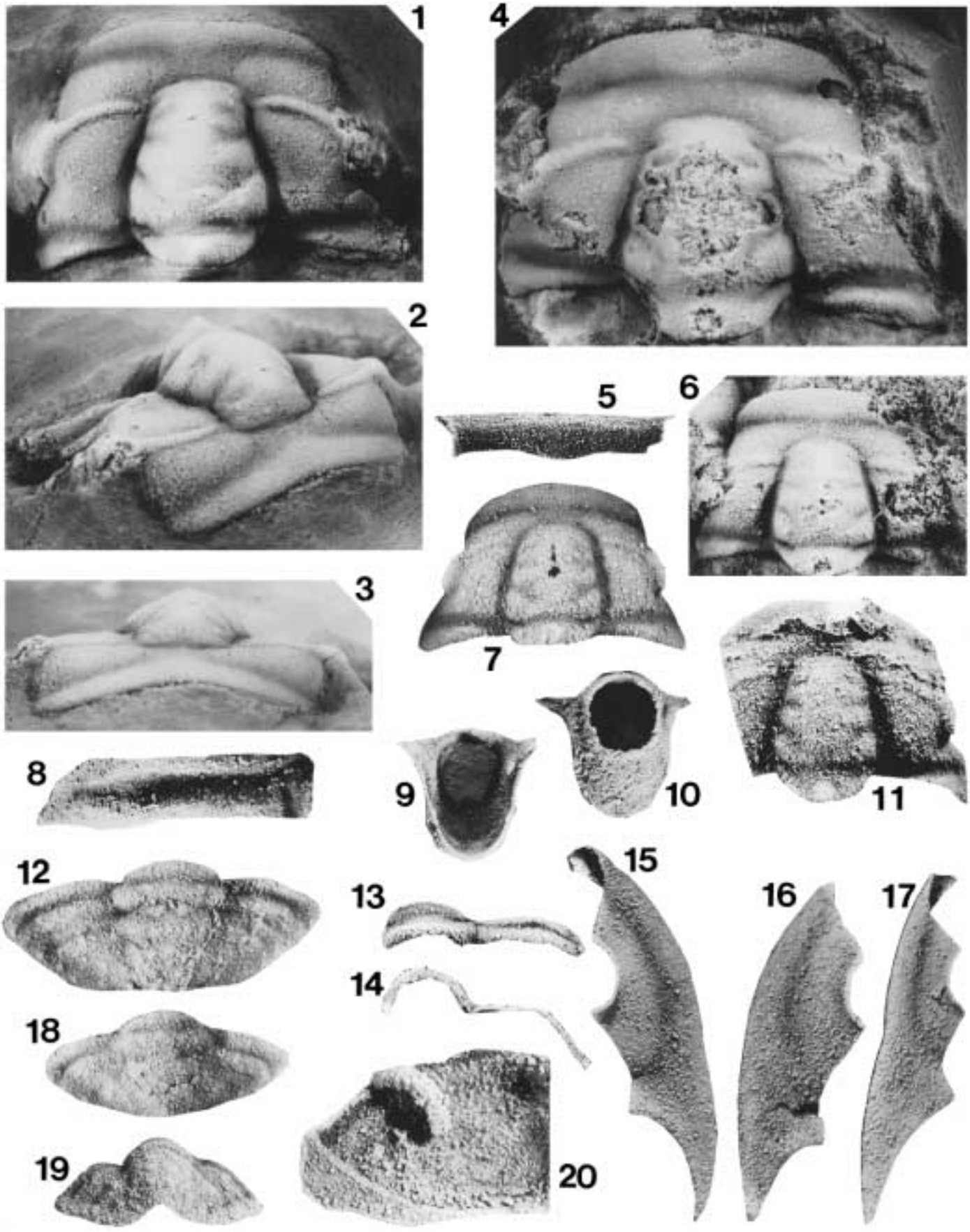
FIGURE *7—1–20, Eokochaspis nodosa* n. gen. and sp., all silicified (although some remain in limestone matrix) and paratypes unless otherwise mentioned; *1–3,* holotype cranidium (USNM 497818) from USNM locality 41447, ×8.5; *4,* large cranidium (USNM 497823) from USNM locality 41447, ×8.2; *5,* rostral plate (USNM 497859) from USNM locality 41209, ×10.0; *6,* small cranidium (USNM 497827) from USNM locality 41447, ×8.2; *7,* small cranidium (USNM 497843) from USNM locality 41209, ×11.5; *8,* hypostoma (USNM 497840) from USNM locality 41211, ×12.5; *9,* hypostoma (USNM 497839) from USNM locality 41211, ×12.5; *10,* small cranidium (USNM 497844) from USNM locality 41209, ×10.0; *11,* thoracic pleural segment (USNM 497860) from USNM locality 41209, ×10.0; *12,* silicified pygidium (USNM 497831) from USNM locality 41433, ×12.5; *13, 14,* thoracic segment (USNM 497861) from USNM locality 41209, ×10.0; *15,* librigena (USNM 497850) from USNM locality 41209, ×12.5; *16,* librigena (USNM 497852) from USNM locality 41209, ×12.5; *17,* librigena (USNM 497853) with unusual librigenal spine from USNM locality 41209, ×12.5; *18,* pygidium (USNM 497833) from USNM locality 41433, ×15.0; *19,* posterior view showing the posterior arch of the pygidium (USNM 497835) from USNM locality 41433, ×12.5; *20,* ventral view of the doublure of a pygidium (USNM 497849) from USNM locality 41209, ×12.5.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piece; border furrow absent. Doublure widest at anterolateral corners, thinning towards posterior margin, absent across median notch.

Exoskeleton granular on glabella, fixigena, and pygidium.

Etymology.—For the prominent occipital node.

Types.—Holotype, cranidium USNM 497818 from USNM locality 41447; paratypes, USNM 497819–497830 from USNM locality 41447; 497831–497835 from USNM locality 41433; 497836–497838 from USNM locality 41429; 497839–497840 from USNM locality 41211; 497841–497861 from USNM locality 41209.

Occurrence.—*Eokochaspis nodosa* Biozone, Comet Shale Member, Pioche Shale, Nevada. USNM localities 41209, 41211, 41429, 41433, 41436, 41442, 41443, 41447, and 41449.

Discussion.—The basal limestone of the Comet Shale Member contains the common silicified remains of *Eokochaspis nodosa.*

Eokochaspis nodosa differs from *E. delamarensis* in having an unequal division of the frontal area with a shorter preglabellar area and a slight median inbend of anterior border furrow; longer glabella with deeper glabellar, axial, posterior border, and anterior border furrows; stronger occipital node; librigena with a relatively longer, broad based genal spine that forms a smooth curve with the lateral margin; pygidium with better defined pleural bands, two axial rings, and better developed median notch; and granular ornamentation.

Eokochaspis nodosa differs from *E. longspina* in having an unequal division of the frontal area with a shorter preglabellar area, a slight median inbend of anterior border furrow, and narrower (trans.), convex anterior border; longer glabella with deeper glabellar furrows; stronger occipital node; librigena with shorter librigenal spine; pygidium that is less transversely elongated which has better defined pleural bands and more strongly arched pygidium; and granular ornamentation.

Eokochaspis nodosa is the lowest species in the Comet Shale Member and is intermediate in some aspects between *Eokochaspis metalaspis* from the underlying Combined Metals Member (uppermost *Olenellus* Biozone) and the overlying species of *Eokochaspis.* Both *E. nodosa* and *E. metalaspis* possess similar cranidial outlines, facial sutures, medial inbending of the anterior border, thoracic segments, and pygidium. A statistical analysis of the standard measurements of similar size specimens (2.7 to 5.5 mm) of *E. nodosa* (N = 12) and *E. metalaspis* (N = 14) illustrates that their measurements significantly differ (Fisher PLSD and Scheffe F-test, $P < 0.05$) with *E. nodosa* having a relatively narrower cranidium (A_1/J_1: 75 ± 4 vs. 70 ± 8); longer (B_1/A_1: 74 ± 2 vs. 70 ± 4), wider (K_2/A_1: 55 ± 4 vs. 49 ± 3), and more tapered (K_6/K_1: 73 ± 3 vs. 77 ± 5) glabella; shorter occipital ring (E/A_1: 19 ± 4 vs. 25 ± 3); shorter frontal area ($[G_1+H]/A_1$: 26 ± 2 vs. 30 ± 3) with a narrower anterior border (G_1/A_1: 17 ± 3 vs. 23 ± 3 and ($G_1/[G_1+H]$: 33 ± 5 vs. 78 ± 7) and wider preglabellar area ($H/[G_1+H]$: 33± 5 vs. 22 ± 8); and shorter palpebral lobes (C/B_1: 32 ± 5 vs. 38 ± 4). Other differences between the two species are that *E. nodosa* has a more pronounced occipital node, glabellar furrows, ocular ridges, and frontal lobe; less curvature of the anterior border; sharper termination to the posterior area of the fixigena; the greater length of the facial suture from the palpebral lobe to the anterior border; and a wider genal area of the librigena. Specimens of *E. nodosa* from the basal 10 to 20 cm of the basal limestone have slightly more effaced glabellar furrows, shorter anterior branches of the facial sutures, and narrower fixigena. These characteristics are similar to *E. metalaspis.*

Eokochaspis nodosa differs from *E. piochensis* in having an unequal division of the frontal area with a shorter preglabellar area, a slight median inbend of anterior border furrow, and wider (trans.), and less tapered, convex anterior border; longer, more inflated glabella with deeper glabellar furrows; stronger occipital node; recurved librigenal spine; a pygidium that has better defined pleural bands and better developed median notch; and granular ornamentation.

EOKOCHASPIS DELAMARENSIS new species
Figures 8.1–8.15, 9.1–9.3

Diagnosis.—Cranidium slightly convex; anterior margin moderately narrow (width 71 ± 5 percent cranidial width). Preglabellar area moderate length (44 ± 5 percent frontal area length). Anterior border slightly convex, furrow with no median inbending; slight medial swelling. Anterior branch of facial suture relatively long. Glabellar length 68 ± 2 percent cranidial length, convexity low, glabellar furrows poorly defined; occipital node small. Ocular ridge poorly defined. Posterior area of fixigena sharply terminated, directed slightly posteriorly; posterior border slightly convex. Librigena with wide genal area, border furrow poorly defined, and librigenal spine short (17 ± 3 percent librigenal length) and deflected laterally. Pygidium oval, weakly arched, axis with 1 or 2? axial rings, plural bands poorly defined, anterolateral corners rounded, poorly developed median notch. No granular ornamentation.

Description.—Cranidium small to moderate size, length 6.0 ± 2.4 mm (n = 13); subtrapezoidal to subquadrate, length 73 ± 3 percent width; moderately convex (sag. and trans.), height 17 ± 3 percent width; anterior margin strongly and evenly curved, width (J_2) 71 ± 5 percent cranidial width (J_1); posterior margin, excluding occipital ring, curved slightly posterolaterally. Anterior branches of facial sutures very slightly divergent to midlength (exsag.) of anterior border, convergent to anterior margin; posterior branches moderately divergent. Glabella moderately elongated, strongly to moderately tapered, width at anterior end 74 ± 3 percent glabellar width (K_2); low convexity (sag. and trans.); frontal lobe bluntly to moderately rounded; length 68 ± 2 percent and width 47 ± 3 percent cranidial length; width 35 ± 3 percent cranidial width. Axial furrow shallow, deeper posteriorly, slightly convex in outline and moderately convergent from S0 to S2 then slightly convergent; preglabellar furrow shallow, uniform depth, narrow, slightly to moderately curved. Lateral glabellar furrows very shallow to shallow; S1 bifurcated and directed posteriorly, S2 directed laterally, S3 and S4 directed slightly anteriorly. Occipital ring slightly elevated above glabella, slightly convex, length 21 ± 3 percent glabellar length; small occipital node; posterior margin convex posteriorly; doublure approximately 50 percent of occipital ring length medially. S0 straight and moderate depth, deepest laterally. Frontal area subequally divided; length 31 ± 2 percent cranidial

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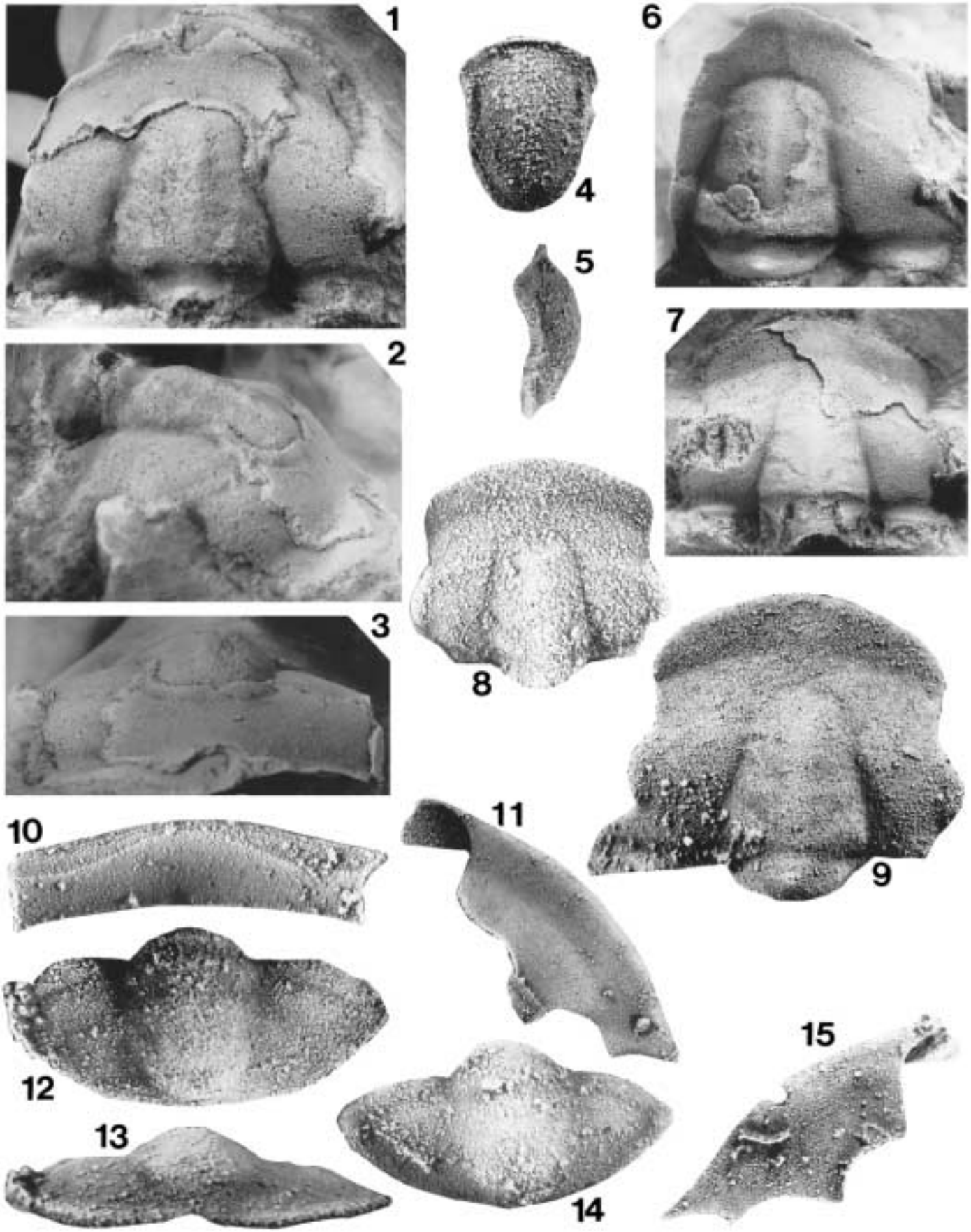
FIGURE *8—1–15, Eokochaspis delamarensis* n. gen. and sp., all silicified (although some remain in limestone matrix), from USNM locality 41448, and paratypes unless otherwise mentioned; *1–3,* mostly exfoliated holotype cranidium (USNM 497862), ×5.0; *4, 5,* hypostoma (USNM 497879), ×13.0; *6,* cranidium (USNM 497888), ×11.0; *7,* mostly exfoliated cranidium (USNM 497871), ×4.5; *8,* small cranidium (USNM 497897) from USNM locality 41438, ×11.5; *9,* mostly exfoliated partial cranidium (USNM 497865), ×5.0; *10,* rostral plate (USNM 497895), ×11.5; *11,* librigena (USNM 497891), ×7.5; *12, 13,* dorsal and posterior view of pygidium (USNM 497889), ×13.0; *14,* pygidium (USNM 497898) from USNM locality 41438, ×11.5; *15,* librigena (USNM 497890), ×7.5.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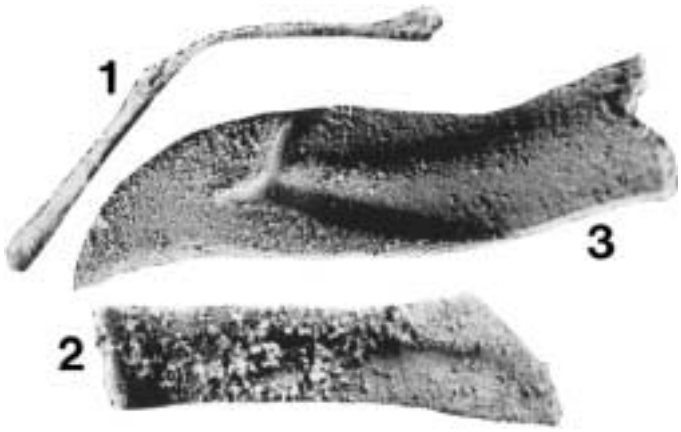

FIGURE 9—*1–3, Eokochaspis delamarensis* n. gen. and sp., all silicified, from USNM locality 41448, and are paratypes; *1, 2,* dorsal and posterior views of thoracic segment (USNM 497884), ×11.8; *3,* ventral view of thoracic segment (USNM 497885) from USNM locality 41448, ×11.3.

length. Preglabellar field slightly convex, moderately downsloping, length 44 ± 5 percent frontal area length. Anterior border slightly convex, level, slightly tapering laterally, margin evenly curved, length 18 ± 1 percent cranidial length, 56 ± 5 percent frontal area length. Anterior border furrow evenly curved, narrow, shallow, shallower medially, shallower than axial furrows. Weak medial boss crossing anterior border furrow may be present. Fixigena slightly convex, level to slightly downsloping, anterior area downsloping, width 60 ± 5 percent glabellar width (K_2). Palpebral lobes upturned, narrow and moderately long, width 26 ± 5 percent lobe length, length 37 ± 6 percent glabellar length; anterior margin located about opposite of S3 or L4, 22 ± 4 percent glabellar length behind glabellar anterior margin; palpebral furrow moderate depth. Ocular ridge weak, straight, directed moderately posterolaterally from glabella at 70 ± 4 degrees to axis. Posterior area of fixigena triangular, downsloping, sharply terminated; length 48 ± 3 percent glabellar width, 33 ± 3 percent glabellar length; width 66 ± 5 percent glabella length. Posterior border moderately convex, expanding distally; border furrow moderate depth, straight, not expanding.

Librigena moderate size, length 6.3 ± 1.9 mm (n = 7); moderately wide, width 41 ± 2 percent length without spine; lateral margin moderately curved. Anterior part of dorsal surface developed as short projection. Genal field slightly convex, width 42 ± 8 percent librigenal width. Border very slightly convex, uniform thickness, width 33 ± 3 percent librigenal width; lateral border furrow very shallow and uniform depth; posterior border furrow very short, very shallow and uniform depth. Librigenal spine short, 17 ± 3 percent librigenal length, slightly deflected laterally. Doublure wide, as wide as lateral border, wider posteriorly than border.

Rostral plate nearly as wide as anterior margin, length approximately 20 percent width, arched, lateral sutures concave, posterior margin without slight point at axial line. Transverse terrace lines present on anterior margin.

Hypostoma small, length 2.0 ± 0.3 mm (n = 5); suboval, moderately convex (sag. and trans.); anterior margin slightly curved; lateral margins straight, parallel; posterior margin strongly curved; length 140 ± 3 percent width. Middle body moderately convex (sag. and trans.); suboval; macula not evident; subequally divided into poorly differentiated anterior and posterior lobes; anterior lobe moderately convex, length 65 ± 4 percent of hypostomal length; posterior lobe moderately convex, length 24 ± 3 percent of hypostomal length; furrow very shallow to absent. Anterior border weakly convex, narrow, 8 ± 3 percent of hypostomal length, prominent anterior wings; border furrow moderate depth, wide. Lateral borders well defined, convex, narrow, 10 ± 1 percent of hypostomal width; border furrows shallow. Posterior border weakly convex, narrow, 3 ± 1 percent hypostomal length; border furrow narrow, shallow.

Thoracic pleura project horizontally to fulcrum then downwardly to distal end, some distal section anteriorly expanded; anterior and posterior pleural bands uniform length, straight; posterior pleural band slightly wider than anterior pleural band; pleural tips slightly posterolaterally directed, pointed; pleural furrow moderate depth, narrow, uniform width. Axial furrows well defined, moderate depth, slightly shallower next to anterior pleural band. Articulating surface not apparent.

Pygidium small, length 2.2 ± 0.6 mm (n = 8); suboval, length 42 ± 2 percent width; moderately convex (sag. and trans.); margin smooth, anterior margin slightly curved posterolaterally, anterolateral corners moderately rounded, adjacent to axial midlength; lateral margins moderately curved; median notch small, weakly arched in posterior view. Axis slightly to very slightly tapered, width at midlength 95 ± 4 percent anterior width, anterior width 39 ± 3 percent pygidial width; length 91 ± 5 percent pygidial length, no postaxial ridge; 1 or 2? axial rings, moderately convex; terminal axial piece large, posteriorly rounded; axial furrow shallow, uniform depth; axial ring furrows very shallow and uniform depth to absent. Pleural regions moderately defined, sagittally elongate; slightly convex, downsloping; anterior pleural furrow narrow and shallow, extending to border, curved slightly posterolaterally; 1 additional pleural furrow, very shallow or absent; interpleural furrows not visible; first anterior pleural band moderately well to poorly developed, others very weakly convex, posterior pleural bands very poorly developed. Border narrow, wider at anterolateral corners, level; present at anterior notch; border furrow very shallow. Doublure widest at anterolateral corners, thinning towards posterior margin, absent medially.

Exoskeleton smooth on all parts. Very faint genal caeca present in frontal area and anterior portion of the fixigena.

Etymology.—Named for the type locality in the Delamar Mountains.

Types.—Holotype, cranidium USNM 497862 from USNM locality 41448; paratypes, USNM 497863–497895 from USNM locality 41448; 497896–497898 from USNM locality 41438.

Occurrence.—Eokochaspis nodosa Biozone, Comet Shale Member, Pioche Shale, Nevada. USNM localities 41438, 41445, 41448, and 41450.

Discussion.—Eokochaspis delamarensis occurs as silicified specimens in the second ribbon limestone bed in the Comet Shale Member, approximately 3 to 4 m above the boundary limestone. It is possible that *E. delamarensis* occurs as shale specimens, but most *Eokochaspis* preserved in shale have well developed glabellar furrows.

Eokochaspis delamarensis differs from the other species of *Eokochaspis* in its cranidium with less convex glabella, effaced furrows, weak ocular ridge, and a weak occipital node; its librigena with a shorter librigenal spine that is slightly deflected laterally; and its pygidium with a small median notch.

EOKOCHASPIS LONGSPINA new species
Figure 10.1–10.11

Diagnosis.—Cranidium moderately convex; anterior margin moderately wide (width 84 ± 4 percent cranidial width). Preglabellar area moderately wide (50 ± 3 percent frontal area length). Anterior border convex, furrow with no median inbending, slight median swelling. Anterior branch of facial suture relatively long.

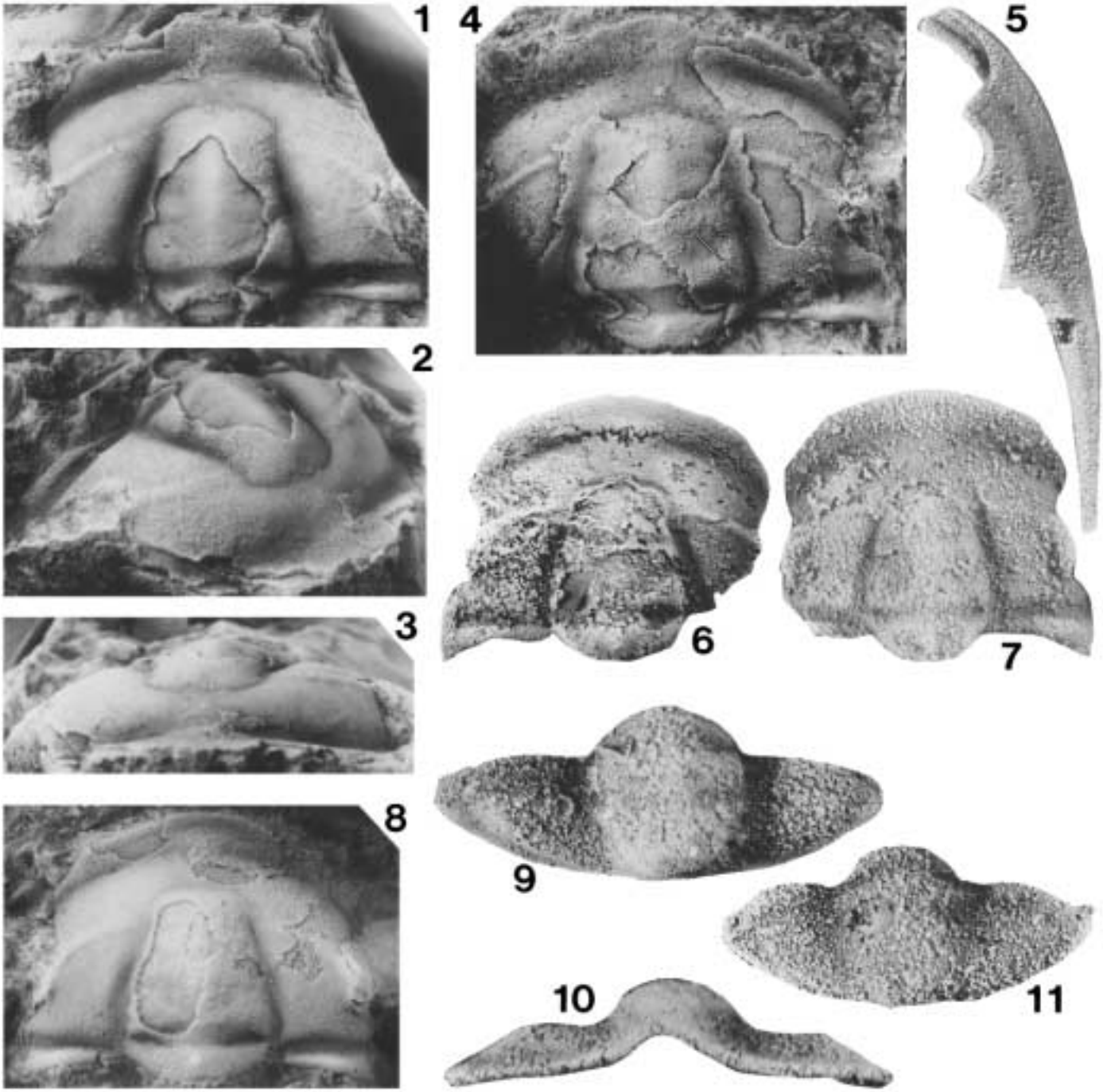

FIGURE *10—1–11, Eokochaspis longspina* n. gen. and sp., all paratypes unless otherwise mentioned; *1–3,* partially exfoliated holotype cranidium (USNM 497899) from USNM locality 41435, ×5.5; *4,* mostly exfoliated cranidium (USNM 497908) from USNM locality 41435, ×5.0; *5,* silicified librigena (USNM 497918) from USNM locality 41439, ×11.5; *6,* silicified cranidium (USNM 497922) from USNM locality 41439, ×10.0; *7,* silicified cranidium (USNM 497923) from USNM locality 41439, ×11.5; *8,* partially exfoliated cranidium (USNM 497900) from USNM locality 41435, ×5.0; *9, 10,* dorsal and posterior view of a silicified pygidium (USNM 497912) from USNM locality 41439, ×12.6; *11,* silicified pygidium (USNM 497913) from USNM locality 41439, ×12.6.

Glabellar length 69 ± 3 percent cranidial length, convexity moderate, glabellar furrows moderately defined; occipital node small. Ocular ridge moderately defined. Posterior area of fixigena sharply terminated, directed slightly posteriorly; posterior border convex. Librigena with wide genal area, moderately well defined border furrows, and librigenal spine long (74 ± 12 percent librigenal length) and projects posteriorly. Pygidium suboval, moderately arched, axis with 1 axial ring, plural bands very poorly defined, anterolateral corners moderately rounded, well developed median notch. No granular ornamentation.

Description.—Cranidium moderate size, length 8.3 ± 2.2 mm (n = 12); subquadrate, length 74 ± 5 percent width; moderately

convex (sag. and trans.), height 20 ± 11 percent width; anterior margin moderately and evenly curved, width (J_2) 84 ± 4 percent cranidial width (J_1); posterior margin, excluding occipital ring, curved moderately to slightly posterolaterally. Anterior branches of facial sutures slightly divergent to midlength (exsag.) of anterior border, strongly convergent to anterior margin; posterior branches moderately divergent, almost parallel distally. Glabella moderately elongated, strongly tapered, width at anterior end 74 ± 3 percent glabellar width (K_2); moderately convex (sag. and trans.); frontal lobe bluntly rounded; length 69 ± 3 percent and width 50 ± 2 percent cranidial length; width 37 ± 2 percent cranidial width. Axial furrow depth moderate, deeper posteriorly, slightly convex in outline and moderately convergent from S0 to S2 then slightly convergent; preglabellar furrow moderately shallow, uniform depth, narrow, slightly curved. Lateral glabellar furrows shallow; S1 bifurcated and directed posteriorly, S2 directed laterally, S3 and S4 directed moderately anteriorly. Occipital ring slightly elevated above glabella, moderately convex, length 20 ± 3 percent glabellar length; small occipital node; posterior margin convex posteriorly; doublure approximately 50 percent of occipital ring length. S0 straight to slightly flexed anteriorly and moderate depth, shallowest medially. Frontal area equally divided; length 31 ± 3 percent cranidial length. Preglabellar field convex, downsloping, length 50 ± 3 percent frontal area length. Anterior border slightly convex, level, uniform length, margin evenly curved to slightly flattened laterally, length 15 ± 2 percent cranidial length, 50 ± 3 percent frontal area length. Anterior border furrow evenly curved, narrow, shallow, shallower medially, shallower than axial furrows. Slight medial boss crossing anterior border furrow. Fixigena slightly convex, level, anterior area downsloping, width 52 ± 5 percent glabellar width (K_2). Palpebral lobe slightly upturned, moderately narrow and moderately short, width 31 ± 7 percent lobe length, length 27 ± 5 percent glabellar length; anterior margin located about opposite of L3 or S3, 27 ± 5 percent glabellar length behind glabellar anterior margin; palpebral furrow shallow. Ocular ridge moderately strong, straight, directed moderately posterolaterally from glabella at 69 ± 6 degrees to axis, larger specimens are approximately 65 degrees. Posterior area of fixigena triangular, downsloping, sharply terminated; length 49 ± 4 percent glabellar width, 36 ± 3 percent glabellar length; width 61 ± 1 percent glabella length. Posterior border moderately convex, expanding distally; border furrow moderate depth, straight, not expanding.

Hypostoma and rostral plate unknown.

Librigena moderate size, length 5.2 ± 1.7 mm (n = 6); moderately wide, width 41 ± 7 percent length without spine; anterior portion of lateral margin moderately curved, otherwise straight to slightly curved. Anterior portion of dorsal surface developed as moderate length projection. Genal field slightly convex, width 41 ± 9 percent librigenal width. Border slightly convex, uniform width, width 31 ± 5 percent librigenal width; lateral border furrow shallow and uniform depth; posterior border furrow short, shallow and uniform depth. Genal spine long, 74 ± 12 percent librigenal length. Doublure as wide as lateral border.

Pygidium small, length 1.6 ± 0.6 mm (n = 6); suboval, length 32 ± 3 percent width; margin smooth, anterior margin moderately to slightly curved posterolaterally, anterolateral corners rounded, adjacent to axial midlength; lateral margins moderately curved; median notch moderately developed, moderately arched in posterior view; moderately convex (sag. and trans.), height approximately 30 percent width. Axis slightly tapered, width at midlength 91 ± 3 percent anterior width, anterior width 30 ± 3 percent pygidial width; length 93 ± 3 percent pygidial length, no postaxial ridge; 1 axial ring, moderately convex; terminal axial piece large, posteriorly rounded; axial furrow shallow, uniform depth; axial ring furrows very shallow and uniform depth. Pleural regions moderately defined, transversely elongate; moderately convex, level to downsloping laterally; anterior pleural furrow narrow width and very shallow depth, extending to border, curved slightly posterolaterally; other furrows not visible; first anterior pleural band weakly developed, others bands not visible. Border narrow, wider at anterolateral corners, slightly downsloping; absent at median notch; border furrow absent.

Exoskeleton smooth on all parts. Faint genal caeca present on internal mold of frontal area and anterior portion of the fixigena.

Etymology.—Named for its long librigenal spine.

Types.—Holotype, cranidium USNM 497899 from USNM locality 41435; paratypes, USNM 497900–497911 from USNM locality 41435; 497912–497923 from USNM locality 41439.

Occurrence.—*Eokochaspis nodosa* Biozone, Comet Shale Member, Pioche Shale, Nevada. USNM localities 41435, 41439, and 41446

Discussion.—*Eokochaspis longspina* occurs in the third ribbon limestone of the Comet Shale Member, approximately 8 m above the boundary limestone. *Eokochaspis longspina* differs from other species of *Eokochaspis* in its long genal spines, broad anterior margin, and flat anterior border. This species is most similar to *E. delamarensis* but differs in having the cranidium with more relief and better defined furrows, the anterior branches of the facial sutures are slightly divergent, the librigenal spines are longer and narrower, and the pygidium has a slightly more pronounced notch.

EOKOCHASPIS METALASPIS new species

Crassifimbra walcotti (RESSER) *in* PALMER 1958, p. 157–169, pl. 25, figs. 4, 7–25, pl. 26, figs. 1–24, text-figs. 5.

not *Crassifimbra walcotti* (RESSER) *in* PALMER 1958, p. 105, pl. 25, figs. 1–3.

Diagnosis.—Cranidium moderately convex; anterior margin moderately narrow (width 73 ± 4 percent cranidial width). Preglabellar area short (26 ± 3 percent frontal area length). Anterior border convex, furrow with pronounced median inbending, medial swelling. Anterior branch of facial suture relatively short. Glabellar length 71 ± 3 percent cranidial length, convexity moderate, glabellar furrows poorly defined; occipital node small. Ocular ridge poorly defined. Posterior area of fixigena bluntly terminated, directed slightly posteriorly; posterior border convex. Librigena with narrow genal area (20 ± 4 percent librigenal width), border furrow poorly defined and librigenal spine moderate length (38 ± 4 percent librigenal length) and straight. Pygidium suboval, axis has 1 axial ring, first plural bands moderately well defined, anterolateral corners moderately rounded, and median notch well developed. Granular ornamentation absent.

Etymology.—Named for its occurrence in the Combined Metals Member.

Types.—Holotype, cranidium USNM 133202c from USGS locality 1400-CO; paratypes, USNM 133202a–b, 133202d–h, 133203a–h, 133203k, 133203m, 133205a–h, 133205k, 133205m–n, 133205p, 133227, USGS locality 1400-CO.

Other material examined.—25 cranidia and 10 librigenae from USNM locality 41800.

Occurrence.—*Olenellus* Biozone, Combined Metals Member, Pioche Shale, Nevada. USNM locality 41800, USGS localities 1399-CO, 1400-CO.

Discussion.—Palmer's (1958) description and illustrations of "*Crassifimbra walcotti*" are adequate for *Eokochaspis metalaspis*, with the following exceptions: 1) the glabella tapers forward to the S2, then it is parallel sided to the frontal lobe, instead of being slightly tapered; 2) the frontal lobe is well defined from

the surrounding frontal area (see Palmer, 1958, pl. 25, figs. 7, 8), the glabella does not merge ''nearly imperceptibly with the frontal area'' (p. 157); 3) the axial furrows are shallower anteriorly, but they are still well defined posterior of the ocular ridges; 4) the occipital ring is subrectangular in outline; and 5) the rostrum is about two-thirds the width of the anterior border and cranidium. The discussions about facial sutures, hypostoma, and ontogeny given by Palmer (1958) all apply to *E. metalaspis.* Measurements in the diagnosis are based on specimens collected from USNM 41800. The specimens reported as *C. walcotti* by Smith (1998) are also *E. metalaspis*.

Cranidia of *E. metalaspis* differ from those of *C. walcotti* (Fig. 11; comparisons were also made with specimens from Walcott's original collections that are not part of the type collection, but can be referred to as topotypes) in their: 1) more subtrapezoidal outline instead of a more subtriangular outline; 2) higher convexity of the glabella and anterior border instead of very low convexity; 3) well-developed axial, occipital ring, posterior border, and anterior border furrows; 4) less distally tapering anterior border; 5) less tapered, narrower and longer glabella; 6) narrower occipital ring; 7) occipital ring furrow (S0) that is continuous across the axis and connected with the axial furrows; 8) wider posterior areas of fixigena; and 9) nongranular internal surface. Other parts of *C. walcotti* are unknown, thus no further comparisons can be made.

Eokochaspis metalaspis occurs in the Combined Metals Limestone, Pioche Shale. *Eokochaspis metalaspis* is most similar to the younger *E. nodosa* but differs in having a cranidium with more poorly defined furrows, the anterior branches of the facial sutures are shorter, stronger inbend of the anterior border, the librigena that have a narrower genal area, and lacking granular surfaces.

EOKOCHASPIS PIOCHENSIS (Palmer *in* Palmer and Halley, 1979)
Figure 12.1–12.3

Eoptychoparia piochensis PALMER *in* PALMER AND HALLEY, 1979, p. 105, pl. 7, figs. 1–5.

Diagnosis.—Cranidium moderately convex; anterior margin narrow (width 59 ± 5 percent cranidial width). Preglabellar area moderately long (51 ± 5 percent frontal area length). Anterior border convex, furrow with no median inbending, no median swelling. Anterior branch of facial suture relatively long. Glabellar length 69 ± 4 percent cranidial length, convexity moderate, glabellar furrows well defined; occipital node moderate size. Ocular ridge moderately well defined. Posterior area of fixigena sharply terminated, directed slightly posteriorly; posterior border convex. Librigena with wide genal area, poorly defined border furrows, librigenal spine moderately short (27 ± 3 percent librigenal length) and projects posterolaterally. Pygidium oval, axis with 1 axial ring, plural bands poorly defined, anterolateral corners moderately rounded, median notch moderately developed. No granular ornamentation.

Emended description.—Cranidium moderate size, length 8.3 ± 2.2 mm (n = 79); subrectangular to subquadrate, length 63 ± 8 percent width; moderately convex (sag. and trans.); anterior margin moderately and evenly curved, width (J_2) 59 ± 5 percent cranidial width (J_1); posterior margin, excluding occipital ring, curved posterolaterally. Anterior branches of facial sutures slightly convergent to midlength (exsag.) of anterior border, strongly convergent to anterior margin; posterior branches moderately divergent, almost parallel distally. Glabella moderately elongated, moderately tapered, width at anterior end 69 ± 4 percent glabellar width (K_2); moderately convex (sag. and trans.); frontal lobe bluntly to moderately rounded; length 70 ± 3 percent and width 52 ± 6 percent cranidial length; width 32 ± 3 percent cranidial width. Axial furrow depth moderate, deeper posteriorly, slightly convex from S0 to S2 then slightly less convergent; preglabellar furrow moderately shallow, uniform depth, narrow, moderately curved. Lateral glabellar furrows moderate depth, S1 bifurcated directed posteriorly, S2 directed laterally, S3 and S4 directed moderately posteriorly, S3 isolated from axial furrows. Occipital ring elevated above glabella, moderately convex, length 20 ± 3 percent glabellar length; small occipital node; posterior margin convex posteriorly; doublure approximately 50 percent of occipital ring length. S0 slightly flexed anteriorly and moderate depth, shallowest medially. Frontal area equally divided; length 30 ± 2 percent cranidial length. Preglabellar field slightly convex, downsloping, length 51 ± 5 percent frontal area length. Anterior border slightly convex to flat, level, slightly tapering laterally, margin evenly curved, length 15 ± 2 percent cranidial length, 49 ± 5 percent frontal area length. Anterior border furrow evenly curved, narrow, shallow, shallower medially, shallower than axial furrows. No medial boss. Fixigena slightly convex, level, anterior area slightly downsloping, width 58 ± 7 percent glabellar width (K_2). Palpebral lobes slightly upturned, moderately narrow and moderately long, width 32 ± 8 percent lobe length, length 31 ± 4 percent glabellar length; anterior margin located about opposite of S3, 20 ± 5 percent glabellar length behind glabellar anterior margin; palpebral furrow moderate depth. Ocular ridge moderately strong, straight, directed slightly posterolaterally from glabella at 78 ± 5 degrees to axis. Posterior area of fixigena triangular, downsloping, sharply terminated; length 60 ± 10 percent glabellar width, 43 ± 5 percent glabellar length; width 76 ± 10 percent glabella length. Posterior border moderately convex, expanding distally; border furrow moderate depth, straight, not expanding.

Hypostoma and rostral plate unknown.

Librigena moderate size, length 6.7 ± 2.6 mm (n = 8); moderately narrow, width 45 ± 4 percent length without spine; anterior portion of lateral margin moderately curved, otherwise straight to slightly curved. Anterior portion of dorsal surface developed as moderate length projection. Genal field slightly convex, width 54 ± 3 percent librigenal width. Border slightly convex, uniform width, width 20 ± 1 percent librigenal width; lateral border furrow shallow, shallower posteriorly; posterior border furrow very short and shallow. Genal spine short, 27 ± 3 percent librigenal length. Doublure as wide as lateral border.

Fifteen thoracic segments, moderately decreasing in width and projecting more posterolaterally posteriorly. Axial furrows well defined, moderate depth, shallower next to anterior pleural band. Thoracic pleura wide, approximately 105 to 135 percent of axial width, projected horizontally to fulcrum then downward and slightly posterolaterally to distal end; anterior and posterior pleural bands uniform length; posterior pleural band narrower than anterior pleural band; pleural tips sightly posterolaterally directed, pointed; pleural furrow deep, narrow, uniform width.

Pygidium small, length 1.1 ± 0.3 mm (n = 5); suboval, length 28 ± 4 percent width; margin smooth, anterior margin slightly curved posterolaterally, anterolateral corners rounded, adjacent to axial midlength; lateral margins moderately curved; median notch moderately developed, arched in posterior view; moderately convex (sag. and trans.). Axis very slightly tapered, width at midlength 90 ± 4 percent anterior width, anterior width 35 ± 3 percent pygidial width; length 89 ± 2 percent pygidial length, no postaxial ridge; 1 axial ring, moderately convex; terminal axial piece large, posteriorly rounded; axial furrow shallow, uniform depth; axial ring furrows very shallow and uniform depth. Pleural regions moderately defined, transversely elongate; slightly convex, level to downsloping laterally; anterior pleural furrow narrow width and very shallow depth, extending to border, curved very slightly posterolaterally; other furrows not visible; first anterior pleural band weakly developed, other bands

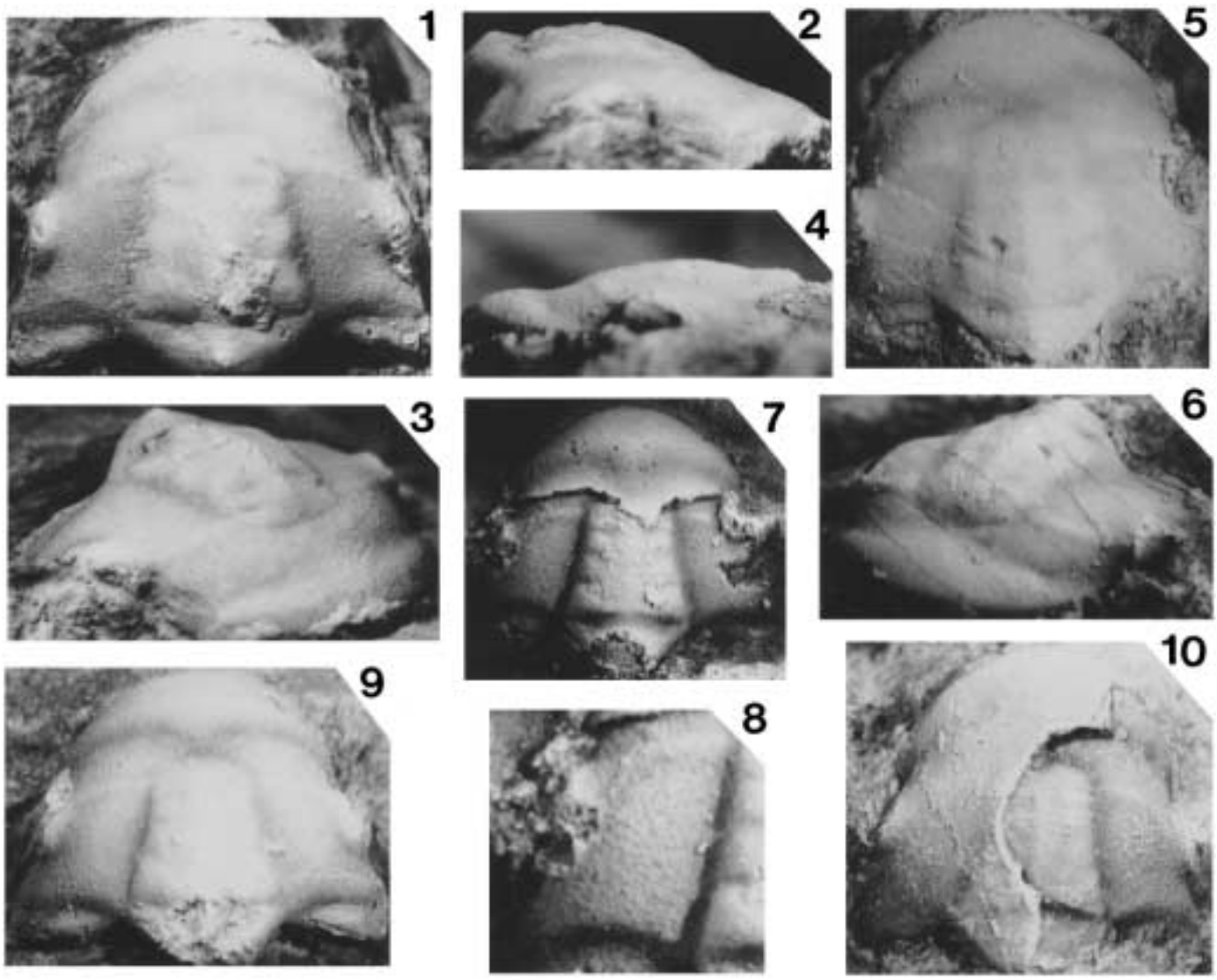

FIGURE *11—1–8, Crassifimbra walcotti* (Resser, 1937), all specimens are ×15.0, testate material, previously figured by Palmer (1958), and from USNM locality 30 unless otherwise mentioned; *1–3,* holotype cranidium (USNM 61642); *4–6,* newly illustrated cranidium (USNM 508988) illustrating the low profile of the glabella and cranidium; *7, 8,* mostly exfoliated cranidium (USNM 508989) showing punctate on fixigena, enlargment of fixigena ×30; *9,* cranidium (USNM 61642a) with damaged occipital ring; *10,* partially exfoliated cranidium (USNM 61642b).

not visible. Border narrow, wider at anterolateral corners, slightly downsloping; absent at median notch; border furrow absent.

Exoskeleton smooth on all parts. Genal caeca present in frontal area and anterior portion of the fixigena.

Material examined.—USNM 493138–493140 and 16 shield or partial shields from USNM locality 41214; 57 shields or partial shields from USNM locality 41210.

Occurrence.—Eokochaspis nodosa Biozone, Comet Shale Member, Pioche Shale, Nevada. USNM localities 41210, 41214, 41430, 41437, and 41444.

Discussion.—Trilobite specimens from the basal 6 m of the Comet Shale Member can be referred to *Eokochaspis piochensis.* They are easily comparable to the type specimens that are compressed in shale and tectonically deformed. However, assigning *Eokochaspis* specimens from the interbedded limestone units in the basal Comet Shale Member to *E. piochensis* is more difficult. The limestone specimens preserve the original convexity, ornamentation, furrow depths, and are not tectonically distorted. Of the limestone assemblages of *Eokochaspis*, only *Eokochaspis* cf. *piochensis* from the second limestone at Antelope Canyon (Fig. 12.4–12.10) is directly comparable to the shale specimens. These specimens possess a subequally divided frontal area, well defined glabellar furrows, prominent occipital node, parallel anterior branches of the facial sutures, and moderately long fixigenal spine that is not deflected outward. The Antelope Canyon specimens are significantly different from Palmer's shale specimens in having longer cranidial length vs. width ratio, wider anterior margin vs. width ratio, less tapering of glabella, wider fixigenal width, and more posteriorly set palpebral lobes. All of these differences can be the result of compaction with the posterior area of the fixigena and the glabella flattening out more than any other part of the cranidia.

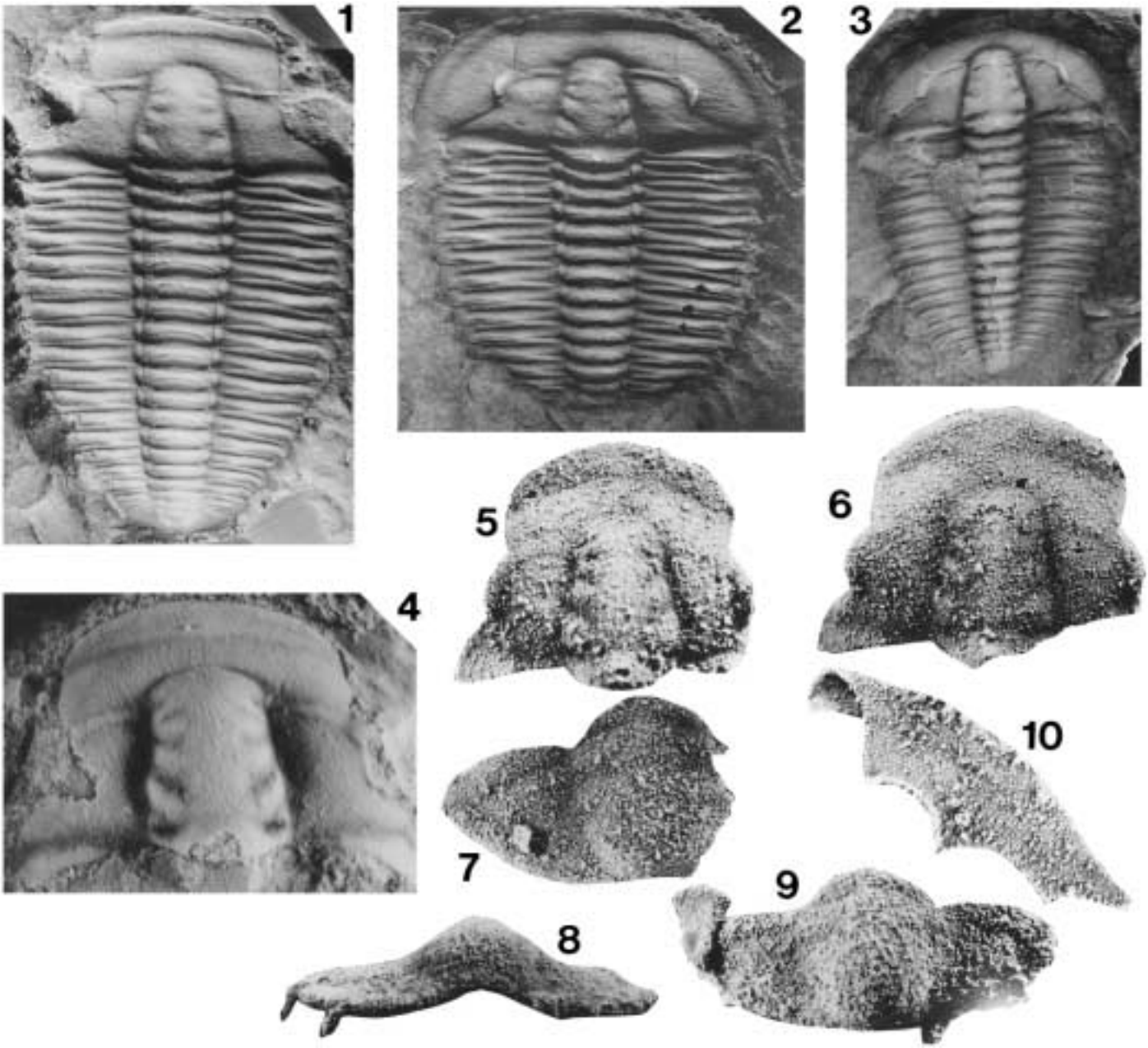

FIGURE *12—1–3, Eokochaspis piochensis* (Palmer *in* Palmer and Halley, 1979), all specimens preserved in shale and from USNM locality 41412; *1,* articulated specimen (USNM 493138) lacking only librigena; ×4.0; *2*), latex cast of a partial, articulated specimen (USNM 493139, ×4.0; *3,* latex cast of a nearly complete shield (USNM 493140), ×4.0. *4–10, Eokochaspis* cf. *piochensis* all are silicified unless otherwise mentioned and from USNM locality 41434; *4,* cranidium (USNM 493141) in limestone, ×8.0; *5,* cranidium (USNM 493142), ×10.0; *6,* cranidium (USNM 493143), ×10.0; *7,* pygidium (USNM 493144), ×12.5; *8, 9,* dorsal and posterior view of a pygidium (USNM 493145), ×12.5; *10,* librigena (USNM 493146), ×10.0.

The shale specimens of *E. piochensis* are dissimilar to *E. nodosa* in having less prominent occipital node, relatively shorter anterior margin, lack of a median inbend of anterior border, shorter less inflated glabella, more curved and more tapered anterior border, recurved librigenal spine, and less pronounced pygidial pleural bands. The shale specimens of *E. piochensis* are dissimilar to *E. delamarensis* in having less effaced axial and glabellar furrows, more pronounced ocular ridges, more recurved posterior area of the fixigena, more prominent occipital node and longer and non-deflected librigenal spines. The shale specimens of *E. piochensis* are dissimilar to *E. longspina* in having more anteriorly placed palpebral lobes, parallel to slightly convergent anterior branch of the facial sutures, slightly convex anterior border, relatively shorter librigenal spine and less transversely elongated pygidium.

The green shales overlying the boundary limestone contain common disarticulated and articulated specimens assigned to *E. piochensis,* including the type specimens described by Palmer

(*in* Palmer and Halley, 1979; personal commun.). However, these specimens are commonly compacted, tectonically distorted, and not as well preserved. This distortion can influence: the shape of the glabella; width of the fixigena; depth of axial and glabellar furrows; lengths of the preglabellar area and anterior border; length and width of the posterior area of the fixigena; and the outline of the pygidium.

EOKOCHASPIS cf. PIOCHENSIS (Palmer *in* Palmer and Halley, 1979)
Figure 12.4–12.10

Material examined.—USNM 493141–493146 and 4 cranidia, 1 librigena, 1 pygidium from USNM locality 41434.

Occurrence.—*Eokochaspis nodosa* Biozone, Comet Shale Member, Pioche Shale, Nevada. USNM locality 41434.

Discussion.—The nomenclature of this species is left open due to the paucity of well preserved specimens and the difficulty in assigning taxa preserved in limestone to those preserved in shales (see Hughes, 1995). *Eokochaspis* cf. *piochensis* differs from *E. piochensis*, which is found only in shales, in having longer cranidial length vs. width ratio, wider anterior margin vs. width ratio, less tapering of glabella, wider fixigenal width, and more posteriorly set palpebral lobes. All of these differences can be the result of compaction with the posterior area of the fixigena and the glabella flattening out more than any other part of the cranidia.

Eokochaspis cf. *piochensis* is dissimilar to *E. nodosa* in having less prominent occipital node, relatively shorter anterior border, lack of a median inbend of anterior border, shorter less inflated glabella, more curved and more tapered anterior border, recurved librigenal spine, and less pronounced pygidial pleural bands. *Eokochaspis* cf. *piochensis* is dissimilar to *E. delamarensis* in having less effaced axial and glabellar furrows, more pronounced ocular ridges, more recurved posterior area of the fixigena, more prominent occipital node and longer, non-deflected librigenal spines, and more developed pygidial median notch. *Eokochaspis* cf. *piochensis* is dissimilar to *E. longspina* in having more anteriorly placed palpebral lobes, parallel to slightly convergent anterior branch of the facial suture, slightly convex anterior border, relatively shorter librigenal spine and less transversely elongated pygidium.

Genus MEXICELLA Lochman 1948

Type species.—*Mexicella mexicana* Lochman, 1948.

Diagnosis.—Cranidia with an anterior border poorly defined, downsloping, generally narrower than preglabellar area, slightly tapered distally, slightly to moderately curved, without a medial inbend. Glabella moderately elongated, strongly tapered from S0 to S2 then slightly tapered or conical; S1 and S2 bifurcated; lateral glabellar furrows generally effaced; axial furrows deepest posteriorly. S0 moderately deep. Fixigena wide, gently convex, slightly downsloping. Posterior area of fixigena triangular, length approximately one-half glabellar length, with sharp termination, border widens distally, border furrow extends to suture. Anterior branches of facial sutures parallel to slightly convergent to midlength (exsag.) of anterior border; posterior branches moderately divergent to posterior border furrow, then nearly parallel. Librigena with or without librigenal spine; librigena spine flattened, broad-based when present. Pygidium subcircular to transversely elongated; axis with one or two axial rings; anterolateral corners pointed opposite anterior half of the axis, posterior margin with poorly developed median notch that is weakly arched in posterior view; doublure absent behind axis.

Discussion.—Lochman (1948) provided only a description of *Mexicella*, thus a diagnosis is provided above. The diagnosis includes not only the species previously assigned to the genus, but also the new species from the Comet Shale Member. These new species are similar to *Mexicella* from the overlying *Albertella* Biozone (Lochman, 1948; Palmer and Halley, 1979; Eddy and McCollum, 1998) in having generally effaced glabella, down-sloping frontal area, small palpebral lobes, parallel to convergent anterior branch of the facial sutures. However, they differ from the younger *Mexicella* in having tapering glabella with axial furrows that are convex and convergent from the S0 to S2 and then nearly parallel instead of smoothly convex from the S0 to S4 and its angular or spinose librigenal corner. *Mexicella robusta* differs from other species in having an anterior border that is wider than the preglabellar area. The pygidium also differs from the younger *Mexicella* (see Lochman, 1948) in its more transversely elongated shape, poorly defined anterior and posterior pleural bands, and more convex axis.

Mexicella stator (Walcott, 1917) of the *Albertella* Biozone (Rasetti, 1951) is intermediate in morphology between species of equivalent age and older species of *Mexicella.* It has similar glabellar outline to the older *M. robusta* and rounded librigenal corners that are typical of the younger species.

Mexicella occurs with *Eokochaspis longspina* in the *Eokochaspis nodosa* Biozone. The two genera are similar in their glabellar outline; however, *Mexicella* can be differentiated from *Eokochaspis* based on its smaller palpebral lobe, down-sloping anterior border, and longer posterior area of the fixigena.

MEXICELLA ROBUSTA new species
Figure 13.1–13.10

cf. *Mexicella*? *stator* (Walcott, 1917). PALMER AND HALLEY, 1979, p. 109–110, pl. 8, fig. 23.

Diagnosis.—Cranidium with glabella slightly inflated; glabellar furrows effaced. Axial furrows effaced; convex and convergent from the S0 to S2 and then nearly parallel to frontal lobe. Ocular ridges effaced. Shield oval shaped, 16 thoracic segments that are slightly tapering posteriorly. Librigena lacking spine, librigenal corner angular.

Description.—Cranidium moderate size, length 9.4 ± 3.2 mm (n = 8; limestone specimens 9.9 ± 3.7 mm n = 6); subtrapezoidal, length 59 ± 5 (72 ± 4) percent width; slightly convex (sag. and trans.), (height 23 ± 2 percent width); anterior margin slightly curved, undulating, width (J_2) 56 ± 5 (76 ± 5) percent cranidial width (J_1); posterior margin, excluding occipital ring, slightly curved anterolaterally to laterally. Anterior branches of facial sutures very slightly divergent or parallel to midlength (exsag.) of anterior border, moderately convergent to anterior margin; posterior branches moderately divergent, almost parallel distally. Glabella moderately elongated, moderately tapered, width at anterior end 67 ± 7 (74 ± 2) percent glabellar width (K_2); slightly convex (sag. and trans.); frontal lobe bluntly rounded; length 74 ± 4 (69 ± 2) percent and width 54 ± 5 (48

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FIGURE *13—1–10, Mexicella robusta* n. sp., all paratypes unless otherwise mentioned; *4, 5, 9,* and *10* preserved in shale; *1–3* and *6–8* preserved in limestone; *1–3,* mostly exfoliated, large cranidium (USNM 497930) from USNM locality 41441, ×5.0; *4,* large cranidium (USNM 497938) from USNM locality 41217, ×3.0; *5,* partial thorax and pygidium (USNM 497945) from USNM locality 41217, ×5.0; *6,* small cranidium (USNM 497936) from USNM locality 41212, ×5.0; *7, 8,* dorsal and posterior view of a partially exfoliated pygidium (USNM 497937) from USNM locality 41212, ×5.1; *9,* librigena (USNM 497951) from USNM locality 41217, ×3.3; *10,* complete holotype shield (USNM 497924) from USNM locality 41216, ×2.4.


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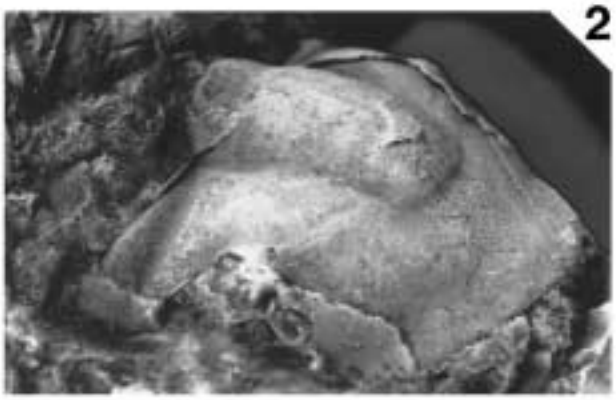
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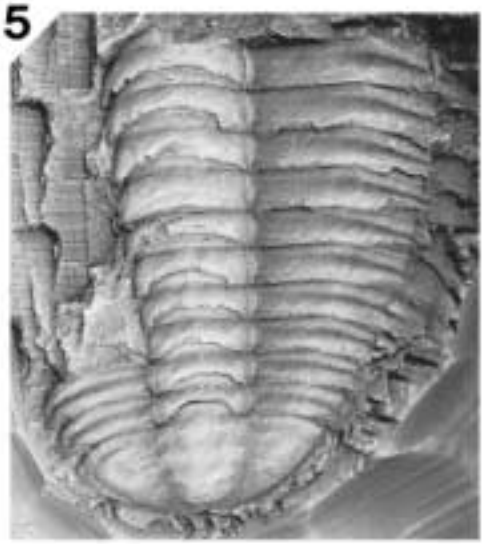
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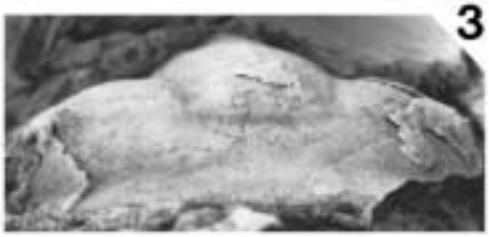
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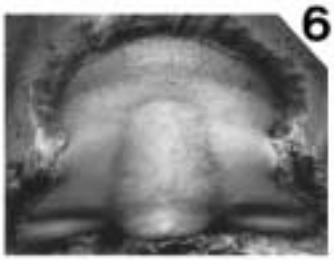
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± 1) percent cranidial length; width 32 ± 2 (35 ± 1) percent cranidial width. Axial furrow very shallow to effaced, slightly deeper posteriorly, slightly convex in outline and moderately convergent from S0 to S2 then nearly parallel; preglabellar furrow very shallow to effaced, uniform depth, narrow, slightly curved. Lateral glabellar furrows very shallow to absent; S1 bifurcated? and directed posteriorly, S2 directed posteriorly?, S3 and S4 when visible directed moderately anteriorly. Occipital ring slightly? elevated above glabella, slightly convex, length 18 ± 2 (19 ± 2) percent glabellar length; small occipital node on smaller specimens; posterior margin convex posteriorly; doublure approximately 50 percent of occipital ring length. S0 straight to slightly flexed anteriorly and very shallow, deeper pits absent. Frontal area subequally divided; length 26 ± 4 (31 ± 1) percent cranidial length. Preglabellar field slightly convex, slightly downsloping, length 40 ± 3 (52 ± 7) percent frontal area length. Anterior border very slightly convex, downsloping, longer medially and at anterolateral corners, margin undulating, length 16 ± 3 (15 ± 3) percent cranidial length, 60 ± 3 (48 ± 7) percent frontal area length. Anterior border furrow evenly curved, narrow, very shallow, shallower than axial furrows, medial boss not present. Fixigena slightly convex, lightly downsloping, anterior area lightly downsloping, width 55 ± 6 (53 ± 3) percent glabellar width (K2). Palpebral lobe level, moderately narrow and short, width 20 ± 4 (34 ± 7) percent lobe length, length 19 ± 2 (25 ± 4) percent glabellar length; anterior margin located about opposite of S3 or L4, 18 ± 2 (28 ± 7) percent glabellar length behind glabellar anterior margin; palpebral furrow effaced. Ocular ridge very faint to absent, straight, directed slightly posterolaterally from glabella at approximately 80 (70) degrees to axis. Posterior area of fixigena triangular, slightly downsloping, sharply terminated; length 75 ± 5 (59 ± 3) percent glabellar width, 55 ± 4 (41 ± 2) percent glabellar length; width 81 ± 11 (64 ± 5) percent glabella length. Posterior border moderately convex, slightly expanding distally; border furrow moderate depth, curved anterolaterally or straight, not expanding.

Hypostoma and rostral plate unknown.

Librigena large, length 13.5 ± 3.3 mm (n = 5); moderately wide, width 46 ± 6 percent length; lateral margin moderately curved, straight to slightly curved posteriorly. Anterior part of dorsal surface developed as short projection. Genal field slightly convex, width 62 ± 5 percent librigenal width. Border very slightly convex, uniform width, width 26 ± 4 percent librigenal width; lateral border furrow very shallow and uniform depth to effaced; posterior border furrow effaced. Librigenal spine absent, reduced to sharp angle. Doublure as wide as lateral border.

Sixteen thoracic segments, moderately decreasing in width and projecting slightly posterolaterally posteriorly. Axial furrows well defined, moderate depth, shallower next to anterior pleural band. Thoracic pleura wide, approximately 125 percent of axial width, projected horizontally to fulcrum then downward and slightly posterolaterally to distal end; anterior and posterior pleural bands uniform length to fulcrum then lengthening; posterior pleural band equal length to anterior pleural band; pleural tips sightly posterolaterally directed, sharp, flat termination; pleural furrow deep, moderately wide, narrowing distally. Articulating surface on posterior margin abaxial of fulcrum; no fulcral sockets or processes apparent.

Pygidium small, length 3.6 ± 0.7 mm (n = 6; limestone specimens 4 to 5 mm, n = 3); alate, length 37 ± 3 (approximately 35) percent width; margin smooth, anterior margin slightly curved posterolaterally, anterolateral corners pointed, adjacent to or anterior of axial midlength; lateral margins slightly curved; broad, no shallow posterior inbending, no obvious median notch; slightly convex (sag. and trans.), (height 10 to 15 percent width). Axis slightly tapered, width at midlength 84 ± 4 (80 to 95) percent anterior width, anterior width 31 ± 4 (30 to 35) percent pygidial width; length 88 ± 8 (90 to 95) percent pygidial length, no postaxial ridge; 3 axial rings, moderately convex; terminal axial piece moderate size, posteriorly rounded; axial furrow shallow, uniform depth; axial ring furrows shallow and uniform depth. Pleural regions well defined, transversely elongate; slightly convex, slightly downsloping; anterior pleural furrow moderately wide and shallow depth, extending to border, curved slightly posterolaterally; other furrows not visible or very shallow; first anterior pleural band well developed, other bands very poorly developed. Border narrow, slightly wider at anterolateral corners, level, flat; absent at posterior end; border furrow very shallow.

Exoskeleton smooth on all parts.

Etymology.—Named for the species' large size.

Types.—Holotype, nearly complete shield USNM 497924 from USNM locality 41216; paratypes, USNM 497925–497928 from USNM locality 41216; 497929, 497930 from USNM locality 41441; USNM 497931–497935 from USNM locality 41215; USNM 497936, 497937 from USNM locality 41212; USNM 497938–497953 from USNM locality 41217.

Occurrence.—Amecephalus arrojosensis Biozone, Comet Shale Member and Susan Duster Limestone Member, Pioche Shale, Nevada. USNM localities 41212, 41213, 41215, 41216, 41217, 41432, 41441, and 41451. Pyramid Shale, Carrara Formation Nevada (Palmer and Halley, 1979).

Discussion.—Mexicella robusta is found compressed and slightly tectonically distorted in the green platy shales one to three meters below the Susan Duster Limestone Member, Pioche Shale. *Mexicella* specimens found in the interbedded limestones are also probably *Mexicella robusta,* they share the effaced cranidia and less inflated glabella. However, no librigena have been found from the limestones, so it is not known if the librigena lacks spines. However, the limestone specimens are assigned to *M. robusta* based on their cranidial morphology. The above description is based on specimens found in shale. The measured ratios and the different morphology of the limestone specimens are presented in parentheses above to allow for their comparison to the shale specimens and other *Mexicella* species that are preserved in limestone. Compression of the specimens in shale had large effects on several of the ratios.

A specimen illustrated as ''cf. *Mexicella stator*'' in Palmer and Halley (1979) is found in the Pyramid Shale, Carrara Formation, at the same stratigraphic level as *M. robusta* and is assigned to this species.

Mexicella robusta differs from *M. antelopea* n. sp. in having more effaced cranidia, less inflated glabella, and a lack of a librigenal spine. *Mexicella robusta* differs from *M. stator* in having more effaced cranidia, less inflated glabella, an angular librigenal corner, and less tapering thorax with only 16 segments instead of 20 segments.

MEXICELLA ANTELOPEA new species
Figure 14.1–14.7

Diagnosis.—Cranidium with glabella moderately inflated; glabellar furrows very shallow to absent. Axial furrows moderately shallow; convex and convergent from the S0 to S2 and then nearly parallel to frontal lobe. Ocular ridges very faint to absent. Librigena with relatively long spine (approximately 40 percent librigenal length).

Description.—Cranidium moderate size, length 10.4 ± 2.0 mm (n = 5); subquadrate, length 62 ± 4 percent width; moderately convex (sag. and trans.), height 18 ± 2 percent width; anterior margin moderately and evenly curved, width (J_2) 65 ±

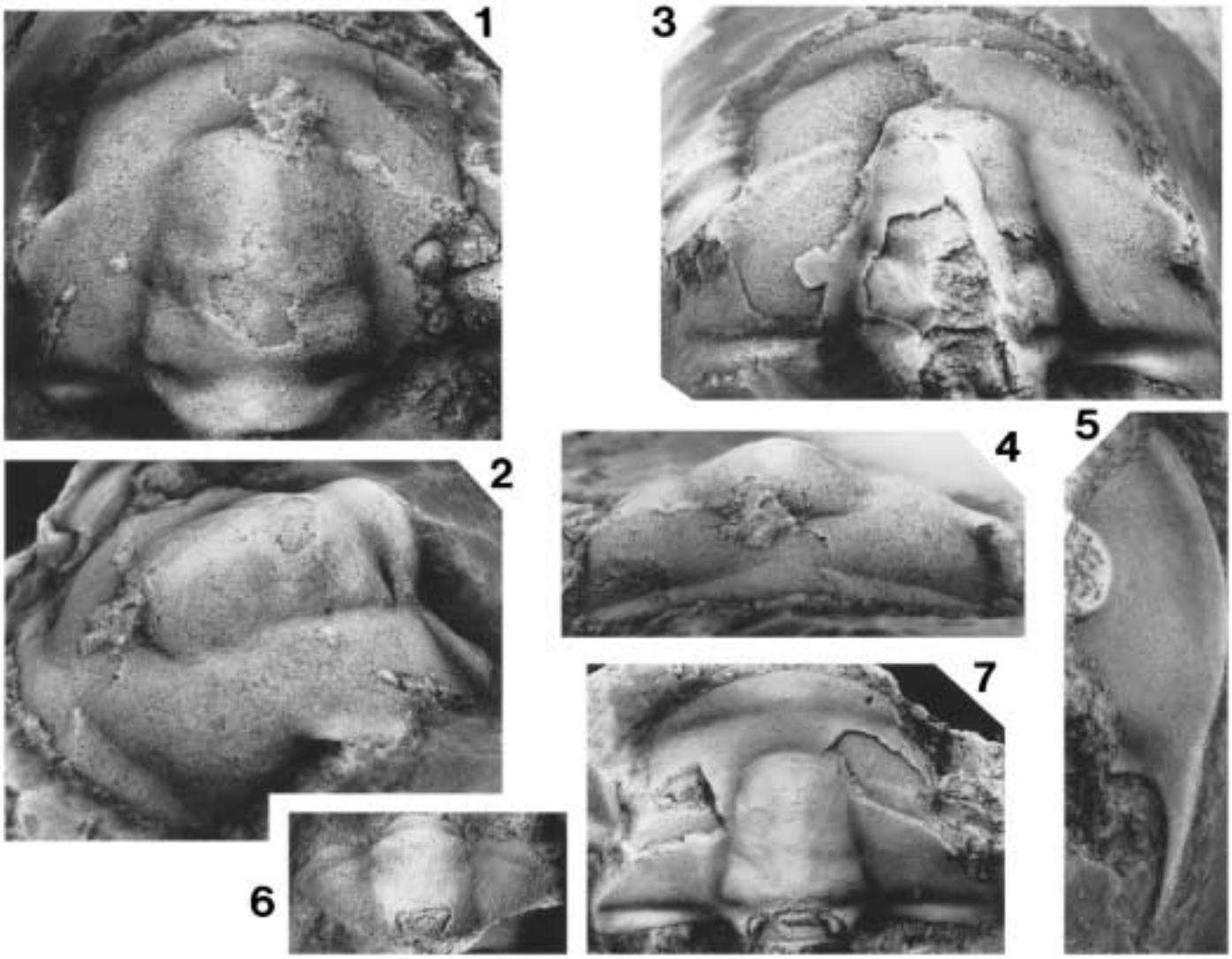

FIGURE *14—1–7, Mexicella antelopea* n. sp., all paratypes unless otherwise mentioned; *1, 2, 4,* large, partially exfoliated, holotype cranidium (USNM 497977) from USNM locality 41435, ×5.0; *3,* large, mostly exfoliated cranidium (USNM 497974) from USNM locality 41439, ×5.2; *5,* librigena (USNM 497976) from USNM locality 41435, ×4.6; *7,* small, pygidium (USNM 497975) from USNM locality 41439, ×8.0; *7,* small, partially exfoliated cranidium (USNM 493149) from USNM locality 41435, ×5.2.

3 percent cranidial width (J_1); posterior margin, excluding occipital ring, slightly curved posterolaterally. Anterior branches of facial sutures very slightly convergent to midlength (exsag.) of anterior border, strongly convergent to anterior margin; posterior branches moderately divergent, almost parallel distally. Glabella moderately elongated, strongly tapered, width at anterior end 71 ± 2 percent glabellar width (K_2); low to moderately convex (sag. and trans.); frontal lobe bluntly rounded; length 72 ± 1 percent and width 55 ± 2 percent cranidial length; width 34 ± 1 percent cranidial width. Axial furrow moderately shallow, deeper posteriorly, slightly convex in outline and moderately convergent from S0 to S2 then nearly parallel; preglabellar furrow shallow, uniform depth, narrow, slightly curved. Lateral glabellar furrows very shallow to absent; S1 bifurcated and directed posteriorly, S2 directed laterally, S3 and S4 when visible directed moderately anteriorly. Occipital ring slightly elevated above glabella, slightly convex, length 19 ± 1 percent glabellar length; small occipital node; posterior margin convex posteriorly, straight medially; doublure approximately 50 percent of occipital ring length. S0 straight to slightly flexed anteriorly and shallow, deeper pits laterally. Frontal area subequally divided; length 28 ± 1 percent cranidial length. Preglabellar field slightly convex, moderately downsloping, length 57 ± 9 percent frontal area length. Anterior border slightly convex, downsloping, uniform length, margin evenly curved to slightly flattened laterally, length 12 ± 3 percent cranidial length, 43 ± 9 percent frontal area length. Anterior border furrow evenly curved, narrow, shallow, shallower medially than axial furrows, possible low medial boss. Fixigena slightly convex, downsloping, anterior area moderately downsloping, width 62 ± 9 percent glabellar width (K_2). Palpebral lobe level, moderately narrow and moderately long, width 24 ± 3 percent lobe length, length 31 ± 4 percent glabellar length; anterior margin located about opposite of S3 or L4, 21 ± 3 percent glabellar length behind glabellar anterior

margin; palpebral furrow very shallow. Ocular ridge very faint to absent, straight, directed moderately posterolaterally from glabella at approximately 70 degrees to axis. Posterior area of fixigena triangular, downsloping, sharply terminated; length 51 ± 6 percent glabellar width, 38 ± 4 percent glabellar length; width 72 ± 7 percent glabella length. Posterior border moderately convex, slightly expanding distally; border furrow moderate depth, straight, not expanding.

Librigena moderate size, length 11 mm (n = 1); moderately wide, width approximately 45 percent length without spine; lateral margin moderately curved. Anterior part of dorsal surface developed as short projection. Genal field slightly convex, width approximately 55 percent librigenal width. Border slightly convex, uniform width, width approximately 25 percent librigenal width; lateral border furrow shallow, shallower posteriorly; posterior border furrow short and shallow. Genal spine moderately long, approximately 40 percent librigenal length.

Hypostoma, rostral plate, and thorax unknown.

Pygidium small size, length 1.9 mm (n = 1); subelliptical, length approximately 50 percent width; margin smooth, anterior margin projects laterally then moderately posterolaterally, anterolateral corners pointed, adjacent to axial midlength; lateral margins slightly curved; no posterior inbending, no obvious median notch; slightly convex (sag. and trans.), height approximately 25 percent width. Axis slightly tapered, width at midlength approximately 90 percent anterior width, anterior width approximately 45 percent pygidial width; length approximately 85 percent pygidial length, no postaxial ridge; 1 axial ring, moderately convex; terminal axial piece large, posteriorly rounded; axial furrow very shallow, uniform depth; axial ring furrow very shallow and uniform depth. Pleural regions moderately defined, transversely elongate; moderately to slightly convex, slightly downsloping; anterior pleural furrow moderately wide and shallow depth, extending to border, curved slightly posterolaterally; other furrows not visible; first anterior pleural band well developed, other bands very poorly developed. Border narrow, slightly wider at anterolateral corners, level, convex; absent at posterior end; border furrow very shallow.

Exoskeleton smooth on all parts.

Entymology.—Named after the type locality in Antelope Canyon.

Types.—Holotype, cranidium USNM 497977 from USNM locality 41435; paratypes, USNM 493147–493149, 497976 from USNM locality 41435; 497974, 497975 from USNM locality 41439.

Occurrence.—Eokochaspis nodosa Biozone, Comet Shale Member, Pioche Shale, Nevada. USNM localities 41435 and 41439.

Discussion.—A single small pygidium is known for this species.

Mexicella antelopea differs from *M. robusta* and *M. stator* in having less effaced cranidia, more inflated glabella, and a librigenal spine. *Mexicella antelopea* differs from the co-occurring *Eokochaspis longspina* by having stronger downsloping and convexity of the fixigena and frontal area; wider posterior area of the fixigena, fixigena, and cranidial width; longer posterior area of the fixigena and palpebral lobes; slightly divergent anterior branch of the facial sutures; and librigena with shorter genal spines and wider genal area, and rounded lateral border.

Genus KOCHINA Resser, 1935

Type species.—Olenopsis americanus Walcott, 1912b.

Discussion.—Resser (1935) differentiated this genus from *Kochaspis* in having a narrower to nearly absent preglabellar area, convergent anterior branch of the facial sutures, and more anterior position of the palpebral lobes. The type species and *Kochina macrops* Rasetti, 1951 has the additional feature of a nearly straight anterior border furrow. Re-evaluation of the genus will be included in a future study on trilobites from the Emigrant Formation, where an additional, unnamed species has been found.

Kochina as presently recognized differs from *Eokochaspis* in having cranidium with a more strongly tapered anterior border, shallower anterior border furrow, posterior border that does not widen laterally, convergent anterior branches of the facial suture, the lateral extent of the posterior branch of the facial suture not parallel, and moderate eye ridge strength; thorax with longer plural spines; and pygidium having a doublure behind the axis.

KOCHINA? WALCOTTI new species
Figure 15.1–15.6

Diagnosis.—Cranidium with a preglabellar area 47 ± 5 percent frontal area length, anterior border moderately tapered, and glabella 32 ± 1 percent cranidial width. Pygidium small, anterolateral corners rounded, shallow pleural furrows.

Description.—Cranidium moderate size, length 5.9 ± 1.0 mm (n = 12) (limestone specimens: 5.1 mm, n = 2); subrectangular, length 74 ± 5 percent width; moderately convex (sag. and trans.); anterior margin moderately and evenly curved, width (J_2) 57 ± 4 percent cranidial width (J_1); posterior margin, excluding occipital ring, project laterally. Anterior branches of facial sutures slightly divergent to midlength (exsag.) of preglabellar area, then slightly convergent to anterior border, strongly convergent to anterior margin (parallel then moderately convergent to anterior margin); posterior branches strongly divergent. Glabella moderately elongated, moderately tapered, width at anterior end 67 ± 4 (65 to 70) percent glabellar width (K_2); moderately convex (sag. and trans.); frontal lobe bluntly to moderately rounded; length 72 ± 3 (approximately 70) percent and width 55 ± 5 (approximately 55) percent cranidial length; width 32 ± 1 percent cranidial width. Axial furrow deep, deeper posteriorly, slightly convex in outline and convergent from S0 to S2 then nearly parallel; preglabellar furrow moderately shallow, uniform depth, narrow, moderately curved (slightly curved). Lateral glabellar furrows moderate depth; S1 not bifurcated and directed posteriorly, S2 directed slightly posteriorly, S3 and S4 directed slightly to moderately anteriorly (lateral to slightly anteriorly directed). Occipital ring slightly elevated above glabella, moderately convex, length 21 ± 3 (approximately 20) percent glabellar length; small occipital node; doublure approximately 50 (25) percent of occipital ring length; posterior margin convex posteriorly. S0 slightly flexed anteriorly and moderate depth, shallowest medially. Frontal area equally divided; length 27 ± 3 (approximately 30) percent cranidial length. Preglabellar field slightly convex, slightly downsloping, length 47 ± 5 (45 to 50) percent frontal area length. Anterior border moderately convex, level, tapering laterally, margin evenly curved, length 14 ± 2 (approximately 15) percent cranidial length, 53 ± 5 (50 to 55) percent frontal area length. Anterior border furrow evenly and slightly curved to straight, narrow, shallow, shallower than axial furrows, shallower medially. No medial boss. Fixigena moderately convex, level, anterior area moderately downsloping, width 55 ± 5 (50 to 65) percent glabellar width (K_2). Palpebral lobes slightly upturned, moderately narrow and moderately long, width 30 ± 4 (approximately 35) percent lobe length, length 40 ± 4 (approximately 35) percent glabellar length; anterior margin located about opposite of S4, 19 ± 3 (approximately 15) percent glabellar length behind glabellar anterior margin; palpebral furrow moderate depth. Ocular ridge moderate strength, slightly

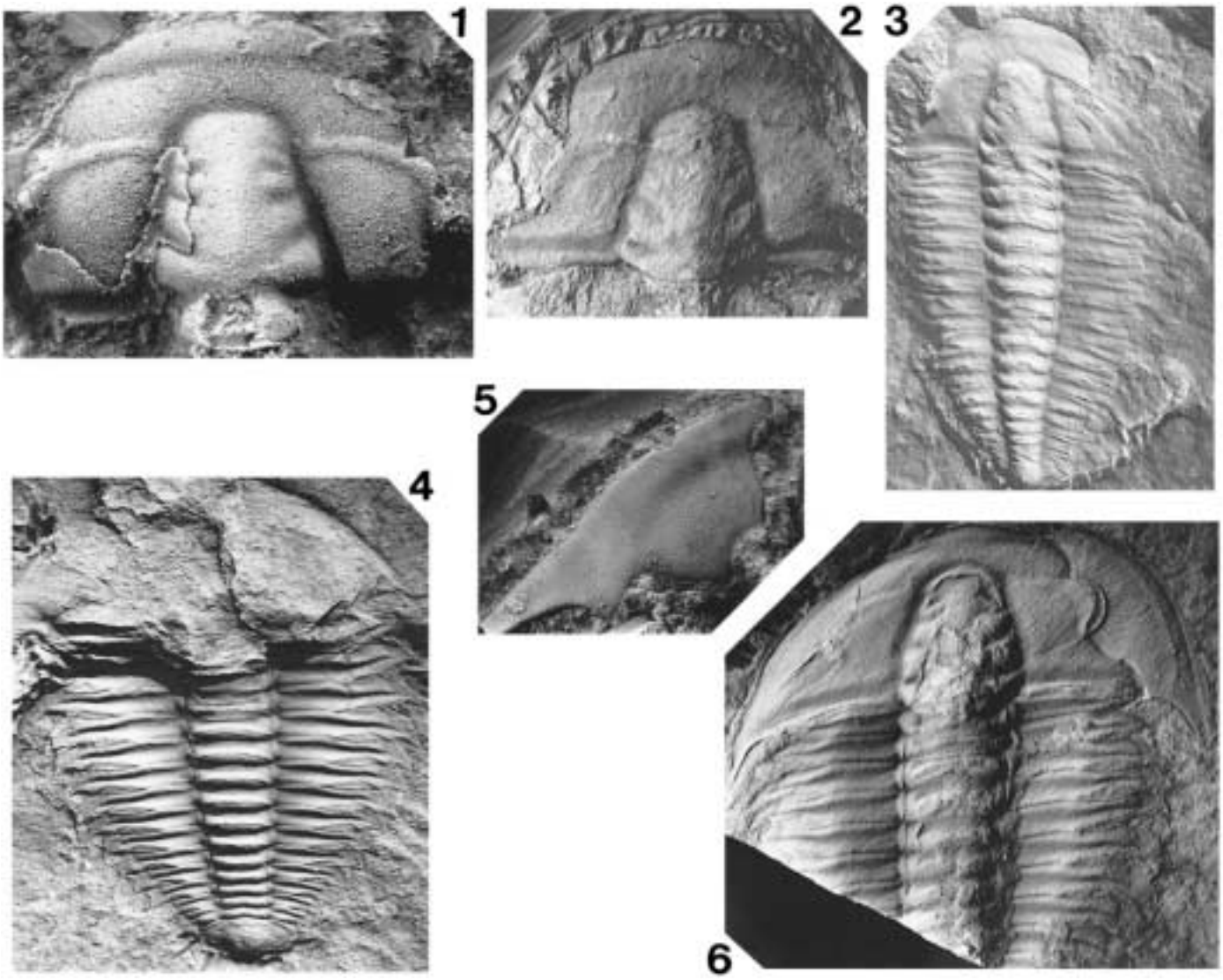

FIGURE *15—1–6, Kochina*? *walcotti* n. sp., all paratypes unless otherwise mentioned; *2–4, 6* preserved in shale; *1, 5* preserved in limestone; *1,* cranidium (USNM 497962) from USNM locality 41452, ×10.0; *2.* cranidium (USNM 497966) from USNM locality 41217, ×6.4; *3,* nearly complete, holotype shield (USNM 497954) from USNM locality 41216, ×4.0; *4,* partial shield (USNM 497959) from USNM locality 41216, ×4.1; *5,* librigena (USNM 497964) from USNM locality 41441, ×5.4; *6,* partial shield (USNM 497955) from USNM locality 41216, ×6.0.

arched, directed slightly posterolaterally from glabella at 75 to 80 degrees to axis. Posterior area of fixigena strap-like, downsloping, sharply terminated; length 50 ± 4 (approximately 55) percent glabellar width, 38 ± 3 (approximately 40) percent glabellar length; width 78 ± 7 percent glabella length. Posterior border moderately convex, slightly expanding distally; border furrow moderate depth, straight, not expanding.

Hypostoma and rostral plate unknown.

Librigena moderate size, length 5.7 ± 1.1 mm (n = 5); moderately wide, width 47 ± 3 percent length without spine; anterior portion of lateral margin moderately curved, posterior portion straight to slightly curved. Anterior part of dorsal surface developed as short length projection. Genal field slightly convex?, width 48 ± 3 percent librigenal width. Border slightly convex, uniform width, width 18 ± 3 percent librigenal width; lateral border furrow moderately shallow, uniform depth; posterior border furrow short and moderately shallow. Genal spine moderate length, 44 ± 8 percent librigenal length. Doublure as wide as lateral border.

Fourteen to seventeen (smaller holaspid) thoracic segments, projecting laterally, rapidly decreasing in width posteriorly. Axial furrows well defined, moderate depth, uniform depth. Thoracic pleura wide, 100 to 135 percent of axial width anteriorly and approximately 100 percent posteriorly, projected horizontally to fulcrum then downward and very slightly posterolaterally to distal end; anterior and posterior pleural bands uniform length; posterior pleural band wider than anterior pleural band; pleural tips posterolaterally directed, pointed; pleural furrow deep, narrow, narrowing laterally after fulcrum.

Pygidium small, length 1.5 to 1.6 mm (n = 2); suboval, length 40 to 45 percent width; margin smooth, anterior margin slightly curved posterolaterally, anterolateral corners rounded, adjacent to axial midlength; lateral margins moderately curved; median

notch unknown; moderate? convexity (sag. and trans.). Axis very slightly tapered, width at midlength 90 to 95 percent anterior width, anterior width 45 to 50 percent pygidial width; length 90 to 95 percent pygidial length, no postaxial ridge; 2 axial rings, moderately convex; terminal axial piece large, posteriorly rounded; axial furrow shallow, uniform depth; axial ring furrows very shallow and uniform depth. Pleural regions moderately defined, transversely elongate; slightly convex, level to downsloping laterally; anterior pleural furrow narrow width and shallow depth, extending to border, curved very slightly posterolaterally; other furrows not visible; first anterior pleural band weakly developed, other bands very faint or not visible. Border narrow, wider at anterolateral corners, slightly downsloping; border furrow absent.

Fine granules are present on cranidia preserved in limestone. Genal caeca are present on the frontal area and fixigena. Other parts appear to be smooth.

Etymology.—Named in honor of Charles Walcott.

Types.—Holotype, nearly complete shield USNM 497954 from USNM locality 41216; paratypes, USNM 497955–497961 from USNM locality 41216; USNM 497962, 497963 from USNM locality 41452; USNM 497964 from USNM locality 41441; USNM 497965–497973 from USNM locality 412l7.

Occurrence.—Amecephalus arrojosensis Biozone, Comet Shale Member, Pioche Shale, Nevada. USNM localities 41213, 41216, 41217, 41218, 41441, and 41451.

Discussion.—Kochina? *walcotti* n. sp. is questionably assigned to the genus based on its lack of a straight anterior boarder furrow, less tapered anterior border, and wider preglabellar area. *Kochina*? *walcotti* is most similar to *K. americanus* from the *Albertella* Biozone (see Rasetti, 1951, pl. 19, figs. 20–23), but differs in a wider preglabellar area, wider glabella, less tapered anterior border, fewer thoracic segments, and a smaller pygidium with rounded anterolateral corners and shallower pleural furrows.

Kochina? *walcotti* is known from two cranidia and one questionably assigned librigena preserved in limestone from Big Lime Mountain and Hidden Valley and several disarticulated and articulated specimens from clay shales 2 to 3 m below the Susan Duster Limestone Member. The limestone specimens are used for the convexity information in the description. Convexity based on shale specimens are stated with''?''.

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LOCALITY AND FAUNAL REGISTER

All sections are complete and of the Comet Shale Member, Pioche Shale unless otherwise noted. All localities are USNM unless otherwise noted (ICS = Institute for Cambrian Studies or CO = U.S. Geologic Survey). All stratigraphic distances are from the bottom contact of the member.

HIGHLAND RANGE

30—12.8 km (8 mi) ''north of Bennetts Spring, on the west slope of the Highland Range, Lincoln County, Nev. (C. D. Walcott and J. E. W., 1885).'' (Walcott, 1912a, p. 189). Most likely from the Combined Metals Member, Pioche Shale.

One Wheel Canyon Section.—NE¼, SW¼, sec. 29, T1N, R66E, 37°54′55, 114°36′18″, Highland Peak 7.5′ quadrangle, Nevada (1969). The measured section of the Comet Shale Member covers 33 m on the north side of One Wheel Canyon.

1400-CO—Upper meter of the Combined Metals Member (see Palmer, 1958). *Eokochaspis metalaspis,* numerous silicified specimens.

41209—Basal 70 cm. *Eokochaspis nodosa,* numerous silicified specimens from silty ribbon limestone.

41210—From 0.7–6 m. *Eokochaspis piochensis.*

Log Cabin Mine Section.—SW¼, SW¼, sec. 32, T1N, R66E 37°53′53″, 114°36′30″, Highland Peak 7.5′ quadrangle, Nevada (1969). The measured section covers 34 m in a roadcut 400 m south of the Log Cabin Mine.

41211—Basal 70 cm. *Eokochaspis nodosa,* numerous silicified specimens from silty ribbon limestone.

41212—At 33 m. *Amecephalus arrojosensis, Mexicella robusta* from 10 cm thick bioclastic limestone.

41213—At 33.1–34 m. *Mexicella robusta, Kochina*? *walcotti* from shale interval.

South of Log Cabin Mine Section.—NW¼, NW¼, SW¼, sec. 32, T1N, R66E 37°54′08″, 114°36′30″, Highland Peak 7.5′ quadrangle, Nevada (1969).

41800—Four to 22 m above the base of the Combined Metals Member. *Eokochaspis metalaspis,* numerous silicified specimens.

Comet Mine Section.—SE¼, SE¼, unsurveyed sec. 4, T1S, R66E 37°53′27″, 114°36′26″, Highland Peak 7.5′ quadrangle, Nevada (1969). The measured section covers 34 m, near a roadcut 450 m east of Comet Mine.

41214—From 0.7–10 m. *Eokochaspis piochensis, Oryctocephalites rasettii.*

41215—At 33 m. *Amecephalus arrojosensis, Mexicella robusta* from 10 cm thick, bioclastic limestone.

41216—From 33.1–34 m. *Mexicella robusta, Kochina*? *walcotti* from shale interval.

Pan American Mine Section.—SW¼, NW¼, unsurveyed sec. 9, T1S, R66E 37°52′33″, 114°36′20″, Highland Peak 7.5′ quadrangle, Nevada (1969). The measured section covers 34 m exposed just to the west of Comet Road, 300 m south of Lyndon Gulch and 500 m north of the Pan American Mine.

41217—At 33 m. *Mexicella robusta, Kochina*? *walcotti* from shale.

PIOCHE HILLS

Mount Ely Section.—NW¼, NW¼, sec. 21, T1N, R67E 37°56′15″, 114°28′45″, Pioche 7.5′ quadrangle, Nevada (1969). The measured section covers 30 m on the northeast flank of Mount Ely along a mining road.

41218—At 30 m. *Kochina*? *walcotti* in shale interval.

Near Mount Ely Section.—SE¼, SW¼, SW¼, sec. 16, T1N, R67E 37°56′20″, 114°28′44″, Pioche 7.5′ quadrangle, Nevada (1969).

1399-CO.—Upper meter of the Combined Metals Member (see Palmer, 1958). *Eokochaspis metalaspis,* numerous silicified specimens.

CHIEF RANGE

Klondike Gap Section.—SE¼, SE¼, unsurveyed sec. 23, T2S, R66E 37°45′18″, 114°33′15″, Bennett Pass 7.5′ quadrangle, Nevada (1970). The measured section covers 34 m along an unnamed creek 1,200 m east of Klondike Gap.

41429—Basal 70 cm. *Eokochaspis nodosa,* numerous silicified specimens from silty ribbon limestone.

41430—From 0.7–2 m. *Eokochaspis piochensis.*

41431—At 33 m. *Amecephalus arrojosensis* from 20 cm thick, bioclastic limestone.

41432—From 33.2–34 m. *Mexicella robusta* from shale.

Antelope Canyon Section.—NW¼, NW¼, unsurveyed sec. 5, T4S, R67E 37°38′00″, 114°30′55″, Chief Mountain 7.5′ quadrangle, Nevada (1970). The measured section covers 17 m along the north side of Antelope Canyon.

41433—Basal 70 cm. *Eokochaspis nodosa,* numerous silicified specimens from a silty ribbon limestone.

41434—At 3.2 m. *Eokochaspis* cf. *piochensis* from a 70 cm thick, silty ribbon limestone.

41435—At 8.6 m. *Eokochaspis longspina, Mexicella antelopea* from 40 cm thick, silty ribbon limestone.

BURNT SPRINGS RANGE

Hidden Valley Section.—SE¼, SW¼, sec. 12, T4S, R64E 37°36′36″, 114°45′40″, Pahroc Spring SE 7.5′ quadrangle, Nevada (1970). The measured section covers 35 m in a small wash between hill 5690 and hill 5991 at an elevation of 1,667 m (5,500 ft).

41436—Basal 70 cm. *Eokochaspis nodosa,* numerous silicified specimens from a silty ribbon limestone.

41437—From 0.7–1 m. *Eokochaspis piochensis* from shale.

41438—At 3.7 m. *Eokochaspis delamarensis* from 80 cm thick, silty ribbon limestone.

41439—At 8.75 m. *Eokochaspis longspina, Mexicella antelopea, Amecephalus* sp. A from 25 cm thick, silty nodular limestone.

41440—At 31 m. *Amecephalus arrojosensis* from 25 cm thick, bioclastic limestone.

41441—At 33 m. *Amecephalus arrojosensis, Mexicella robusta, Kochina*? *walcotti* from 20 cm thick, bioclastic limestone.

Seven Oaks Spring Section.—NE¼, SE¼, sec. 13, T4S, R64E 37°35′50″, 114°45′08″, Pahroc Spring SE 7.5′ quadrangle, Nevada (1970). The measured section covers 35 m, 700 m northeast of Seven Oaks Spring.

41442—Basal 70 cm. *Eokochaspis nodosa,* numerous silicified specimens from a silty ribbon limestone.

DELAMAR MOUNTAINS

Oak Springs Section.—NE¼, NE¼, unsurveyed sec. 8, T4S, R65E 37°37′05″, 114°22′53″, Chokecherry Mountain 7.5′ quadrangle, Nevada (1970). This section covers 30 m.

41443—Basal 70 cm. *Eokochaspis nodosa,* numerous silicified specimens from a silty ribbon limestone.

41444—From 0.7–1 m. *Eokochaspis piochensis* from shale.

41445—At 3.7 m. *Eokochaspis delamarensis* from a 30 cm thick, silty ribbon limestone.

41446—At 8 m. *Eokochaspis longspina* from a 10 cm thick, silty nodular limestone.

Grassy Spring Section.—NW¼, NW¼, sec. 14, T5S, R64E 37°31′15″, 114°47′28″, Pahroc Spring SE 7.5′ quadrangle, Nevada (1970). The measured section covers 30 m, 2 km south of Grassy Spring.

41447—Basal 70 cm. *Eokochaspis nodosa,* numerous silicified specimens from a silty ribbon limestone.

41448—At 3.7 m. *Eokochaspis delamarensis* from a 70 cm thick, silty ribbon limestone. (= ICS 1047)

Big Lime Mountain Section.—SE¼, SW¼, sec. 23, T6S, R64E 37°24′20″, 114°47′15″, Delamar 7.5′ quadrangle, Nevada (1969). The measured section covers 32 m.

41449—Basal 70 cm. *Eokochaspis nodosa,* numerous silicified specimens from a silty ribbon limestone.

41450—At 1.8 m. *Eokochaspis delamarensis* from a 1 m thick, silty ribbon limestone.

41451—At 31 m. *Amecephalus arrojosensis, Mexicella robusta, Kochina*? *walcotti* from a 15 cm thick, bioclastic limestone.