# KOCHIELLA POULSEN, 1927, AND HADROCEPHALITES NEW GENUS (TRILOBITA: PTYCHOPARIIDA) FROM THE EARLY MIDDLE CAMBRIAN OF WESTERN NORTH AMERICA

# FREDERICK A. SUNDBERG AND LINDA B. MCCOLLUM

Las Animas High School, 300 Grove Avenue, Las Animas, CO 81054 <fred.sundberg@lasanimasK12.co.us>, and Department of Geology, Eastern Washington University, Cheney 99004-2499, <lmccollum@mail.ewu.edu>

ABSTRACT—Kochaspids are an informal group of ptychopariid trilobites that were both abundant and widespread in the early Middle Cambrian of North America. Based on the reassociation of pygidia and cranidia of some kochaspids, *Kochiella* Poulsen, 1927, is redefined and *Hadrocephalites* n. gen. is proposed. *Hadrocephalites* includes taxa previously assigned by Rasetti and Palmer to *Schistometopus* Resser, 1938a. *Schistometopus* is considered *nomen dubium*. Representatives of *Kochiella* and *Hadrocephalites* from the Pioche Shale and Carrara Formation of Nevada are described, including the new species *Kochiella rasettii*, *K. brevaspis*, *Hadrocephalites lyndonensis*, and *H. rhytidodes*. Other kochaspids previously assigned to *Kochaspis* Resser, 1935; *Eiffelaspis* Chang, 1963; *Schistometopus*; and *Kochiella* are discussed and some are reassigned. The type specimens of *Kochiella augusta* (Walcott, 1886); *K. crito* (Walcott, 1917b); *K. chares* (Walcott, 1917a); *K. mansfieldi* Resser, 1939; *K. arenosa* Resser, 1939; *Hadrocephalites carina* (Walcott, 1917b), and *H. cecinna* (Walcott, 1917b) are re-illustrated.

## INTRODUCTION

URING A study of trilobites from the Plagiura-Poliella Biozone of the Pioche Shale and Carrara Formation of southeastern Nevada, it became apparent that the cranidia and pygidia of some kochaspid trilobites have been incorrectly associated (e.g., Resser, 1935, 1938a, 1938b, 1939; Rasetti, 1951, 1957; Palmer and Halley, 1979). These incorrect associations probably resulted from the misassociation of the cranidium and spinose pygidium of Kochaspis liliana (Walcott, 1886, type species of Kochaspis Resser, 1935) and the placement of the spinose pygidium of Kochaspis augusta (Walcott, 1886) to the same genus. Walcott (1886, 1890, 1916) originally assigned these species to Crepicephalus Owen, 1852, and then Resser (1935) assigned them to Kochaspis. Walcott's and Resser's incorrect assignments probably resulted from several kochaspids occurring at the type locality (personal observation of type lot USNM locality 31a and nearby localities) and the lack of articulated material.

This paper proposes new pygidial associations for some kochaspids; differentiates the distinctive genera *Kochiella* Poulsen, 1927, and *Hadrocephalites* n. gen. based on these reassociations; and describes their representatives in the Pioche Shale and Carrara Formation of southeastern Nevada. *Hadrocephalites* includes species previously assigned to *Schistometopus* Resser, 1938a, by Rasetti (1951, 1957) and Palmer (*in Palmer and Halley*, 1979). *Schistometopus* is considered as *nomen dubium* because of the poor and partial preservation of its type species *S. typicalis* Resser, 1938a, as discussed under *Hadrocephalites*.

This study is part of a series of papers that includes the reanalysis of the kochaspids and the description of trilobites from the Lower–Middle Cambrian boundary interval of the southern Great Basin (Sundberg and McCollum, 1997, 2000; Eddy and McCollum, 1998). Kochaspids are an informal group of ptychopariid trilobites from the early Middle Cambrian of North America (Palmer and Halley, 1979, p. 99). These trilobites are characterized by granular ornamentation and similar cranidia, including a prominent tapered glabella with several pairs of moderately to strongly developed lateral glabellar furrows, in which the glabella tends to be slightly concave opposite of the second pair (S2) of lateral glabellar furrows. Genera were based primarily on pygidial characteristics.

Palmer (*in* Palmer and Halley, 1979) included *Caborcella* Lochman, 1948; *Kochaspis* Resser, 1935; *Kochiellina* Palmer (*in* Palmer and Halley, 1979); *Nyella* Palmer (*in* Palmer and Halley,

1979); and *Schistometopus*; and possibly *Kochiella* and *Kochina* Resser, 1935, within his concept of kochaspids. *Eokochaspis* Sundberg and McCollum, 2000, should also be included in the kochaspids. These trilobites are common in strata ranging from the *Eokochaspis nodosa* to *Albertella* biozones of western North America, including the Arrojos Formation of Mexico (Lochman, 1948); the Carrara Formation (Palmer and Halley, 1979), Pioche Shale (Walcott, 1886; Palmer *in* Merriam, 1964; Sundberg and McCollum, 1997, 2000; Eddy and McCollum, 1998; this report), Brigham Quartzite (Resser, 1939), and Langston Formation (Resser, 1939) of the United States; and the Mount Whyte Formation (Walcott, 1917b; Rasetti, 1951), 1957), Cathedral Formation (Walcott, 1917a; Rasetti, 1951), and an unnamed formation (Norford, 1968) of Canada.

#### STRATIGRAPHY

The kochaspid trilobites described in this report are from the lower Middle Cambrian portion of the Lower and Middle Cambrian Pioche Shale and Carrara Formation in southeastern Nevada. This study is confined to the mountain ranges near the type area of the Pioche Shale in eastern Lincoln County, Nevada, and to the Carrara Formation exposed in the northern Groom Range in the western part of Lincoln County (Fig. 1).

The Pioche Shale and Carrara Formation consist of a mixed siliciclastic and carbonate facies assemblage. The bases of both formations appear to be time-equivalent, i.e., *Arcuolenellus arcuatus* assemblage, upper *Olenellus* Biozone. The top of the Pioche Shale coincides with the top of the *Albertella* Biozone, whereas the upper Carrara Formation includes the lower portion of the overlying *Glossopleura* Biozone (Palmer and Halley, 1979; Eddy and McCollum, 1998). Both formations have been divided into a series of members (Fig. 2). Merriam (1964) proposed two formal and four informal members for the Pioche Shale, and subsequently Eddy and McCollum (1998) and Sundberg and McCollum (2000) have replaced the informal A- through D-shale members with formal member names. Palmer and Halley (1979) proposed nine formal members for the Carrara Formation.

The species of *Kochiella* and *Hadrocephalites* described in this report are from the *Plagiura-Poliella* Biozone portion of the Susan Duster Limestone and overlying Log Cabin members, Pioche Shale, and the middle portion of the Pyramid Shale Member, Carrara Formation. The Susan Duster Limestone Member is an approximately 6-m-thick package of deeping upward, bioclastic



FIGURE 1—Location of the stratigraphic sections and faunas of the Log Cabin and Susan Duster Limestone members, Pioche Shale in Lincoln County, Nevada. Sections: BC = Black Canyon; CM = Comet Mine; GR = Groom Range; GS = Grassy Spring and Grassy Springs Wash; KG = Klondike Gap; LCM = Log Cabin Mine; OS = Oak Springs; PAM = Pan American Mine and Lyndon Gulch; PC = Peaslee Canyon; PD = Pioche Divide; and PP = Old Pioche-Panaca Road and Highway 93 Roadcut sections 1 and 2.

limestone. The basal 75 cm consists of cross-bedded, shallow subtidal bioclastics dominated by trilobites of the *Amecephalus arrojosensis* Biozone (Sundberg and McCollum, 2000). *Poliella* Walcott, 1916, occurs just above and marks the base of the *Plagiura-Poliella* Biozone in the southern Great Basin. A slightly thinner, 4-m-thick limestone exists in the middle of the Pyramid Shale Member, and contains the same faunal succession (Sundberg and McCollum 1999, unpublished data). In the northern Groom Range, this limestone is overlain by a 21-m-thick black shale interval that contains a moderately diverse fauna, including articulated specimens of *Kochiella rasettii* n. sp.



FIGURE 2—Stratigraphic nomenclature of the Pioche Shale (from Sundberg and McCollum, 2000) and a portion of the Carrara Formation (from Palmer and Halley, 1979) showing lithologic and chronostratigraphic equivalency of the units.

## ABBREVIATIONS AND MEASUREMENTS

Specimens described here are deposited in the U.S. National Museum of Natural History (USNM), Smithsonian Institute, Washington D.C. Measurements used are illustrated in Figure 3. Terminology and abbreviations are derived from Shaw (1957), Whittington and Kelly (*in* Keasler, 1997), and Sundberg and McCollum (1997, 2000). Sagittal (sag.) and exsagittal (exsag.)



FIGURE 3—Measurements and lobe and furrow labels used in the trilobite descriptions.

measures are referred to as lengths and transverse (trans.) measures are referred to as widths. Measures are given as averages plus one standard deviation when five or more specimens were included. Ranges of percentages are given if two to four specimens were 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 USNM numbers and unfigured specimens are listed by the number of cranidia, librigenae, hypostomes, and pygidia inspected from each locality.

All photographed specimens were coated with colloidal graphite (except previous USNM type specimens) and ammonium chloride sublimate.

## CRANIDIAL AND PYGIDIAL ASSOCIATIONS

Because of their cranidial similarities, Palmer (*in* Palmer and Halley, 1979) emphasized that the kochaspid genera are recognized by their distinctive pygidia. However, most kochaspids have been recognized by disarticulated sclerites with only a few complete shields known. Compounded with the fact that several different kochaspids are commonly found in the same bed (e.g., Rasetti, 1951, 1957), it is difficult to determine which pygidia belong to which cranidia. As a result, generic identification of kochaspid cranidia based on Palmer's criteria is at best tenuous.

The association of cranidia and pygidia can be reliably achieved through two methods: 1) articulated specimens and 2) monotaxic assemblages with abundant specimens, at least relative to a specific group of trilobites (e.g., for Alokistocare subcoronatum [Hall and Whitfield, 1877]; see Sundberg, 1999). Articulated remains of kochaspids where the cranidium and pygidium are known exists for Nyella granosa (Resser, 1939), Eokochaspis piochensis (Palmer in Palmer and Halley, 1979; Sundberg and McCollum, 2000), E. metalaspis Sundberg and McCollum, 2000 (see Palmer, 1958); Kochina americana (Walcott, 1912b; illustrated by Rasetti, 1951), Kochina? walcotti Sundberg and Mc-Collum (2000), and Kochiella rasettii. Associations of cranidia and pygidia for other taxa through monotaxic assemblages that have abundant specimens include Eokochaspis nodosa Sundberg and McCollum, 2000; E. longspina Sundberg and McCollum, 2000; and E. delamarensis Sundberg and McCollum, 2000. Based on these species, some taxa that were previously assigned to Kochaspis, Kochiella, Schistometopus, and Eiffelaspis Chang, 1963, are either reassigned or are reinterpreted based on new combinations of cranidia and pygidia.

*Kochiella rasettii*, known from articulated specimens, possesses a cranidium that has a relatively broad preglabellar field, low relief glabella with deep lateral glabellar furrows, arcuate palpebral lobes, and a concave anterior border. The pygidium has anterolateral corners developed as broad-based, flat lobes at the posterior margin (Fig. 4.2). [Note that the term "anterolateral corner" is maintained despite its posterior position. This is due to its homologous position of the distal termination on the anteriormost pleural band and furrow close to the anterolateral corner in the non-spinose/lobe pygidia (Fig. 4.1).] This association demonstrates that the pygidium previously assigned to *Hadrocephalites convexus* (Rasetti, 1951; illustrated in Rasetti, 1957) is incorrect and should be reassigned to *Kochiella eiffelensis* (Rasetti, 1951). It also follows that *Kochaspis augusta*, which was previously known only by its pygidium, belongs in *Kochiella*.

The cranidium and pygidium of *Kochaspis liliana* need to be separated into two genera. *Kochaspis liliana* cranidia are common at the type and nearby localities. These cranidia are similar to those of *Nyella granosa* and some species of *Eokochaspis* with



FIGURE 4—Three types of kochaspid pygidia showing the homologous location of the "anterolateral corners" (arrows) based on the intersection of the anterior interpleural furrow and the pygidial border. *1, Eokochaspis delamarensis* Sundberg and McCollum, 2000, with the location of the anterior-lateral corner adjacent to about the mid-length of the axis. *2, Kochiella rasettii* n. sp. with the location of the corner posterior of the axis and developed as rounded lobes. *3, Hadrocephalites lyndonensis* n. gen. and sp. with the location of the corner posterior of the axis and developed as sharp, long spines.

their well defined preglabellar fields, slightly arcuate palpebral lobes, strong convexity, and well developed furrows. However, the pygidium of *K. liliana* is similar to those assigned here to *Hadrocephalites* (e.g., Fig. 4.3) and not to the small, transversely elongated, non-spinose, suboval pygidia with the anterolateral corners at the level of the axial midlength (Fig. 4.1) seen in both *N. granosa* and *Eokochaspis*. This suggests that the pygidium of *K. liliana* does not belong to the assigned cranidium. In addition, pygidia of *K. liliana* are very rare at the type and nearby localities. Rare cranidia assigned to *Hadrocephalites* are known from the same stratigraphic position from near the type locality. These rare cranidia and pygidia probably belong to the same species. Palmer (1954) referred to the types of *Kochaspis liliana* as cotypes; the cranidium (USNM 15428a) is here designated as the lectotype and the pygidium is removed from the species. The rare cranidia and the type pygidium (USNM 15428b) are assigned to *Hadrocephalites* sp. A.

# SYSTEMATIC PALEONTOLOGY Class TRILOBITA Walch, 1771 Order Ptychopariida Swinnerton, 1915 Suborder Ptychopariina Richter, 1933 Superfamily Ptychopariacea Matthew, 1887 Family Undetermined

The taxa described below are not assigned to a family pending a detailed phylogenetic analysis of the kochaspid trilobites.

## Genus KOCHIELLA Poulsen, 1927

Kochiella POULSEN, 1927, p. 259; RESSER, 1935, p. 38–39; RASETTI, 1951, p. 227–228; RASETTI, 1955, p. 5; HOWELL *in* MOORE 1959, p. O240; POULSEN, 1964, p. 19–21.

Eiffelaspis CHANG, 1963, p. 479.

*Type species.—Kochiella tuberculata* Poulsen, 1927, by original designation.

*Emended diagnosis.*—Cranidium with low relief glabella and frontal area, rounded frontal lobe, occipital ring short, anterior border furrow boss absent, fixigena flat, commonly coarse granules, and palpebral lobes long, wide, and strongly curved. Pygidium with broad-based, flat lobes.

Discussion.—This group is relatively easy to recognize from the lower Middle Cambrian of North America. The coarse granular ornamentation, relatively flat relief, concave to slightly convex anterior border, and strongly curved palpebral lobes of the cranidia are distinctive. Eiffelaspis is here synonymized with Kochiella. Chang (1963) only provided a description of the genus, but never compared it to Kochiella even though the type species is Kochiella? maxeyi Rasetti, 1951. However, V. Poulsen (1964) distinguished Kochiella from Kochiella? maxeyi by its broad posterior flexure of the anterior border furrow toward the frontal lobe, less convex preglabellar field, unequal preglabellar field and anterior border, inflation and tilt of the anterior border, and wider cranidia. The flexure of the anterior border is well developed in K. tuberculata and less so in K. gracilis Poulsen, 1927; K. mackenziensis Norford, 1968; and Kochina americana. Given the overall similarities between Kochiella and the other taxa previously assigned to this genus or Eiffelaspis, this flexure, wider cranidia, character of the preglabellar area, anterior border inflation and tilt seem insignificant to define a genus.

The pygidium of *Kochiella* is also distinctive based on the short axis, broad-based lobes, and the low relief of the pleural regions. Pygidial characteristics are variable in this group. Pygidial lobes are either broadly rounded (e.g., *K. maxeyi* and *K. arenosa* Resser, 1939), sharply rounded (e.g., *K. rasettii*), or sharply pointed [e.g., *K. augusta*, *K. chares* (Walcott, 1917a), and *K. eiffelensis*]. The flat pleural fields of the pygidia of *K. maxeyi*, *K. chares*, and *K. arenosa* are uniformly downsloping instead being nearly level pleural fields seen in other *Kochiella* species. However, a preliminary phylogenetic analysis suggests that these differences as well as the cranidial differences discussed above do not define distinct clades (unpublished data).

As discussed by Rasetti (1951), a pygidium cannot be assigned to either the type species *Kochiella tuberculata*, nor to *K. gracilis*. C. Poulsen (1927) reported *Crepicephalus* cf. *cecinna* Walcott, 1917b, from the same horizon, which Resser (1935) and V. Poulsen (1964) assigned to *K. tuberculata*. This pygidium probably belongs in *Hadrocephalites*, but no cranidia similar to *Hadrocephalites* were illustrated by Poulsen (1927). It is possible that the pygidium belongs to either Kochiella or Inglefieldia Poulsen, 1927.

The pygidia of *Kochiella eiffelensis* and *Hadrocephalites convexus* illustrated by Rasetti (1951, pl. 14, figs. 9, 10; 1957, pl. 121, figs. 15–17) are here reassigned. Both species co-occur and the *Kochiella*-like pygidia that Rasetti assigned to *H. convexus* in 1957 probably belongs to *K. eiffelensis*. The *Hadrocephalites*-like pygidia that Rasetti (1951) assigned to *K. eiffelensis* probably belong to *H. convexus* (see further discussion under *Hadrocephalites*).

*Kochiella crito* (Walcott, 1917b; Fig. 5.8–5.10) was possibly correctly assigned by Resser (1935). It appears to be non-granulose, but it is preserved in a fine-grained sandstone, which may obscure this character. The pygidium of this species is unknown. The types of *Kochiella fitchi* (Walcott, 1887) are too small to determine their taxonomic affinity. *Kochiella fitchi* reported by Lochman (1956) and *Kochiella? pennsylvanica* Resser, 1938b, are too poorly preserved to determine if they are correctly assigned to *Kochiella*.

Rasetti (1951) agreed with the association of the cranidia and pygidia of *Kochiella mansfieldi* Resser, 1939 (Fig. 5.1–5.4). Whereas the cranidia belong to the genus, the pygidia do not. The pygidia have strong, thin anterior pleural bands and low relief or flat posterior bands and thin spines formed from the extension of the anteriormost pleural band. *Kochaspis maladensis* Resser, 1939, which is known only from pygidia, has nearly identical characteristics. These pygidia probably belong to a corynexochid, either *Albertella* Walcott, 1908b, or *Stephenaspis* Rasetti, 1951. The cranidia and pygidia of *Kochiella arenosa* (Fig. 5.5–5.7) and *K. chares* (Fig. 6), however, do belong together, based on their similarity to *K. rasettii*. Walcott (1917b) designated only syntypes for *Kochiella chares*. The pygidium USNM 63747 is here designated as the lectotype, and specimens USNM 63744–63746 and 509777–509779 are paralectotypes.

Neither *Kochiella? devlicis* Rasetti, 1963, nor *K.? tumida* Rasetti, 1963, belong in *Kochiella*. Both species have laterally directed ocular ridges, a wide frontal area, a low curvature of palpebral lobes, a strong boss in preglabellar field, a short posterior area of the fixigena, and a non-offset position of the anterior and posterior branch of the facial suture. These two taxa need to be reassigned to another genus.

*Kochiella* is similar to *Kochiellina* but differs in lacking a medial swelling in the anterior border region and the pygidia having pygidial lobes and a subrectangular shape. *Kochiella gibbosa* Rasetti, 1957, may belong to *Kochiellina* based on its strong medial swelling and its similarity to *Kochiella janglensis* Palmer (*in* Palmer and Halley, 1979). However, the pygidium of *Kochiella gibbosa* is unknown, preventing confirmation of its taxonomic placement.

The age of *Kochiella* in Greenland is equivocal. C. Poulsen (1927) reported that the type species from the Cape Kent Limestone occurred with olenellids, and assigned the fauna to the Lower Cambrian. He reaffirmed this assignment to Rasetti (1951, p. 85), which was subsequently accepted by V. Poulsen (1964). However, Troelsen (1950) stated that nearly all of the fossils from the 10- to 20-m thick Cape Kent Limestone were obtained from talus slopes and expressed the possibility that more than one faunal zone may be present. The only other age constraints for this formation is the underlying Wulff River Formation, which contains olenellid trilobites (C. Poulsen, 1958), and overlying the Cape Wood Formation, which contains trilobites of the *Glossopleura* Biozone (C. Poulsen, 1927; V. Poulsen, 1964).

In western North America, *Kochiella* is restricted to the early Middle Cambrian. *Kochiella* occurs in the *Plagiura-Kochaspis* 



FIGURE 5—1–4, Type specimens of *Kochiella mansfieldi* Resser, 1939, from the Langston Formation; 1, holotype cranidium (USNM 98557A), ×2.5; 2, 3, paratype pygidia (USNM 98557B, 98557D) that are probably the corynexochid *Albertella* or *Stephenaspis*, ×3.0; 4, fragmentary paratype librigena (USNM 509783) that is correctly assigned to *Kochiella*, ×2.5. 5–7, Type specimens of *Kochiella arenosa* Resser, 1939, from the Langston Formation; all specimens are preserved in medium-grained sandstones; 5, latex cast of the holotype partial cranidium (USNM 98556A), ×2.5; 6, paratype librigena (USNM 98556C), ×2.5; 7, poorly preserved paratype pygidium (USNM 98556D), ×2.5. 8–10, Type specimens of *Kochiella crito* (Walcott, 1917b) from the Mount Whyte Formation, Alberta; all specimens preserved in fine-grained sandstone; 8, small, incomplete paratype cranidium (USNM 64373), ×3.0; 9, large, incomplete holotype cranidium (USNM 64371) with most of the anterior border missing, ×2.2; 10, latex cast of large, paratype librigena (USNM 64372), ×2.9.

Biozone in the Mt. Whyte Formation, southern Canadian Rocky Mountains (Walcott, 1917b; Rasetti, 1951, 1957); the *Plagiura-Poliella* Biozone in an unnamed formation in the Mackenzie district of northwest Canada (Norford, 1968), Pioche Shale in Nevada (Sundberg and McCollum, 1997; this paper), and Carrara Formation in Nevada and California (Sundberg and McCollum, 1997); and the *Albertella* Biozone in the Brigham Quartzite and Langston Formation in southern Idaho (Resser, 1939). Assigned species.—Taxa belonging to Kochiella include: K. arenosa; K. augusta; K. brevaspis n. sp.; K. chares; K. eiffelensis; K. gracilis; K. mackenziensis; K. macrops (Rasetti, 1951); K. mansfieldi; K. maxeyi; K. rasettii; and K. tuberculata. Based on plaster casts of the type specimens of C. Poulsen (1927) at USNM, Kochiella tuberculata includes K. propinqua (also see V. Poulsen, 1964) and K. arcana; K. gracilis is distinct based on its absence of coarse granules and upsloping fixigena.



FIGURE 6—1–5, Type specimens of *Kochiella chares* (Walcott, 1917a) from the Cathedral Formation, Alberta; *1*, exfoliated, partial, paralectotype cranidium (USNM 63744), ×7.0; *2*, exfoliated, partial, paralectotype cranidium (USNM 509777), ×6.75; *3*, testate paralectotype librigena (USNM 63745), ×7.0; *4*, testate, partial, paralectotype pygidium (USNM 63746), ×7.5; *5*, testate lectotype pygidium (USNM 63747), ×7.5.

# KOCHIELLA AUGUSTA (Walcott, 1886) Figure 7.1–7.9

- Crepicephalus augusta WALCOTT [part], 1886, p. 208–209, fig. 28, fig. 2a; WALCOTT, 1890, p. 653, pl. 96, fig. 9a; WALCOTT, 1916, p. 204, pl. 29, fig. 6a; SHIMER AND SHROCK, 1944, p. 611, pl. 257, fig. 16.
- *Kochaspis augusta* (Walcott), RESSER, 1935, p. 37; PALMER, 1954, p. 80, p. 17, fig. 6; PALMER *in* PALMER AND HALLEY, 1979, p. 105–106, pl. 8, figs. 15, 16.

*Emended diagnosis.*—Cranidia with moderately short glabella (66  $\pm$  2 percent cranidial length), moderately deep lateral glabellar furrows, moderately posteriorly directed ocular ridges, anterior border furrow evenly curved, concave to flat anterior border, frontal area long (34  $\pm$  2 percent cranidial length) and moderately wide (approximately 60 percent cranidial width), and moderate size granules. Pygidium subrectangular; relatively wide; nearly straight sides; nearly level pleural field; scattered granules; sharp, moderately long lobes (147  $\pm$  19 percent axial length); and 2 to 3 axial rings.

*Emended description.*—Cranidium moderate size, length 8.7  $\pm$  0.4 mm (n = 6); subtrapezoidal, length 50 to 55 percent width; low convexity (sag. and trans.); anterior margin moderately and evenly curved, width (J<sub>1</sub>) approximately 60 percent cranidial width (J<sub>2</sub>); posterior margin, excluding occipital ring, straight to distally directed slightly posterolateral. Anterior branches of facial sutures bowed outwards, slightly divergent to interborder furrow and then moderately convergent to anterior margin; posterior branch strongly divergent to posterior border furrow then nearly posteriorly directed. Glabella moderately elongated, strongly tapered, width at anterior end 73  $\pm$  4 percent glabellar width (K<sub>2</sub>); low convexity (sag. and trans.); frontal lobe bluntly rounded; length 66  $\pm$  2 percent cranidial length; width approximately 30

percent cranidial width. Axial furrow shallow, shallower posteriorly, slightly concave in outline and convergent from SO to S2 then nearly straight and parallel; preglabellar furrow moderately shallow, shallower medially, narrow, slightly curved. Lateral glabellar furrows moderately deep, S1 bifurcated directed posteriorly, S2 directed slightly posteriorly, S3 directed slightly anteriorly, may be isolated from axial furrow, S4 faint or absent, directed anteriorly. Occipital ring slightly elevated above glabella, slightly convex, length  $21 \pm 2$  percent glabellar length; occipital node present; posterior margin slightly convex to straight. SO straight and moderately deep, shallower medially. Frontal area length  $34 \pm 2$  percent cranidial length, subequally divided. Preglabellar field slightly convex, moderately downsloping, length 47  $\pm$  5 percent frontal area length. Anterior border flat to concave, level to upsloping, slightly tapering laterally, margin evenly curved, length  $18 \pm 2$  percent cranidial length. Anterior border furrow evenly curved, narrow, shallower than axial furrows; shallow interborder furrow. Fixigena flat to slightly concave, slightly upsloping, anterior area downsloping, width 49  $\pm$  9 percent glabellar width (K<sub>2</sub>). Palpebral lobes upturned, crescent shaped, moderate to wide and long, width 30 to 45 percent lobe length, length  $40 \pm 4$  percent glabellar length; anterior margin located about opposite of S2 or L2, 27  $\pm$  5 percent glabellar length behind anterior glabellar margin; palpebral furrow shallow. Ocular ridge strong, straight, directed moderately posterolaterally from glabella at 65 to 70 degrees to axis. Posterior area of fixigena strap-like, downsloping, sharply terminated; length 20 to 30 percent glabellar length; width 100 to 105 percent glabella length. Posterior border moderately convex, moderately expanding and flattening distally; border furrow moderately deep, shallowing distally, straight, not expanding.



FIGURE 7—1–9, Kochiella augusta (Walcott, 1886) from the Log Cabin Member, Pioche Shale, Nevada, all specimens are from USNM locality 41765 and ×5.0 except where noted; 1–3, mostly exfoliated, partial cranidium (USNM 509463); 4, mostly exfoliated, partial cranidium (USNM 509462); 5, librigena (USNM 509467) illustrating the v-shaped doublure; 6, holotype pygidium (USNM 15430) from USNM locality 31a, ×5.0; 7, testate librigena (USNM 509466); 8, testate, nearly complete pygidium (USNM 509465); 9, testate pygidium (USNM 509464). 10, Kochiella maxeyi Rasetti, 1951, partially exfoliated pygidium (USNM 509469) from USNM locality 41765, ×9.25.

Librigena moderate size, length 7.8 to 8.3 mm (n = 3); moderately wide, width approximately 50 percent length without spine; lateral margin slightly curved. Genal field moderately convex, width 40 to 60 percent librigenal width. Border slightly concave, uniform width; width 30 to 50 percent librigenal width; lateral border furrow shallow; posterior border furrow short, shallow; interborder furrow shallow in lateral border and projects to near tip of genal spine. Genal spine broad-based, short, 40 to 45 percent librigenal length. Doublure wide, has v-shaped ridge that extends to near the end of librigenal spine and that closely coincides with the interborder furrow on the dorsal surface.

Rostral plate, hypostome, and thorax unknown.

Pygidium moderate size, length  $1.5 \pm 0.2 \text{ mm}$  (n = 8); subrectangular, length  $55 \pm 3$  percent width; slightly convex (sag. and trans.); anterior margin next to axis projects laterally, distal portion strongly curved posterolaterally, anterolateral corners developed into two posteriorly directed, broad based, distally pointed, flat lobes posterior of axis, lobe length  $147 \pm 19$  percent pygidial length. Axis moderately tapered, width at midlength 76  $\pm 8$  percent anterior width, anterior width  $36 \pm 4$  percent pygidial width; length  $62 \pm 12$  percent pygidial length, no postaxial ridge; 2 to 3 axial rings, strongly convex; terminal axial piece small size, posteriorly rounded; axial furrow shallow, deeper anteriorly; axial ring furrows moderately shallow, shallower laterally. Pleural



FIGURE 8—1–9, Kochiella brevaspis n. sp. from the Susan Duster and Log Cabin members, Pioche Shale, Nevada; all paratypes unless otherwise mentioned; 1–3, testate holotype cranidium (USNM 509453) from USNM locality 41742, ×7.25; 4, partial, testate cranidium (USNM 509457) from USNM locality 41767, ×7.25; 5, large, partial, testate cranidium (USNM 509498) from USNM locality 41764; ×5.0; 6, partial, testate cranidium (USNM 509460) with a narrower and longer frontal area, from USNM locality 41738, ×7.25; 7, testate librigena (USNM 509452) from USNM locality 41757, ×7.5; 8, testate librigena (USNM 509459) from USNM locality 41767, ×6.75; 9, partial cranidium (USNM 509451) from USNM locality 41757, ×7.25.

regions well defined, exsagittally elongate; low convexity, level; 3 anterior pleural furrows moderately wide and shallow, extending to near posterior margin, curved strongly posterolaterally; interpleural furrows not visible; first anterior pleural band moderately well developed, others weakly convex, posterior pleural bands weakly developed. Border poorly developed. Doublure widest at anterolateral corners, thinning towards axis.

Moderate size granules scattered on the cranidium, librigena, and posterior pleural bands of pygidium. Genal caeca on the preglabellar field and genal area of the librigena.

*Type.*—Holotype, nearly complete pygidium USNM 15430 from USNM locality 31a.

*Other material examined.*—USNM 509462–509467 and two cranidia, pygidium, and librigena from USNM locality 41765; two cranidia, two librigenae, and five pygidia from USNM locality 41132.

*Occurrence.—Plagiura-Poliella* Biozone, Log Cabin Member, Pioche Shale, eastern Nevada. USNM localities 31a, 41132, 41735, 41741, 41744, 41749, 41753, 41754, 41759, 41760, 41765, 41771, 41779, 41780, and 41782.

*Discussion.*—As recognized by previous authors (Resser, 1935; Palmer, 1954; Palmer *in* Palmer and Halley, 1979), the cranidium

and pygidium illustrated by Walcott (1886) do not belong to the same genus. Cranidia similar to *K. rasettii* co-occur with typical *K. augusta* pygidia and are here assigned to *K. augusta*. This type of cranidium is also present in the type and topotype material, but they were apparently not recognized by Walcott, Resser, or Palmer.

Kochiella augusta differs from K. rasettii in its sharply pointed and slightly longer pygidial lobes. The cranidia are similar to the cranidia of K. maxeyi, but differ in having shallower lateral glabellar furrows, more posteriorly directed eye ridges, flat to concave anterior border, and smaller granules. Samples from USNM locality 41753 show variation in density of coarse granules.

*Kochiella augusta* differs from *K. chares* (Fig. 6) in its more posteriorly directed ocular ridges and its relatively wider pygidium with straighter sides, less downsloping pleural fields, and 2 to 3 axial rings.

# KOCHIELLA BREVASPIS new species Figure 8.1–8.11

*Diagnosis.*—Cranidia with elongated glabella ( $73 \pm 2$  percent cranidial length), moderately deep lateral glabellar furrows, strongly to moderately posteriorly directed ocular ridges, anterior











border furrow evenly curved, slightly convex anterior border, frontal area short ( $27 \pm 2$  percent cranidial length) and moderately wide (60 to 65 percent cranidial width), and coarse granules.

Description.—Cranidium moderate size, length  $5.3 \pm 0.7$  mm (n = 8); subtrapezoidal, length 55 to 60 percent width; moderately convexity (sag. and trans.), anterior margin moderately and unevenly curved, straighter laterally, width  $(J_1)$  60 to 65 percent cranidial width (J<sub>2</sub>); posterior margin, excluding occipital ring, straight to distally slightly posterolaterally directed. Anterior branches of facial sutures bowed outwards, slightly divergent to anterior border, moderately convergent to anterior margin; posterior branches strongly divergent to posterior border furrow then directed posterolaterally. Glabella moderately elongated, strongly tapered, width at anterior end 68  $\pm$  4 percent glabellar width (K<sub>2</sub>); moderate convexity (sag. and trans.); frontal lobe rounded; length  $73 \pm 2$  percent cranidial length; width approximately 35 percent cranidial width. Axial furrow moderately deep, shallower anteriorly, slightly concave in outline and convergent from SO to S2 then nearly straight and parallel; preglabellar furrow shallow, uniform depth, narrow, moderately curved. Lateral glabellar furrows moderately deep, S1 bifurcated directed posteriorly, S2 directed slightly posteriorly, S3 directed laterally to slightly anteriorly, S4 shallow or absent. Occipital ring not elevated above glabella, slightly convex, length  $21 \pm 1$  percent glabellar length; moderate occipital node; posterior margin moderately convex. SO straight and moderately shallow, shallower medially. Frontal area subequally divided; length 27  $\pm$  2 percent cranidial length. Preglabellar field slightly convex, slightly downsloping, length 42  $\pm$  4 percent frontal area length. Anterior border slightly convex, level, slightly tapering laterally, margin straighter laterally, length 16  $\pm$ 1 percent cranidial length. Anterior border furrow evenly curved, narrow, shallow, much shallower than axial furrows; interborder furrow not visible. Fixigena slightly convex, upsloping, anterior area moderately downsloping, width 54  $\pm$  15 percent glabellar width (K<sub>2</sub>). Palpebral lobes crescent shaped, upturned, narrow to moderately wide and long, width  $31 \pm 5$  percent lobe length, length 47  $\pm$  2 percent glabellar length; anterior margin located about opposite of S2 or L2, 29  $\pm$  4 percent glabellar length behind anterior glabellar margin; palpebral furrow shallow. Ocular ridge moderately strong, straight, directed strongly to moderately posterolaterally from glabella at 60 to 75 degrees to axis. Posterior area of fixigena strap-like, downsloping, sharply terminated; length 19  $\pm$  3 percent glabellar length; width 65 to 80 percent glabella length. Posterior border moderately convex, expanding and flattening distally; border furrow moderately deep, shallowing laterally, straight, not expanding.

Librigena moderate size, length 5.1 to 6.3 mm (n = 2); moderately wide, width approximately 50 percent length without spine; lateral margin slightly curved; height approximately 55 percent width. Genal field slightly convex, width 40 to 45 percent librigenal width. Border flat with raised rim, uniform width, width 25 to 35 percent librigenal width; lateral border furrow shallow; posterior border furrow short, shallow; interborder furrow visible on genal spine only. Genal spine broad-based, short, 30 to 35 percent librigenal length; pointed in smaller specimens, blunted in larger specimens.

Rostral plate, hypostome, thorax, and pygidium unknown.

Coarse granules scattered primarily on frontal area and anterior

border of cranidium and the librigena. Smaller granules on cranidium and librigena.

Etymology.—Greek, brevaspis = short, for the short frontal area.

*Types.*—Holotype, nearly complete cranidium USNM 509453 from USNM locality 41742; paratypes USNM 509450–509452 from USNM locality 41757; USNM 509454–509456 from USNM locality 41742, USNM 509457, 509459 from USNM locality 41767; 509460 from USNM locality 41738; and USNM 509498 from USNM locality 41764.

*Occurrence.—Plagiura-Poliella* Biozone, Susan Duster Limestone and Log Cabin members, Pioche Shale, eastern Nevada. USNM localities 41738, 41739, 41742, 41752, 41756, 41757, 41764, 41767, 41774, and 41792.

*Discussion.*—Most of the complete cranidia are smaller specimens, which have a more developed anterior border furrow. Fragments of larger specimens with convex anterior borders are also present in the same deposits as the smaller specimens. USNM locality 41767 has a single specimen (Fig. 8.6) with a longer frontal area, straighter and longer anterior branch of the facial suture, and more fully posteriorly directed ocular ridge. Given the limited number of specimens and the relatively minor differences, this specimen is included in *K. brevaspis*. Another cranidium from USNM locality 41792 has no coarse granules, but it otherwise resembles this species.

The cranidium of this species differs from that of other species of *Kochiella* in its convex anterior border, narrower frontal area and/or coarser granules.

## KOCHIELLA MAXEYI Rasetti, 1951 Figure 7.10

Kochiella? maxeyi Rasetti, 1951, p. 228, pl. 13, figs. 5–8; Rasetti, 1957, p. 961, pl. 120, figs. 1–3; Chang, 1963, p. 479; Poulsen, 1964, p. 20–21.

*Material examined.*—USNM 509469 and a pygidium from USNM locality 41765.

*Occurrence.—Plagiura-Poliella* Biozone, Log Cabin Member, Pioche Shale, eastern Nevada. USNM locality 41765. Mt. Whyte Formation, British Columbia, Canada (Rasetti, 1951, 1957).

*Discussion.*—Two pygidia from the Pioche Shale are similar to those illustrated by Rasetti (1957), but differ in having slightly smaller granules on the axis and posterior pleural bands. No cranidia of this species have been recognized in the collections.

#### KOCHIELLA RASETTII new species Figure 9.1–9.6

*Diagnosis.*—Cranidia with moderately short glabella ( $64 \pm 2$  percent cranidial length), shallow to moderately deep lateral glabellar furrows, moderately posteriorly directed ocular ridges, anterior border furrow evenly curved, concave anterior border, frontal area long ( $36 \pm 1$  percent cranidial length) and moderately wide ( $64 \pm 2$  percent cranidial width), and moderate size granules. Pygidium subrectangular; relatively wide; nearly straight sides; nearly level pleural field; scattered granules; rounded, short lobes ( $141 \pm 23$  percent axial length); and 2 to 3 axial rings.

Description.—Cranidium moderate size, length  $8.1 \pm 2.2$  mm

 $\leftarrow$ 

FIGURE 9—1–5, Kochiella rasettii n. sp., all specimens are from the Pyramid Shale Member, Carrara Formation and are paratypes unless otherwise mentioned; *1*, nearly complete, partially testate shield (USNM 509431) showing the impression of the hypostoma, from USNM locality 41793, ×4.9; *2*, *3*, nearly complete, partially testate shield (USNM 509435) from USNM locality 41793, ×3.9 and ×9.0; *4*, latex cast of nearly complete, holotype shield (USNM 509430) from USNM locality 41793, ×4.9; *5*, exfoliated cranidium (USNM 509442) from USNM locality 41797, ×4.5.

(n = 13); subtrapezoidal, length 57  $\pm$  3 percent width; moderately low convexity? (sag. and trans.), anterior margin moderately and evenly curved, width  $(J_1)$  64  $\pm$  2 percent cranidial width  $(J_2)$ ; posterior margin, excluding occipital ring, straight to distally slightly posterolaterally directed. Anterior branches of facial sutures bowed outwards, slightly divergent to anterior border, moderately convergent to anterior margin; posterior branches strongly divergent to posterior border furrow then nearly posteriorly directed. Glabella moderately elongated, strongly tapered, width at anterior end 69  $\pm$  4 percent glabellar width (K<sub>2</sub>); low convexity (sag. and trans.); frontal lobe bluntly rounded; length  $64 \pm 2$ percent cranidial length; width  $28 \pm 2$  percent cranidial width. Axial furrow moderately deep, shallower posteriorly, slightly concave in outline and convergent from SO to S2 then nearly straight and parallel; preglabellar furrow moderately shallow, uniform depth, narrow, slightly curved. Lateral glabellar furrows moderately deep to shallow, S1 bifurcated directed posteriorly, S2 directed slightly posteriorly, S3 directed laterally to slightly anteriorly, S4 shallow or absent. Occipital ring not elevated above glabella, slightly convex, length  $19 \pm 4$  percent glabellar length; moderate occipital node; posterior margin slightly convex. SO straight and moderately shallow, shallower medially. Frontal area equally divided; length  $36 \pm 1$  percent cranidial length. Preglabellar field slightly convex, slightly downsloping?, length 51  $\pm$ 2 percent frontal area length. Anterior border slightly concave, slightly upsloping?, slightly tapering laterally, margin evenly curved, length  $18 \pm 1$  percent cranidial length. Anterior border furrow evenly curved, narrow, shallow, much shallower than axial furrows; shallow interborder furrow. Fixigena slightly convex, upsloping?, anterior area slightly downsloping?, width 72  $\pm$  8 percent glabellar width (K<sub>2</sub>). Palpebral lobes crescent shaped, upturned, narrow and long, width  $23 \pm 7$  percent lobe length, length  $48 \pm 7$  percent glabellar length; anterior margin located about opposite of S2 or L3, 28  $\pm$  3 percent glabellar length behind anterior glabellar margin; palpebral furrow shallow. Ocular ridge strong, straight, directed moderately posterolaterally from glabella at 65 to 75 degrees to axis. Posterior area of fixigena strap-like, downsloping?, sharply terminated; length  $22 \pm 3$  percent glabellar length; width 98  $\pm$  8 percent glabella length. Posterior border moderately convex, expanding and flattening distally; border furrow moderately deep, shallowing laterally, straight, not expanding.

Librigena moderate size, length 5.7 to 8.4 mm (n = 4); moderately wide, width 35 to 55 percent length without spine; lateral margin slightly curved. Genal field slightly convex, width 45 to 70 percent librigenal width. Border flat, uniform width, width 20 to 35 percent librigenal width; lateral border furrow shallow; posterior border furrow short, shallow; interborder furrow not preserved. Genal spine broad-based, short, 40 to 50 percent librigenal length. Doublure has v-shaped ridge near posterior margin that extends to nearly the end of the librigenal spine.

Hypostome incompletely preserved, small; suboval, moderate convexity (sag. and trans.); anterior margin moderately curved; lateral margins smooth, slightly convergent; posterior margin strongly curved. Middle body moderately convex (sag. and trans.); suboval; macula not evident; anterior and posterior lobes not evident. Anterior border not present. Lateral borders moderately defined, convex, narrow; border furrows shallow. Posterior wings and border not preserved.

Rostral plate poorly preserved, continuation of v-shaped ridge from ventral surface of librigena.

Fourteen to 15 thoracic segments, moderately decreasing in width posteriorly. Axial furrows well defined, moderately deep, slightly shallower next to posterior pleural band. Thoracic pleura projecting laterally to weakly developed fulcrum and then posterolaterally to distal end, width approximately 200 percent of axial width; anterior and posterior pleural bands uniform length, distal end forming sightly posterolaterally directed, sharp, flat spines; posterior pleural band equal length to anterior pleural band; pleural furrow deep, moderately long, shorter distally, extending into pleural spines. Articulating surface poorly defined on anterior margin abaxial of fulcrum; no fulcral sockets or processes apparent.

Pygidium moderate size, length  $1.4 \pm 0.2$  mm (n = 8); subsquare to subrectangular, length 42  $\pm$  3 percent width; slightly convexity (sag. and trans.); anterior margin next to axis projects laterally, distal part strongly curved posterolaterally, anterolateral corners developed into two posteriorly directed, broad-based, distally rounded, flat lobes, lobe length  $141 \pm 24$  percent pygidial length. Axis moderately tapered, width at midlength  $80 \pm 5$  percent anterior width, anterior width  $26 \pm 3$  percent pygidial width; length 71  $\pm$  9 percent pygidial length, no postaxial ridge; 2 to 3 axial rings, strongly convex; terminal axial piece moderate size, posteriorly rounded; axial furrow shallow, uniform depth; axial ring furrows shallow, deeper medially. Pleural regions well defined, exsagittally elongate; slightly convex, flat?; 3 anterior pleural furrows moderately wide and deep, extending to near posterior margin, curved strongly posterolaterally; interpleural furrows not visible; first anterior pleural band moderately well developed, others weakly convex, posterior pleural bands moderately developed. Border poorly developed. Doublure widest at anterolateral corners, thinning towards axis, posterior margin nearly at posterior end of axis.

Moderate size granules scattered on the cranidium, librigena, posterior pleural bands of the thorax and pygidium, and posterior margin of the axial rings.

Etymology.---Named in honor of F. Rasetti.

*Types.*—Holotype, nearly complete shield USNM 509430 from USNM locality 41793; paratypes USNM 509431–509436 from USNM locality 41793; USNM 509437–509439 from USNM locality 41794; USNM 509440 from USNM locality 41795; USNM 509441 from USNM locality 41796; USNM 509442 from USNM locality 41797; USNM 509443–509448 from USNM locality 41083.

*Occurrence.—Plagiura-Poliella* Biozone, upper Pyramid Shale Member, Carrara Formation, eastern Nevada. USNM localities 41083, 41793–41799.

Discussion.—Compaction of the specimens in shale has accentuated the depth of the glabellar and axial furrows and decreased the slopes of the fixigena and frontal area. *Kochiella rasettii* differs from *K. augusta* in its rounded, shorter pygidial spines. *Kochiella rasettii* differs from *K. maxeyi* in having shallower lateral glabellar furrows, smaller granules, and a more transversely elongated pygidium. *Kochiella rasettii* differs from *K. chares* in its more posteriorly directed ocular ridges and its relatively wider pygidium with straighter sides, less downsloping pleural fields, rounded pleural lobes, and 3 axial rings.

# HADROCEPHALITES new genus

Type species.—Hadrocephalites lyndonensis new species.

*Diagnosis.*—Cranidium with glabella elongated, strongly convex, and deep axial furrows; preglabellar field short or absent; and anterior border straight or slightly curved. Pygidium transversely elongate, subrectangular, posterior border nearly straight, wide; long, relatively narrow-based pygidial spines; wide posterior border; strong pleural bands, postaxial notch absent.

*Etymology.*—Greek, *hadro* = strong, *cephalites* = head, for the prominent furrows and anterior border of the cranidium.

*Discussion.*—This genus is distinct from other trilobites in the *Plagiura-Poliella* Biozone because of its elongated and strongly convex glabella, deep furrows, coarse granules on most species,



FIGURE 10—1–4, Hadrocephalites cecinna (Walcott, 1917b) from the Mount Whyte Formation, Alberta; 1, testate, small holotype cranidium (USNM 64365), ×6.7; 2, fragmentary, larger, mostly exfoliated, hypotype cranidium (USNM 509780), ×3.3; 3, partially exfoliated, fragmentary, hypotype librigena (USNM 509781), ×3.0; 4, testate, nearly complete, paratype pygidium (USNM 64366), ×6.6. 5, Holotype of Hadrocephalites carina (Walcott, 1917), partial, mostly testate, cranidium (USNM 64400) from the Mount Whyte Formation, Alberta, ×3.0.

and convex and nearly straight anterior border, and the pygidium's thin, long pygidial spines that are narrow-based (Fig. 4.3).

Rasetti (1951, 1957) and Palmer and Halley (1979) assigned species to *Schistometopus* that are within the concept of *Hadrocephalites* and are here reassigned. The type species of *Schistometopus*, *S. typicalis*, is known from a single cranidium that is crushed in shale and incomplete. The only diagnostic characters the type species has are the straight anterior border with a central raised area and a tapered glabella. These characters alone are insufficient to characterize *Schistometopus*; thus, the genus is considered *nomen dubium* and the term is restricted to the type specimen of the type species.

*Hadrocephalites cecinna* (Walcott, 1917b) is based on a small cranidium and a moderate size pygidium (Fig. 10.1, 10.4). Additional specimens of *H. cecinna* were found in the type material of *Kochiella chares* (Walcott's unfigured syntypes later assigned USNM type numbers 509780–509782), which includes larger fragmented cranidia and a partial librigena (Fig. 10.2, 10.3).

The pygidia of *Kochiella eiffelensis* and *Hadrocephalites convexus* illustrated by Rasetti (1951, 1957) are reassigned here. The *Kochiella*-like pygidia that Rasetti assigned to *H. convexus* in 1957 probably belongs to *K. eiffelensis* and the *Hadrocephalites*-like pygidia that Rasetti (1951) assigned to *K. eiffelensis* probably belong to *H. convexus*. The *Hadrocephalites*-like pygidia illustrated by Rasetti in 1957 (pl. 121, figs. 15–17) are probably a different species. These pygidia are similar to *H. lyndonensis* n. sp. with the axis hanging over the posterior margin, but differs by having the pleural furrows reaching only the base of slightly broader (tr.) spines. The pygidia assigned to *H. convexus* (Rasetti, 1951, pl. 14, figs. 9, 10) are more like *H. rhytidodes* n. sp. in that they do not have an axis that overhangs the posterior margin, narrower pleural bands, narrower spines, and coarse genal caeca.

Schistometopus collaris Rasetti, 1951, and S. minor Rasetti,

1957, are not included in *Hadrocephalites*. *Schistometopus collaris* is more similar to *Nyella* and *S. minor* is more similar to *Syspacephalus* Resser, 1936, or *Pachyaspis* Resser, 1939, in their glabellar characteristics. The pygidial characters of neither species are known.

*Hadrocephalites* in western North America occurs in the lower Middle Cambrian *Plagiura-Poliella* Biozone based on its co-occurrence with other Middle Cambrian taxa. *Hadrocephalites* is possibly from the upper Lower Cambrian of Greenland, based on *Crepicephalus* cf. *cecinna* reported by Poulsen (1927; see discussion of age under *Kochiella* above).

Assigned species.—Hadrocephalites carina (Walcott, 1917b), H. cecinna, H. convexus, H. lyndonensis, and H. rhytidodes. In addition, the specimens of Schistometopus spp. illustrated by Palmer and Halley (1979) and Crepicephalus cf. cecinna illustrated by Poulsen (1927) belong to Hadrocephalites. Hadrocephalites carina and H. cecinna may be conspecific. The single specimen of H. carina is an incomplete and somewhat flattened cranidium (Fig. 10.5), but is similar to the larger specimen of H. cecinna (Fig. 10.2).

# HADROCEPHALITES LYNDONENSIS new species Figure 11.1–11.11

*Diagnosis.*—Cranidia with rectangular outline (length 50 to 60 percent width), no preglabellar field, straight anterior border in larger specimens, plectrum absent, wide fixigena ( $47 \pm 4$  percent glabellar width), moderately posterolaterally directed ocular ridges, coarse and fine granules. Pygidium subrectangular with 3 axial rings, large terminal piece that overhanging the pygidial border, and longer (exsag.) pleural furrows that extend to nearly the tip of relatively broad-based spines.

Description.—Cranidium moderate size, length  $4.5 \pm 0.8$  mm



FIGURE 11—1–11, Hadrocephalites lyndonensis n. gen. and sp. from the Log Cabin Member, Pioche Shale, Nevada, all from USNM locality 41742, testate material, and paratypes unless otherwise mentioned; 1–3, holotype cranidium (USNM 509470), ×5.5; 4, cranidium (USNM 509473), ×5.5; 5, small, partial librigena (USNM 509481), ×7.0; 6, 7, small cranidium (USNM 509499), ×5.5, ×10.0; 8, partial cranidium (USNM 509474), ×5.5; 9, partial pygidium (USNM 509478), ×7.0; 10, partial pygidium (USNM 509479), ×7.0; 11, 12, partial, larger pygidium (USNM 509477), ×4.0.

(n = 7); subrectangular, length 50 to 60 percent width; high convexity (sag. and trans.); anterior margin straight to slightly curved in smaller specimens, width  $(J_1)$  60 to 70 percent cranidial width  $(J_2)$ ; posterior margin, excluding occipital ring, straight to directed slightly posterolateral distally. Anterior branches of facial sutures

bowed outward, slightly divergent to anterior border furrow and then moderately convergent to anterior margin; posterior branch strongly divergent to posterior border furrow then directed posterolaterally to nearly posteriorly in smaller specimens. Glabella elongated, moderately tapered, width at anterior end  $78 \pm 4$  percent glabellar width (K<sub>2</sub>); high convexity (sag. and trans.); frontal lobe rounded; length 85  $\pm$  2 percent cranidial length; width 35 to 40 percent cranidial width. Axial furrow deep, shallower posteriorly, slightly concave in outline and convergent from SO to S2 then nearly parallel; preglabellar furrow moderately deep, shallower medially, narrow, moderately curved. Lateral glabellar furrows deep, S1 bifurcated directed posteriorly, S2 directed slightly posteriorly, S3 directed slightly anteriorly, S4 directed anteriorly. Occipital ring strongly elevated above glabella, moderately convex, length 21  $\pm$  2 percent glabellar length; occipital node present; posterior margin straight. SO straight to curved anteriorly in smaller specimens and moderately deep, shallower medially. Frontal area unequally divided, length  $15 \pm 2$  percent cranidial length. Preglabellar field small or absent,  $5 \pm 8$  percent frontal area length. Anterior border concave, flattened dorsally, slightly downsloping, slightly tapering laterally, margin straight to slightly curved in smaller specimens, length 15  $\pm$  1 percent cranidial length. Anterior border furrow straight to slightly curved in smaller specimens, moderately wide, moderately deep, shallower than axial furrows. Fixigena flat to slightly convex, slightly upsloping, anterior area strongly downsloping, width 47  $\pm$  4 percent glabellar width  $(K_2)$ . Palpebral lobes slightly upturned, crescent shaped, wide and long, width  $43 \pm 8$  percent lobe length, length  $41 \pm 2$  percent glabellar length; anterior margin located about opposite of S2 or L3, 29  $\pm$  3 percent glabellar length behind anterior glabellar margin; palpebral furrow shallow. Ocular ridge strong, straight, directed moderately posterolaterally from glabella at approximately 70 degrees to axis. Posterior area of fixigena strap-like, downsloping, sharply terminated; length 22  $\pm$  3 percent glabellar length; width 65 to 80 percent glabella length. Posterior border moderately convex, moderately expanding and flattening distally; border furrow deep, shallowing distally, straight, not expanding.

Librigena moderate size, single fragmented specimen length 5.1 mm; moderately wide, width approximately 40 percent length without spine; lateral margin moderately curved. Genal field moderately convex, width approximately 40 percent librigenal width. Border slightly convex, wider posteriorly; width approximately 30 percent librigenal width; lateral border furrow deep; posterior border furrow short, deep; interborder furrow shallow in posterior portion of lateral border. Genal spine broken, moderately narrowly based, possibly short.

Rostral plate, hypostome, and thorax unknown.

Pygidium moderate size, length 1.9 to 5.3 mm (n = 4); subrectangular, length 40 to 50 percent width; moderately convex (sag. and trans.); anterior margin next to axis projects laterally, distal portion strongly curved posterolaterally, anterolateral corners developed into two posterodorsally directed, narrow-based, elongated, pointed, spines posterior of axis, spine length approximately 155 percent pygidial length. Axis moderately tapered, width at midlength 85 to 95 percent anterior width, anterior width 40 to 45 percent pygidial width; length 90 to 110 percent pygidial length, no postaxial ridge; 3 axial rings, strongly convex; terminal axial piece moderate size, posteriorly rounded, overhanging posterior border; axial furrow shallow, deeper anteriorly; axial ring furrows moderately deep, shallower laterally. Pleural regions well defined, exsagittally elongate; moderate convexity, downsloping; 2 anterior pleural furrows moderately wide and deep, extending as shallow furrows into spine, curved strongly posterolaterally; interpleural furrows not visible; first anterior pleural band well developed, others weakly convex, first posterior pleural band well developed. Border poorly developed.

Fine granules on the cranidium and genal area of librigena. Coarse granules scattered on cranidium, posterior portion of the lateral boarder of librigena, and posterior pleural bands and axis of pygidium. Genal caeca? on posterior area of pleural field and terminal piece of pygidium.

*Etymology.*—Named for the type location in Lyndon Gulch, Highland Range, Nevada.

*Types.*—Holotype, nearly complete cranidium USNM 509470 from USNM locality 41742; paratypes USNM 509471–509481, 509499 from USNM locality 41742.

*Occurrence.—Plagiura-Poliella* Biozone, Susan Duster Limestone and Log Cabin members, Pioche Shale, eastern Nevada. USNM localities 41742, 41752, and 41783.

Discussion.—Hadrocephalites lyndonensis is most similar to H. convexus (given the reassociation of cranidia and pygidia discussed under Kochiella), in lacking a preglabellar field and coarse ornamentation, prominent terminal piece, and fewer pygidial axial rings. Hadrocephalites lyndonensis differs from H. convexus in its straighter anterior border in larger specimens, lower length-to-width ratio, lacking a weak plectrum, wider fixigena, longer (exsag.) pleural furrows on the pygidium, and more rectangular pygidium.

*Hadrocephalites lyndonensis* differs from *H. rhytidodes* and *H. cecinna* in its absence of a preglabellar field, fewer pygidial segments, large terminal piece that overhangs the pygidial border, and pygidial furrows that persist into relatively broad based spines.

## HADROCEPHALITES RHYTIDODES new species Figure 12.1–12.14

*Diagnosis.*—Cranidia with rectangular outline (approximately 60 percent width), preglabellar field present (25 to 30 percent cranidial length), straight anterior border in larger specimens, plectrum present, wide fixigena (45 to 60 percent glabellar width), strongly posterolaterally directed ocular ridges, coarse and fine granules. Pygidium subrectangular with 3 to 4 axial rings, large terminal piece not overhanging pygidial border, and longer (exsag.) pleural furrows that extends only a short distance on to relatively narrow-based spines.

Description.—Cranidium large, length 12.5 to 16.6 mm (n =4); subrectangular, length approximately 60 percent width; high convexity (sag. and trans.); anterior margin straight to slightly curved, width  $(J_1)$  approximately 75 percent cranidial width  $(J_2)$ ; posterior margin, excluding occipital ring, directed slightly posterolateral distally. Anterior branches of facial sutures bowed outward, slightly divergent to furrow and then moderately convergent to anterior margin; posterior branch strongly divergent to posterior border furrow then directed posterolaterally. Glabella elongated, moderately tapered, width at anterior end 70 to 75 percent glabellar width  $(K_2)$ ; high convexity (sag. and trans.); frontal lobe rounded; length 70 to 75 percent cranidial length; width approximately 30 percent cranidial width. Axial furrow deep, slightly shallower posteriorly, slightly concave in outline and convergent from SO to S2 then nearly parallel; preglabellar furrow shallow, uniform depth, narrow, moderately curved. Lateral glabellar furrows deep, S1 bifurcated directed posteriorly, S2 directed slightly posteriorly, S3 directed slightly anteriorly, S4 shallow to absent, directed anteriorly. Occipital ring elevated above glabella, moderately convex, length 15 to 20 percent glabellar length; occipital node present; posterior margin straight. SO straight and moderately deep, shallower medially. Frontal area length 25 to 30 percent cranidial length. Preglabellar field slightly convex, downsloping, length 25 to 35 percent frontal area length, plectrum present. Anterior border concave, flattened dorsally, slightly downsloping, slightly longer laterally, margin straight to curved posteriorly medially, length 15 to 20 percent cranidial length. Anterior border furrow straight, moderately wide, moderately deep, shallower medially, shallower than axial furrows. Fixigena slightly convex, triangular area next to L1 relatively level, distal part



![](_page_14_Picture_2.jpeg)

![](_page_14_Picture_3.jpeg)

![](_page_14_Picture_4.jpeg)

![](_page_14_Picture_5.jpeg)

![](_page_14_Picture_6.jpeg)

![](_page_14_Picture_7.jpeg)

![](_page_14_Picture_8.jpeg)

![](_page_15_Picture_1.jpeg)

FIGURE 13—1, 2, Hadrocephalites sp. A from the Log Cabin Member, Pioche Shale, Nevada; 1, type pygidium for *Crepicephalus liliana* Walcott 1886, mostly exfoliated, (USNM 15428b) from USNM locality 31a, ×4.75; 2, latex cast of a fragmented cranidium (USNM 509785) from USNM locality 41132, ×3.0. *3, 4, Hadrocephalites* sp. B from the Log Cabin Member, Pioche Shale, Nevada; *3,* testate pygidium (USNM 509784) from USNM locality 41747, ×5.0; *4,* latex cast of cranidium (USNM 509594) from USNM locality 41735, ×4.25.

of fixigena upsloping, anterior area strongly downsloping, width 45 to 60 percent glabellar width ( $K_2$ ). Palpebral lobes tilted slightly upward, crescent shaped, narrow and moderately long, width 20 to 25 percent lobe length, length 25 to 35 percent glabellar length; anterior margin located about opposite of S1 or L2, 30 to 40 percent glabellar length behind anterior glabellar margin; palpebral furrow shallow. Ocular ridge strong, straight, directed strongly posterolaterally from glabella at 55 to 60 degrees to axis. Posterior area of fixigena strap-like, downsloping, sharply terminated; length 25 to 30 percent glabellar length; width 75 to 80 percent glabella length. Posterior border strongly convex, moderately expanding and flattening distally; border furrow deep, shallowing distally, straight, not expanding.

Librigena large, length 12.5 to 17.5 mm (n = 2); moderately wide, width 50 to 55 percent length without spine; lateral margin slightly curved. Genal field moderately convex, width 50 to 55 percent librigenal width. Border slightly convex, wider posteriorly; width 25 to 30 percent librigenal width; lateral border furrow

deep, shallowing posteriorly; posterior border furrow short, deep; interborder furrow absent. Genal spine moderately narrowly based, strongly curved abaxially, long, approximately 70 percent librigenal length.

Rostral plate, hypostome, and thorax unknown.

Pygidium moderate size to large, length 6.7  $\pm$  2.8 mm (n = 6); subrectangular, length 42  $\pm$  5 percent width; moderately convex (sag. and trans.); anterior margin next to axis projects laterally, distal portion strongly curved posterolaterally, anterolateral corners developed into two posterodorsally directed, narrow-based, elongated, pointed, spines posterior of axis, spine length approximately 250 percent pygidial length. Axis moderately tapered, width at midlength 79  $\pm$  5 percent anterior width, anterior width 34  $\pm$  4 percent pygidial width; length 94  $\pm$  3 percent pygidial length, no postaxial ridge; 3 to 4 axial rings, moderately convex; terminal axial piece small to moderate size, posteriorly rounded, not overhanging posterior border; axial furrow shallow, deeper anteriorly; axial ring furrows moderately deep, shallower

 $<sup>\</sup>leftarrow$ 

FIGURE 12—1–14, Hadrocephalites rhytidodes n. gen. and sp. from the Pioche Shale, Nevada, all specimens are paratypes, mostly testate material, and ×2.5 unless otherwise mentioned; 1–4, partial, holotype cranidium (USNM 509485) from USNM locality 41792, 3 is a latex cast; 5, partial cranidium (USNM 509486) from USNM locality 41738; 6, complete librigena (USNM 509489) from USNM locality 41738; 7, partial cranidium (USNM 509487) from USNM locality 41738; 8, small cranidium (USNM 509500) from USNM locality 41791, ×7.75; 9, partial pygidium (USNM 509482) from USNM locality 41791; 10, pygidium (USNM 509490) with damaged spine from USNM locality 41767; 11, 12, latex cast of pygidium (USNM 509493) from USNM locality 41792; 13, pygidium (USNM 509488) from USNM locality 41738; 14, large, exfoliated pygidium (USNM 509492) from USNM locality 41792.

laterally. Pleural regions well defined, transversely elongate; moderately convex, downsloping; 2 anterior pleural furrows moderately wide and deep, extending as shallow furrows onto spine base, curved strongly posterolaterally; third anterior pleural furrow shallow projects posterolaterally; interpleural furrows not visible; first anterior pleural band well developed, others weakly convex, first and second posterior pleural band well developed. Border poorly developed. Doublure widest at spine base, thinning towards axis and anteriorly.

Moderate size granules on the cranidium and genal area of librigena. Coarse granules scattered on cranidium and posterior pleural bands and axis of pygidium. Genal caeca on posterior area pleural field and terminal piece of pygidium and plectrum.

*Etymology.*—Greek, *rhytidodes* = wrinkled, named for the coarse genal caeca on the pygidium.

*Types.*—Holotype, nearly complete cranidium USNM 509485 from USNM locality 41792; paratypes USNM 509482, 509483, 509500 from USNM locality 41791; USNM 509484 from USNM locality 41789; USNM 509486–509489 from USNM locality 41738; USNM 509490, 509491 from USNM locality 41767; USNM 509492, 509493 from USNM locality 41792.

*Occurrence.—Plagiura-Poliella* Biozone, upper Susan Duster Limestone and Log Cabin members, Pioche Shale, eastern Nevada. USNM localities 41738, 41739, 41753, 41767, 41774, 41789, 41791, and 41792.

Discussion.—The pygidia of smaller specimens of Hadrocephalites rhytidodes have a higher relief axis that is more like that of *H. lyndonensis*, but differ in a narrower based spines that have furrows extending only to the spine base. The cranidia of *H. rhy*tidodes differs from *H. lyndonensis* in the presence of a welldeveloped preglabellar field.

Hadrocephalites rhytidodes differs from H. convexus in its straighter anterior border in larger specimens, a stronger plectrum, wider fixigena, longer (exsag.) pleural furrows on the pygidium, 3–4 axial rings, and more rectangular pygidium. Hadrocephalites rhytidodes differs from H. cecinna in its straighter anterior border, more posteriorly directed ocular ridges, and straight posterior margin of the pygidium.

# HADROCEPHALITES sp. A Figure 13.1, 13.2

- *Crepicephalus liliana* WALCOTT, 1886, p. 207–208, pl. 28, fig. 3a (only); WALCOTT, 1890, p. 653, pl. 96, fig. 7a (only); WALCOTT, 1916, p. 209, pl. 29, fig. 5c (only).
- Kochaspis liliana (WALCOTT, 1886) PALMER, 1954, p. 80, pl. 17, fig. 7 (only); LOCHMAN-BALK *in* MOORE, 1959, p. O250, fig. 187.7b (only).

*Occurrence.—Plagiura-Poliella* Biozone, upper Log Cabin Member, Pioche Shale, eastern Nevada. USNM localities 31a, 41132.

*Material examined.*—USNM 15428b from USNM locality 31a, USNM 509785 from USNM locality 41132.

Discussion.—This species is left in open nomenclature due to the few, fragmented specimens known. The pygidium of Hadrocephalites sp. A was assigned originally to Crepicephalus liliana, but is removed here based on the discussion under "Cranidial and Pygidial Associations." The pygidium of H. sp. A is most similar to H. rhytidodes based on its narrow spines, 4 axial rings, and the pleural furrows that do not extend far into the pygidial spines. It differs from H. rhytidodes in having a pygidial axis that nearly hangs over the posterior margin, similar to H. lyndonensis. The fragment of a large cranidium is similar to H. rhytidodes in its straight anterior border and plectrum.

# HADROCEPHALITES sp. B Figure 13.3, 13.4

*Occurrence.—Plagiura-Poliella* Biozone, upper Log Cabin Member, Pioche Shale, eastern Nevada. USNM localities 41735, 41747.

*Material examined.*—USNM 509494 from USNM locality 41735, USNM 509784 from USNM locality 41747.

*Discussion.*—The two specimens are left in open nomenclature due to the lack of material. They may represent one or two species. The cranidium can be distinguished from the other species of *Hadrocephalites* by its moderately curved anterior border, no plectrum, median sulcus in the glabella, and no coarse granules. The pygidium differs from the other species in its smooth exoskeleton. The pygidium also has narrow spines that are projected posterolaterally and a rounded posterior margin, which further differentiates *H*. sp. B from *H. rhytidodes*.

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#### LOCALITY REGISTER

All localities are USNM and are from either the Susan Duster and Log Cabin members of the Pioche Shale or from the Pyramid Shale Member, Carrara Formation, in northern Groom Range. Taxa listed are only those discussed in this paper. Complete faunal lists and stratigraphic sections will be presented in a subsequent paper.

#### HIGHLAND RANGE

- Peaslee Canyon Section.—SW¼, SW¼, sec. 32, T1S, R66E 37°53'52", 114°36'25", Highland Peak 7.5' quadrangle, Nevada (1969).
- 41735—Approximately 49 m above the base of the Log Cabin Member. Kochiella augusta, Hadrocephalites sp. B.
- Log Cabin Mine Section.—SW<sup>1</sup>4, SW<sup>1</sup>4, sec. 32, T1N, R66 E 37°53'53", 114°36'29", Highland Peak 7.5' quadrangle, Nevada (1969). Roadcut south of the mine.
- 41738—From 1 to 2 m above the base of the Susan Duster Limestone Member. *Kochiella brevaspis*, *Hadrocephalites rhytidodes*.
- Shallow adit.—NW¼, NW¼, unsurveyed sec. 4, T1S, R66E 37°53'32", 114°36'23", Highland Peak 7.5' quadrangle, Nevada (1969). Collection from shallow adit 0.6 km northeast of Comet Mine.
- 41739—Lower meter of nodular limestone and shale interval, 2.5 to 3.5 m above the base of the Susan Duster Limestone Member. *Kochiella brevaspis, Hadrocephalites rhytidodes*.
- Comet Mine Section.—0.5 km east of Comet Mine, just west of rangefront powerline. SW¼, NW¼, unsurveyed sec. 4, T1S., R66E 37°53'27", 114°36'23", Highland Peak 7.5' quadrangle, Nevada (1969).
- 41741—Probably float material from near 50 m from the base of the Log Cabin Member. *Kochiella augusta*.
- Lyndon Gulch North.—NW¼, NW¼, unsurveyed sec. 9, T1S, R66E 37°52'47", 114°36'13", Highland Peak 7.5' quadrangle, Nevada (1969).
- 41744—Approximately 60 m above the base of the Log Cabin Member. *Kochiella augusta*.
- 41742—Stenothecoides limestone, approximately 30 m above the base of the Log Cabin Member. Kochiella brevaspis, Hadrocephalites lyndonensis.
- Pan American Mine Section.—NE¼, SW¼, unsurveyed sec. 9, T1S, R66E 37°52′20″, 114°36′08″, Highland Peak 7.5′ quadrangle, Nevada (1969). Approximately 300 m east of the Pan American Mine on the west side of the range-front road.
- 41747—Approximately 67 m above the base of the Log Cabin Member. *Hadrocephalites* sp. B.
- *Near Pan American Mine section.*—NE¼, NW¼, unsurveyed sec. 16, T1S, R66E 37°51′57″, 114°36′07″, Bennett Pass 7.5′ quadrangle, Nevada (1970). Roadcut exposure at the junction of the southern entrance to the Pan American Mine and the range-front road.
- 41752—From 1 to 2 m above the base of the Susan Duster Limestone Member. *K. brevaspis, Hadrocephalites lyndonensis.*

#### BLACK CANYON NORTH

- Black Canyon North #4 Section.—NW¼, SW¼, unsurveyed sec. 16, T1S, R66E 37°51′21″, 114°36′05″, Bennett Pass 7.5′ quadrangle, Nevada (1970).
- 41754—Approximately 70 m above the base of the Log Cabin Member. *Kochiella augusta.*
- 41753—Approximately 63 m above the base of the Log Cabin Member. Kochiella augusta, Hadrocephalites rhytidodes.

#### CHIEF RANGE

- Klondike Gap Section.—SW<sup>1</sup>/4, SW<sup>1</sup>/4, unsurveyed sec. 24, T2S, R66E 37°45'18", 114°33'00", Bennett Pass 7.5' quadrangle, Nevada (1970).
- 41760—51 m above the base of the Log Cabin Member. *Kochiella augusta*.
- 41759—48 m above the base of the Log Cabin Member. *Kochiella augusta*.
- 41757—25 m above the base of the Log Cabin Member. *Kochiella brevaspis*.
- 41756—24 m above the base of the Log Cabin Member. *Kochiella bre*vaspis.

#### PIOCHE HILLS

- *Pioche Divide Section.*—NW¼, NE¼, sec. 27, T1N, R67E 37°55'15", 114°27'12", Pioche 7.5' quadrangle, Nevada (1969).
- 41765—Approximately 50 m above the base of the Log Cabin Member. Kochiella augusta, K. maxeyi.
- 41764—From 1 to 2 m above the base of the Susan Duster Limestone Member. *Kochiella brevaspis*.
- Old Pioche-Panaca Road.—E½, sec. 36, T1N, R67E, Pioche 7.5' quadrangle, Nevada (1969).
- 31a— "Lower Cambrian: Limestone and interbedded siliceous shales of the Pioche formation [Walcott, 1908a, p. 11], just above the quartzite on the east side of the anticline, near Pioche, Lincoln County, Nev. (C. D. Walcott and J. E. W., 1885)." (Walcott, 1912a, p. 192; see Sundberg and McCollum, 1997). Most likely uppermost Log Cabin Member. *Kochiella augusta, Hadrocephalites* sp. A.
- *Highway 93 Roadcut Section #1.*—SW<sup>1</sup>/<sub>4</sub>, NE<sup>1</sup>/<sub>4</sub>, sec. 36, T1N, R67E 37°54'19", 114°24'53", Pioche 7.5' quadrangle, Nevada (1969).
- 41132—Approximately 50 m above the base of the Log Cabin Member (also see Sundberg and McCollum, 1997). *Kochiella augusta, Hadrocephalites* sp. A.
- Highway 93 Roadcut Section #2.—SW<sup>1</sup>4, NE<sup>1</sup>4, sec. 36, T1N, R67E 37°54'15", 114°24'53", Pioche 7.5' quadrangle, Nevada (1969).
- 41767—From 1 to 2 m above the base of the Susan Duster Limestone Member. *Kochiella brevaspis, Hadrocephalites rhytidodes.*

#### DELAMAR MOUNTAINS

*Oak Springs Section.*—SE<sup>1</sup>/4, NE<sup>1</sup>/4, unsurveyed sec. 8, T4S, R65E. 37°37'00", 114°42'52", Chokecherry Mountain 7.5' quadrangle, Nevada (1970).

- 41771—Approximately 56 m above the base of the Log Cabin Member. *Kochiella augusta*.
- *Grassy Spring Section.*—NW¼, NW¼, sec. 14, and SW¼, SW¼, sec. 11, T5S, R64E 37°31′17″, 114°47′26″, Pahroc Spring SE 7.5′ quadrangle, Nevada (1970).
- 41783—75 cm thick, echinodermal bioclastic limestone 62–63 m above the base of the Log Cabin Member. *Hadrocephalites lyndonensis*.
- 41782—51–53 m above the base of the Log Cabin Member. *Kochiella augusta*.
- 41780—Approximately 51 m above the base of the Log Cabin Member. *Kochiella augusta*.
- 41779—Approximately 50 m above the base of the Log Cabin Member. Kochiella augusta.
- 41774—From 1 to 2 m above the base of the Susan Duster Limestone Member. *Kochiella brevaspis*, *Hadrocephalites rhytidodes*.
- *Grassy Spring Wash Section.*—SE<sup>1</sup>4, NW<sup>1</sup>4, sec. 14, T5S., R64 E 37°31'03", 114°47'20", Pahroc Spring SE 7.5' quadrangle, Nevada (1970).
- 41749—Approximately 57 m above the base of the Log Cabin Member. *Kochiella augusta*.

#### NORTHERN GROOM RANGE

- *Groom Range Section.*—NW¼, SE¼, unsurveyed sec. 26, T4S, R55E 37°34′07″, 115°45′23″, White Blotch Springs SE 7.5′ quadrangle, Nevada (1987). All localities are in the Pyramid Shale Member, Carrara Formation. Stratigraphic thicknesses are given above the base of the Pyramid Shale Member.
- Log Cabin Member equivalent unit begins at 220 m above the base of the Carrara Formation and 103 m above the base of the Pyramid Shale Member.
- 41799-124 m. Kochiella rasettii.
- 41798—121 m. Kochiella rasettii.
- 41797-113.5 m. Kochiella rasettii.
- 41796-109 m. Kochiella rasettii.
- 41795-108 m. Kochiella rasettii.
- 41794—107 m. Kochiella rasettii.
- 41793-104.5-106.0 m. Kochiella rasettii.
- 41083—Approximately 103 m above the base of the Pyramid Shale Member within the several meters of dark shale starting directly above the Susan Duster Member equivalent, *Kochiella rasettii*. (Also see Sundberg and McCollum, 1997)
- Susan Duster Limestone equivalent unit begins at 216 m above the base of the Carrara Formation and 99 m above the base of the Pyramid Shale Member.
- 41792—102.5–103.0 m, Upper half meter of limestone. Kochiella brevaspis, Hadrocephalites rhytidodes.
- 41791—100–100.2 m, 1.0–1.2 m above base of limestone. *Hadrocephalites rhytidodes*.
- 41789—Student Collection, within the limestone unit. *Hadrocephalites rhytidodes*.