EARLY AND MID CAMBRIAN TRILOBITES FROM THE OUTER-SHELF DEPOSITS OF NEVADA AND CALIFORNIA, USA

by FREDERICK A. SUNDBERG *and* LINDA B. McCOLLUM

ABSTRACT. A latest Early Cambrian and earliest Mid Cambrian polymeroid trilobite fauna, consisting of 16 genera and 25 species, is reported from the peritidal deposits of the Mule Spring Limestone and outer-shelf deposits of the Emigrant and Monola formations of Nevada and California. The Mid Cambrian fauna includes a new genus, *Tonopahella*, and four new species, *T. goldfieldensis*, *Oryctocephalus americanus*, *Onchocephalites claytonensis*, and *Syspacephalus variosus*. The peri-Gondwana species *Oryctocephalus orientalis*, *Oryctocephalites runcinatus*, and *Paraantagmus latus* are recorded in Laurentia for the first time.

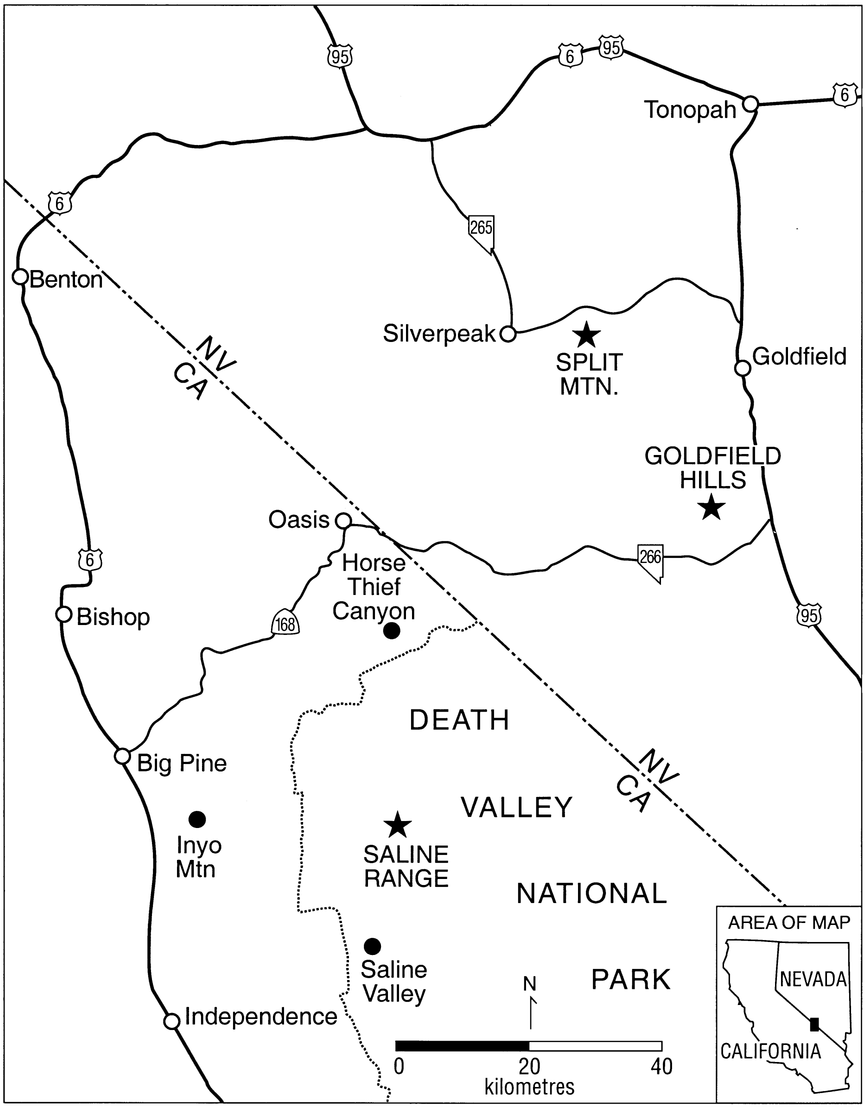
KEY WORDS: Lower/Middle Cambrian Boundary, international correlation, trilobites.

LITTLE is known about the early Mid Cambrian polymeroid trilobites in the outer-shelf environments of Laurentia. Taxonomic work on these assemblages is limited to Rasetti's (1951, 1957) study on the faunas of the Mt. Whyte Formation, southern Canadian Rocky Mountains, and Sundberg and McCollums' (1997) study of oryctocephalid trilobites from the Monola and Emigrant formations. Faunal lists for the Emigrant Formation were also provided by A. R. Palmer (*in* Albers and Stewart 1972) and McCollum and Sundberg (1999). This paper expands upon these previous papers by reporting a moderately diverse polymeroid trilobite fauna from two sections in the basal shale member of the Emigrant Formation at Split Mountain and Goldfield Hills, Esmeralda County, Nevada, and a third section in the basal Monola Formation in the northern Saline Range, Death Valley National Park, Inyo County, California (Text-fig. 1). This fauna, consisting of 11 genera and 18 species, spans three biozones, the *Eokochaspis nodosa*, *Amecephalus arrojosensis*, and *Oryctocephalus indicus*. This paper also reports on the Lower Cambrian trilobites from the uppermost Mule Spring Limestone and basal metre of the Emigrant Formation at the Split Mountain section. This limited fauna consists of seven olenelloid and ptychopariid species.

The occurrence of both endemic and pandemic species allows a direct correlation of early Mid Cambrian faunas of Laurentia with the peri-Gondwana region. Almost a quarter of the species diversity of the basal Emigrant Formation are pandemic, including *Oryctocephalus indicus* (Reed, 1910); *Microryctocara nevadensis* Sundberg and McCollum, 1997; *Oryctocephalus orientalis* Saito, 1934; *Oryctocephalites runcinatus* Shergold, 1969; and *Paraantagmus latus* Yuan and Li, 1999. If the *Oryctocephalus indicus* Biozone is considered as the base of a tripartite series division of the Cambrian, as suggested by Peng and Robison (2000), then Split Mountain would be the best candidate section in Laurentia.

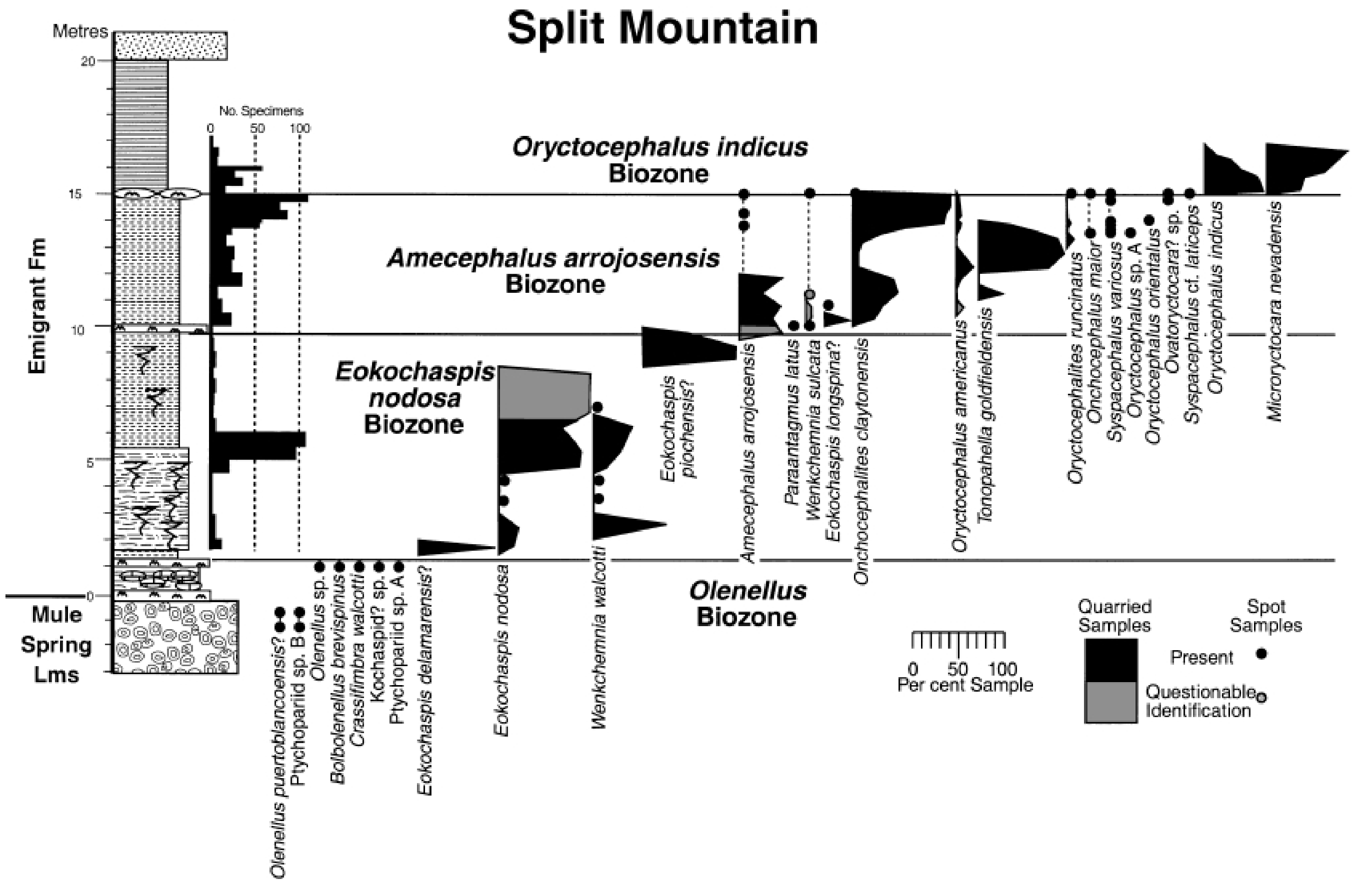
SPLIT MOUNTAIN, NEVADA

The basal 20 m of the Emigrant Formation consists of a mudrock facies containing a few thin, argillaceous limestone beds, in a well-exposed, accessible, and continuously fossiliferous section located 1 km north-east of Split Mountain, in Clayton Ridge, Esmeralda County, Nevada (McCollum and Sundberg 1999). This section occurs in a mining area, where trenching has exposed the non-resistant mudstone facies, and although the fossils are compacted, they are well preserved. The section is on land managed by the Bureau of Land Management, and no permits are required for collecting.

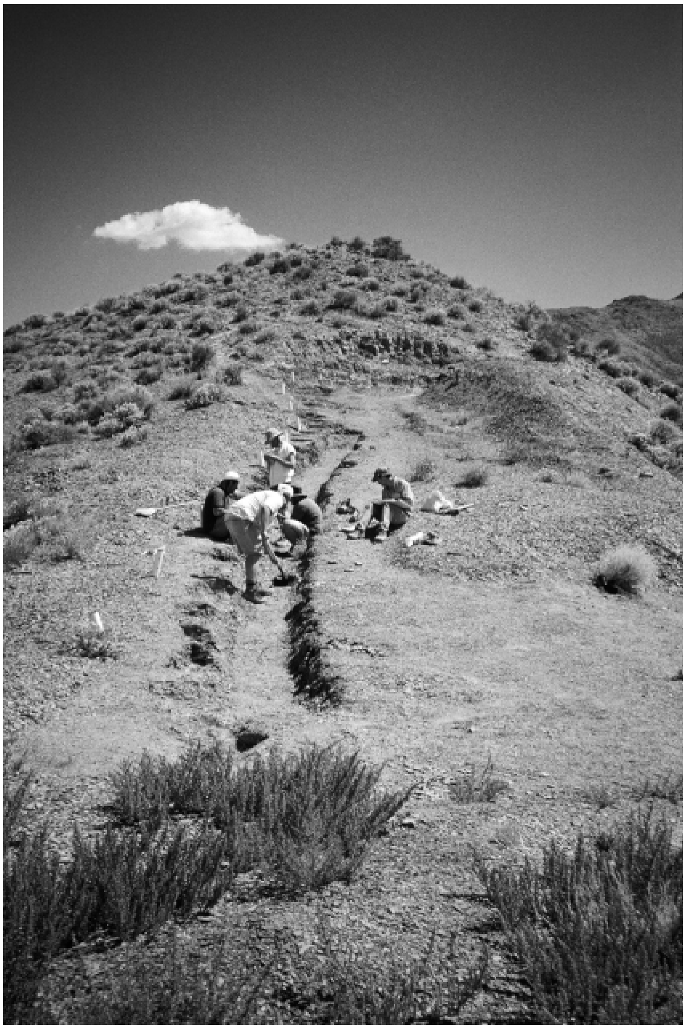


TEXT-FIG. 1. Map to show the location of the basal Middle Cambrian fossil localities in the Emigrant and Monola formations of California and Nevada. Larger dots represent the three sections discussed in the text.

Faunas from the Lower Cambrian *Olenellus* Biozone occur in the upper 1 m of the Mule Spring Limestone and in the basal 1·5 m of the overlying Emigrant Formation (Text-figs 2–3). Trilobites of the *Eokochaspis nodosa* Biozone occur from 1·75 to 9·85 m above the base of the Emigrant Formation. The overlying *Amecephalus arrojosensis* Biozone, which was established by Sundberg and McCollum (2000) at this locality, occurs within a mudstone, beginning at a 15-cm-thick, silty limestone, and ending at a 15-cm-thick, concretionary, bioclastic limestone, in an interval from 9·85 to 15 m above the base of the Emigrant Formation. A 3-m-thick interval of dark, laminated clayshales occurs above the 15-m concretionary horizon, and includes two oryctocephalid species in the lower half, which are assigned to the *Oryctocephalus indicus* Biozone.



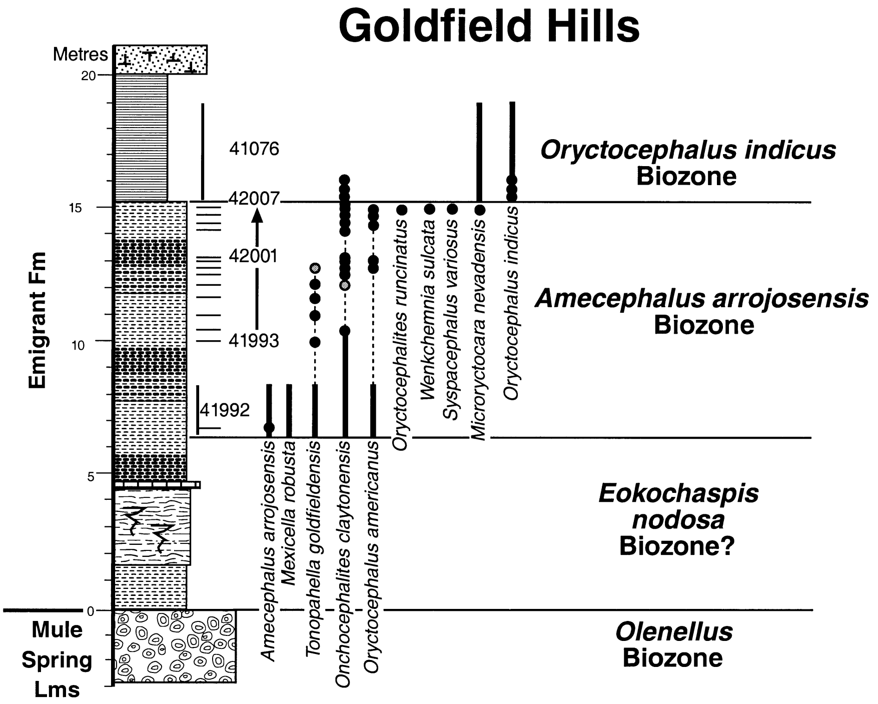
TEXT-FIG. 2. Stratigraphic section and taxon range chart of the uppermost Mule Spring Limestone and lowermost Emigrant Formation at Split Mountain, Nevada; see Text-figure 5 for lithological symbols.



TEXT-FIG. 3. The open trench in the basal mudrock interval of the Emigrant Formation at the Split Mountain section, Nevada.

GOLDFIELD HILLS, NEVADA

The Goldfield Hills section (Text-fig. 4) is also on land administered by the Bureau of Land Management, and is accessible by vehicle. This section was originally described by Albers and Stewart (1972), and included by Sundberg and McCollum (1997) in their discussion of the occurrence of Lower and Middle Cambrian oryctocephalids in the southern Great Basin. No faunas could be recovered from the basal 1·5 m, possibly due to local hydrothermal alteration along the contact between the Mule Spring Limestone and the Emigrant Formation. From 1·5 to 9·5 m, the mudrock facies has been locally altered to a siliceous, dark argillite, which has ledgy outcrops, and forms talus of medium bedded argillites. Trilobites of the *Amecephalus arrojosensis* Biozone occur in the thinly bedded, dark argillites from 9·5 to 15 m above the base. Trilobites of the *Oryctocephalus indicus* Biozone occur in light grey, fissile shale that is exposed only in rodent burrows and in a trenched section.



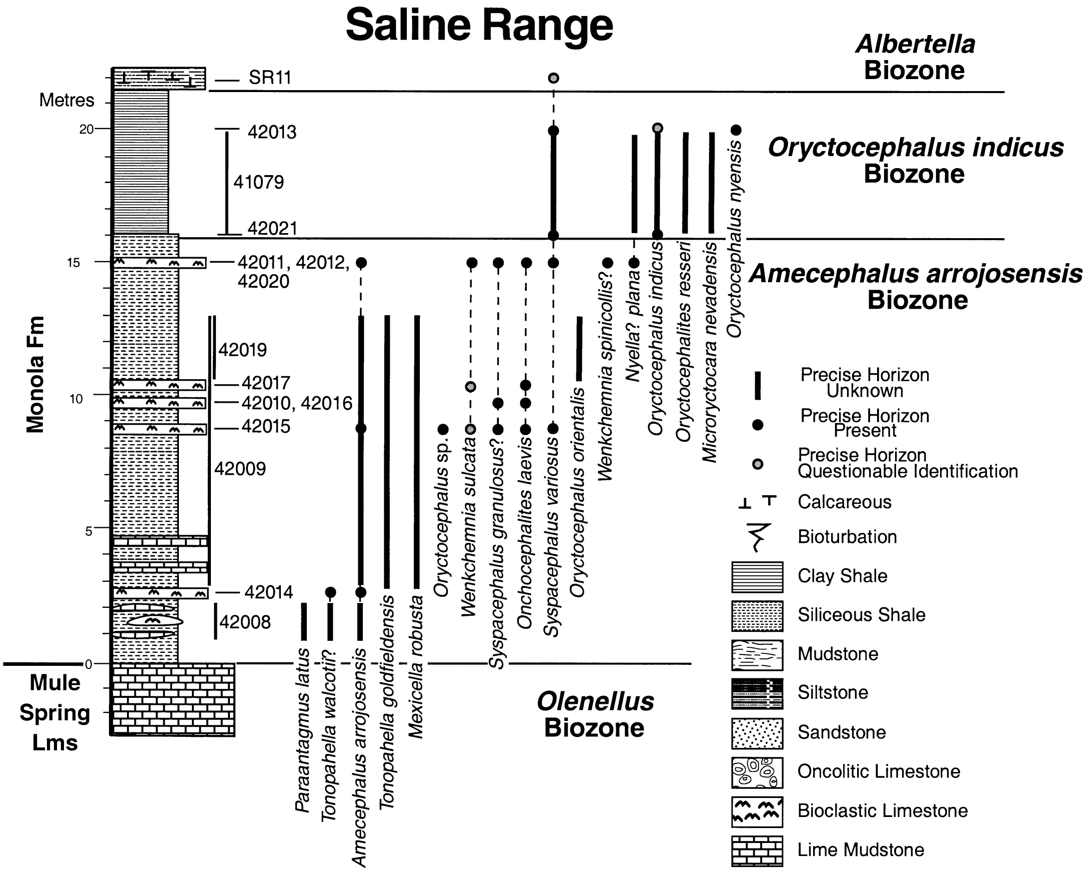
TEXT-FIG. 4. Stratigraphic section and taxon range chart of the uppermost Mule Spring Limestone and lowermost Emigrant Formation at Goldfield Hills, Nevada; see Text-figure 5 for lithological and taxon-range symbols.

NORTH SALINE RANGE, CALIFORNIA

The north Saline Range section of the Monola Formation is within Death Valley National Park, requiring permits and a hike of several kilometres to reach the section. The section is located within the plutonic region of the Last Chance allochthon, and therefore, the strata are altered to argillite and the faunas are somewhat distorted. No faunas attributable to the *Olenellus* or *Eokochaspis nodosa* biozones have been recovered from the Monola Formation. Several thin bioclastic limestones and argillites within the basal 15 m of the formation contain a trilobite assemblage typical of the *Amecephalus arrojosensis* Biozone (Text-fig. 5). The overlying 5-m-thick, greyish black shale interval contains the faunas of the *Oryctocephalus indicus* Biozone. Calcareous siltstones 20–30 m above the base of the Monola Formation contain *Paralbertella* sp. and *Ptarmiganoides* cf. *propiqua* (Resser, 1939), which are indicative of the *Albertella* Biozone (Palmer and Halley 1979).

CHRONOCORRELATION

The Lower Cambrian of Laurentia was originally defined as a range zone, based on *Olenellus* (Walcott, 1890), and the Lower/Middle Cambrian boundary was set at the extinction of the olenelloids. Palmer (1998*a*) established a Laurentian series boundary based on the first occurrence of an endemic ptychopariid species immediately above the last occurrence of olenelloids. Sundberg and McCollum (2000) established two new biozones, the *Eokochaspis nodosa* Biozone immediately above the olenelloid extinction, and the overlying *Amecephalus arrojosensis* Biozone. The first occurrence of trilobites typically found in the *Plagiura-Poliella* Biozone of Lochman-Balk and Wilson (1958) is in a shelf-carbonate facies immediately above the *A. arrojosensis* Biozone (Sundberg and McCollum 2003). In the outer shelf clastic facies, the *Plagiura-Poliella* Biozone faunas are absent, and a low diversity, cosmopolitan oryctocephalid fauna,



TEXT-FIG. 5. Stratigraphic section and taxon range chart of the uppermost Mule Spring Limestone and lowermost Monola Formation at Saline Range, California.

consisting of *Oryctocephalus indicus* and *Microryctocara nevadensis*, occurs in that interval (Sundberg and McCollum 1997).

Oryctocephalus indicus was originally described from the Himalayan Mountains of India (Reed 1910; Jell and Hughes 1997), and first reported from a relatively thin (less than 2 m thick) shale interval from both western North America by Sundberg and McCollum (1997) and South China by Yuan *et al.* (1997). The *Oryctocephalus indicus* Biozone, originally established in South China (Peng *et al.* 2000), is here recognized for the outer shelf facies in Laurentia. As noted above, the *Oryctocephalus indicus* Biozone is the outer shelf equivalent of the *Plagiura-Poliella* Biozone in Laurentia.

The presence of *Oryctocephalus orientalis*, *Oryctocephalites runcinatus*, and *Paraantagmus latus* within the lower Middle Cambrian *Amecephalus arrojosensis* Biozone within the outer shelf facies of Laurentia allows for correlation of the peri-Gondwana region. *Paraantagmus latus* co-occurs with the youngest redlichids in South China (Yuan and Li 1999), and occurs at the base of the *Amecephalus arrojosensis* Biozone in the Emigrant Formation at Split Mountain. *Oryctocephalites runcinatus* occurs within the upper half of the *A. arrojosensis* Biozone at Split Mountain. This species was originally described from the Northern Territory of Australia in the *Xystridura* faunizone, although the exact stratigraphic relations of this fauna cannot be determined, as the material was collected from pebbles in outwash deposits (Shergold 1969).

The ranges of various oryctocephalid species within the Lower–Middle Cambrian boundary interval differs somewhat from continent to continent. All three specimens of *Oryctocephalus orientalis* were found below the first occurrence of *O. indicus* in the Great Basin. This species was originally described from North Korea as occurring with *O. indicus* (Saito 1934; Sundberg and McCollum 1997). *Oryctocephalus* cf. *orientalis* (= *O. orientalis*) was identified from the Kaili Formation, South China (Yuan *et al.* 1999) and occurs above *O. indicus*. *Microryctocara nevadensis* is here recognized in the Kaili Formation, South China, where it occurs within a 1-m-thick interval, co-occurring with *O. indicus* through the upper half metre.

The basal Middle Cambrian in South China is now defined on the first occurrence of *O. indicus* (Peng *et al.* 2000). *O. indicus* occurs just above the redlichid extinction in the Kaili Formation, South China (Sundberg *et al.* 1999). In Laurentia, the *O. indicus* Biozone occurs 15 m and two biozones above the olenelloid extinction. If the FAD of *O. indicus* in Gondwana and Laurentia is nearly synchronous, it appears likely that the olenelloid faunas of Laurentia became extinct prior to the redlichid extinction in Gondwana.

MATERIAL AND METHODS

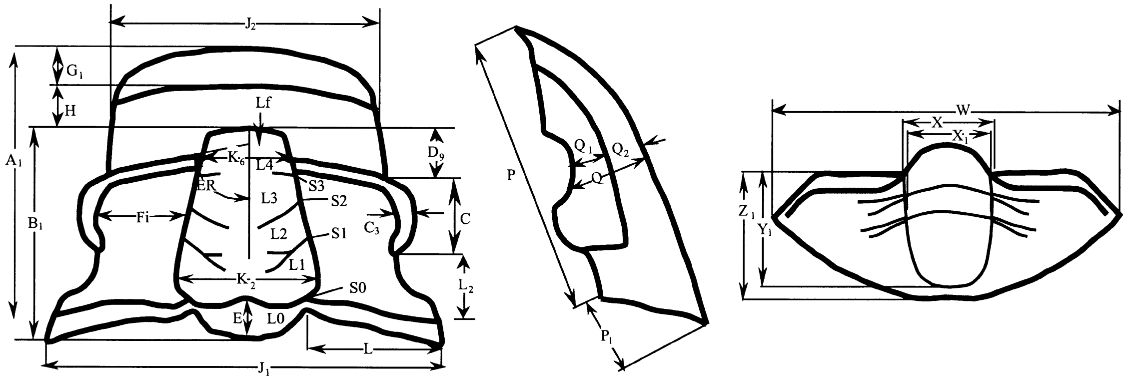
The numerous localities presented in this paper result from nearly 25 years of collecting by L. B. McCollum and M. B. McCollum. The stratigraphic details recorded for the localities during each collecting trip differed depending on the goals of the projects. The initial collecting of each section was during reconnaissance trips, which resulted in fossils being recorded from lithologic units (e.g. lower 16 m of black shales). As the projects developed, more precise collecting was undertaken. These collecting trips occurred in 1993 (Goldfield Hills), 1998 (Split Mountain), 1999 (Split Mountain), and 2000 (Split Mountain, Goldfield Hills, and northern Saline Range).

The Split Mountain section (Text-fig. 3) was first discovered by M. B. McCollum, W. H. Fritz, and S. Hollingsworth in September 1997 and only a few grab samples were made. In May 1998, sampling consisted of 1·5-m-thick stratigraphic intervals, and in June 1999, smaller sampling intervals were taken between 13 and 17 m above the base of the section. At each time, any potentially important specimens found in spoil piles next to a trench were also collected and recorded as to their approximate stratigraphic position. In June 2000, our goal was to document the numeric abundance and taxonomic diversity of the section. We systematically sampled every 0·5 m of strata. During this sampling, we did field identification, counted individual sclerites, and measured the amount of rock material quarried. Only that material needed for taxonomic descriptions was brought back from the field. The 1999 and 2000 samples were used to generate the bar graph indicating the number of specimens and the histograms indicating relative abundance of species (Text-fig. 2). The dots in this figure are used to represent data from earlier samples lacking specimen counts.

The Split Mountain section has too many fossil locality horizons to list on Text-figure 2. United States National Museum of Natural History (USNM) localities 41936 and 41937 are from the upper 1·5 m of the Mule Spring Limestone and represent the *Olenellus* Biozone of the uppermost Lower Cambrian. USNM localities 41938 and 41939 are from the lower 1 m of the Emigrant Formation and represent the *Olenellus* Biozone. USNM localities 41940–41952 are from 1·75 to 9·5 m above the base of the Emigrant Formation and represent the *Eokochaspis nodosa* Biozone of the lowermost Middle Cambrian. USNM localities 41953–41985 are from 9·5 to 15·0 m above the base of the Emigrant Formation and represent the *Amecephalus arrojosensis* Biozone of the lower Middle Cambrian. USNM localities 41986–41991 are from 15·0 to 16·6 m above the base of the Emigrant Formation and represent the *Oryctocephalus indicus* Biozone of the lower Middle Cambrian.

In June 2000, the Goldfield Hills and Saline Range sections were resampled in more detail. These data are integrated into the figures as horizontal locality bars and species dots showing where taxa were found. The longer, solid range bars indicate less precise sampling undertaken during earlier collecting trips.

The type specimens are deposited in the USNM. All specimens and locality numbers are prefixed USNM. Measurements used are illustrated in Text-figure 6. Measurements, terminology, and abbreviations are derived from Shaw (1957), Whittington and Kelly (*in* Kaesler 1997), and Sundberg and McCollum (1997, 2000). Sagittal (sag.) and exsagittal (exsag.) measures are referred to as lengths and



TEXT-FIG. 6. Measurements and lobe and furrow labels used in the trilobite descriptions.

transverse (trans.) measures are referred to as widths. Only larger holaspids were used for measurements. Measures are given as averages plus one standard deviation when five or more specimens are measured. Ranges of percentages are given if 2–4 specimens are measured and these ranges are rounded off to the nearest five per cent (e.g. 54 per cent would be listed as 55 per cent).

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

SYSTEMATIC PALAEONTOLOGY

The number of specimens reported for each taxon discussed below is the number collected and deposited in the USNM. Question marks following a locality number indicate a questionable identification of the species discussed.

Class TRILOBITA Walch, 1771
Order REDLICHIIDA Richter, 1932
Suborder OLENELLINA Walcott, 1890
Superfamily OLENELLIOIDEA Walcott, 1890
Family OLENELLIDAE Walcott, 1890
Subfamily OLENELLINAE Walcott, 1890

Genus OLENELLUS Hall, 1861

Type species. *Olenellus thompsoni* Hall, 1859.

OLENELLUS (OLENELLUS) Hall, 1861

Type species. As for genus.

Olenellus (*Olenellus*) sp.

Plate 1, figures 1, 3

Material. Seven fragmented cephala from USNM localities 41938 and 41939, Emigrant Formation, Split Mountain.

Remarks. One large broken cephalon and several fragments are similar to *Olenellus* (*O.*) *gilberti* (Meek, *in* White 1874) illustrated by Palmer (1998*b*), but they are too fragmented for an accurate identification.

Distribution. *Olenellus* Biozone, Emigrant Formation, Split Mountain, western Nevada.

OLENELLUS (PAEDEUMIAS) Walcott, 1910

Type species. *Paedeumias transitans* Walcott, 1910.

Olenellus (*Paedumias*) *puertoblancoensis*? (Lochman, 1952)

Plate 1, figures 2–3

1952 *Paedeumias puertoblancoensis* Lochman, pp. 94–95, pl. 19, figs 9–16.
1957 *Paedeumias clarki* Resser; Palmer, pl. 19, figs 4–5, 10, 14, 17, 20.
1972 *Olenellus puertoblancoensis* (Lochman); Fritz, pp. 14–15, pl. 17, figs 1–7.
1979 *Olenellus puertoblancoensis* (Lochman); Palmer, *in* Palmer and Halley, p. 74, pl. 4, figs 11, 14. (also reassigned *P. clarki* of Palmer 1957)

Material. Eleven fragmented cephala from USNM localities 41936 and 41937, Mule Spring Limestone, Split Mountain.

Remarks. Two small cephala and several fragments match the specimens illustrated by Lochman (1952), Palmer (1957), Fritz (1972), and Palmer and Halley (1979), but they are too small and or fragmented for an accurate identification.

Distribution. *Olenellus* Biozone, Mule Spring Limestone, Split Mountain, western Nevada; Thimble Limestone and Gold Ace Limestone members, Carrara Formation, California (Palmer and Halley 1979); Combined Metals Member, Pioche Shale, eastern Nevada (Palmer 1957; Palmer and Halley 1979); Buelna Formation, Caborca, Mexico (Lochman 1952); Sekwi Formation, north-western Canada (Fritz 1972).

Subfamily BRISTOLIINAE Palmer and Repina, 1993

Genus BOLBOLENELLUS Palmer and Repina, 1993

Type species. *Olenellus euryparia* Palmer, *in* Palmer and Halley, 1979.

Bolbolenellus brevispinus Palmer, 1998*b*

Plate 1, figures 4–5

1998*b* *Bolbolenellus brevispinus* Palmer, pp. 663–665, figs 5.6, 7.1–7.12.

Material. Cephalon from USNM locality 41938, Emigrant Formation, Split Mountain.

Remarks. One large broken cephalon matches the specimens illustrated by Palmer (1998*b*) in having a cap-shaped frontal lobe.

Distribution. *Olenellus* Biozone, Emigrant Formation, Split Mountain, western Nevada; Pioche Shale, eastern Nevada (Palmer 1998*b*).

Order CORYNEXOCHIDA Kobayashi, 1935
Family DOLICHOMETOPIDAE Walcott, 1916*b*

Genus WENKCHEMNIA Rasetti, 1951

Type species. *Wenkchemnia walcotti* Rasetti, 1951.

Wenkchemnia walcotti Rasetti, 1951

Plate 2, figures 8–10

1916*b* *Bathyuriscus* (*Poliella*) *primus* Walcott (part), p. 352, pl. 46, fig. 6b (only).
1951 *Wenkchemnia walcotti* Rasetti, pp. 186–187, pl. 11, figs 9–15.

Material. Twenty-seven cranidia, three librigenae, and 15 pygidia from USNM localities 41941–41942, 41947 and 41949–41950, Emigrant Formation, Split Mountain.

Remarks. The material from Split Mountain agrees well with the type material illustrated by Rasetti (1951).

Distribution. *Eokochaspis nodosa* Biozone, Emigrant Formation, western Nevada. *Wenkchemnia-Stephenaspis* Biozone, Mount Whyte Formation, British Columbia, Canada.

Wenkchemnia spinicollus? Rasetti, 1951

Plate 8, figure 7

1951 *Wenkchemnia spinicollus* Rasetti, pp. 185–186, pl. 11, figs 4–8.

Material. Twelve cranidia from USNM locality 42012, Monola Formation, Saline Range.

Remarks. The material from the Saline Range bears the large occipital spine typical of the species, but no pygidia have been identified in the collection, thus leaving the specimens questionably identified.

Distribution. *Amecephalus arrojosensis* Biozone, Monola Formation, Saline Range, California. *Wenkchemnia-Stephenaspis* Biozone, Mount Whyte Formation, British Columbia, Canada.

Wenkchemnia sulcata Rasetti, 1951

Plate 5, figures 14–15

1951 *Wenkchemnia sulcata* Rasetti, pp. 186–187, pl. 11, figs 9–15.

Material. Several tens of cranidia, librigenae, and pygidia from USNM localities 41953, 41956?, 41957, and 41985, Emigrant Formation, Split Mountain. Two cranidia, a complete shield, two hypostomata, and one librigena from USNM localities 42005 and 42007, Emigrant Formation, Goldfield Hills. Forty-two cranidia, two librigena, and ten pygidia from USNM localities 42011 and 42015, Monola Formation, Saline Range.

Remarks. The specimens from Split Mountain differ from the type material by having a pygidium that is less transversely elongated with slightly shallower interpleural furrows. However, the type material is tectonically distorted, which could have caused these minor differences.

EXPLANATION OF PLATE 1

Figs 1, 3. *Olenellus* sp. 1, broken, partially testate specimen with right fixigena dislocated, USNM 517501. 3, fragmented, partially testate specimen, USNM 517502. Both from USNM loc. 41939, Emigrant Formation; ×2.

Figs 2, 6. *Olenellus* (*Paedeumias*) *puertoblancoensis*? (Lochman, 1952). 2, latex cast showing the palpebral lobes of USNM 517500. 6, small, mostly exfoliated cephalon, USNM 517500. From USNM loc. 41936, Mule Spring Limestone; ×10.

Figs 4–5. *Bolbolenellus brevispinus* Palmer, 1998*b*. Partially testate glabella, USNM 517485, from USNM loc. 41938, Emigrant Formation; ×2.

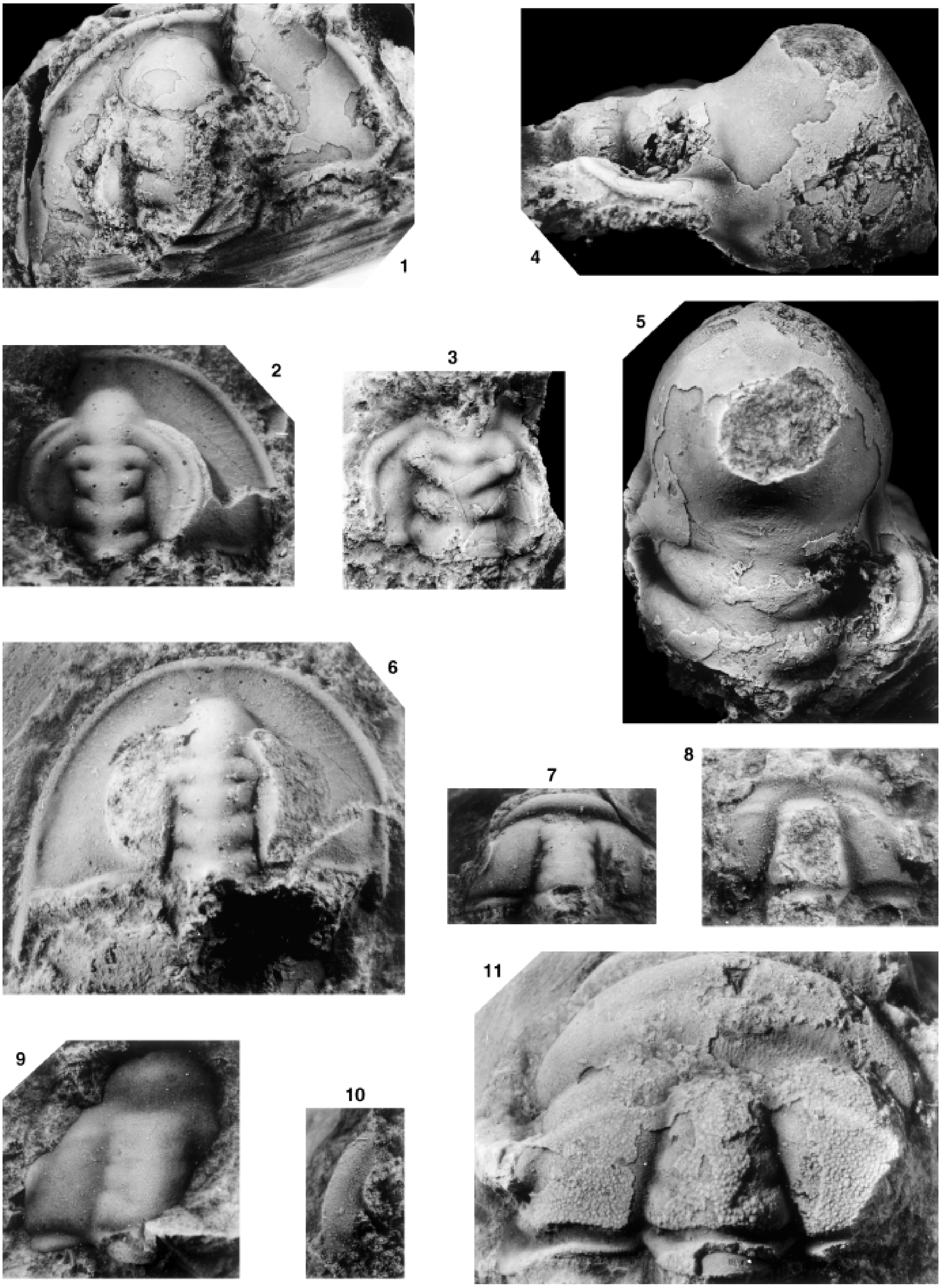
Fig. 7. Ptychopariid sp. B. Testate cranidium, USNM 517604, from USNM loc. 41936, Mule Springs Limestone; ×10.

Fig. 8. Ptychopariid sp. A. Exfoliated, damaged cranidium, USNM 517603, from USNM loc. 41939, Emigrant Formation; ×10.

Figs 9–10. *Crassifimbra walcotti* (Resser, 1937). 9, latex cast of partial cranidium, USNM 517486. 10, librigena, USNM 517487. Both from USNM loc. 41939, Emigrant Formation; ×10.

Fig. 11. Kochaspid? Testate cranidium, USNM 517496, from USNM loc. 41936, Emigrant Formation; ×7.

All specimens are from the *Olenellus* Biozone (uppermost Lower Cambrian), Split Mountain, Nevada.



SUNDBERG and McCOLLUM, Cambrian trilobites

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain and Goldfield Hills, western Nevada; Monola Formation, Saline Range, California. *Wenkchemnia-Stephenaspis* Biozone, Mount Whyte Formation, British Columbia, Canada (Rasetti 1951).

Family ORYCTOCEPHALIDAE Beecher, 1897
Subfamily ORYCTOCEPHALINAE Beecher, 1897

Genus ORYCTOCEPHALUS Walcott, 1886

Type species. *Oryctocephalus primus* Walcott, 1886.

Oryctocephalus americanus sp. nov.

Plate 4, figures 1–4, 7–8

1951 *Oryctocephalus* sp. 2 Rasetti, p. 193, pl. 9, fig. 23.
2003 *Oryctocephalus* sp. Sundberg and McCollum, p. 345, pl. 9.12–9.14.

Derivation of name. Named for its occurrence in North America.

Holotype. Cranidium USNM 517583 (Pl. 4, fig. 4) from USNM locality 41978, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, Nevada.

Paratypes. USNM 517576 from USNM locality 41961; USNM 517577 (Pl. 4, fig. 2) from USNM locality 41964; USNM 517578 (Pl. 4, fig. 1) and 517579 from USNM locality 41971; USNM 517580 (Pl. 4, fig. 8) from USNM locality 41976; USNM 517581 and 517582 from USNM locality 41977; USNM 517584 (Pl. 4, fig. 7) and 517585 from USNM locality 41978; USNM 517586 from USNM locality 41979; USNM 517587 (Pl. 4, fig. 3), 517588, and 517589 from USNM locality 41984. All from the *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, Nevada.

Additional material. One thorax, 18 cranidia, and five pygidia from USNM localities 41955, 41959, 41961, 41969, 41971, 41973, 41977–41978, 41981 and 41984, Emigrant Formation, Split Mountain. Eight cranidia and a pygidium from USNM localities 41992, 41999–42000 and 42003–42005, Emigrant Formation, Goldfield Hills.

Diagnosis. Cranidium with a parallel-sided glabella, S1 transglabellar furrow, eye ridges directed moderately posterolaterally, moderately wide fixigena (71 ± 8 per cent glabellar width), intergenal spines, slightly curved anterior margin, and anterior border without curvature towards frontal lobe. Twelve thoracic segments, each with flat pleural spines. Pygidium with two axial rings; anterior pleural

---

EXPLANATION OF PLATE 2

Figs 1–2, 4. *Eokochaspis nodosa* Sundberg and McCollum, 2000. 1, latex cast of cranidium, USNM 517491, showing the granular surface, USNM loc. 41942; ×10. 2, latex cast of nearly complete, articulated specimen, USNM 517493, showing the librigena and number of thoracic segments, USNM loc. 41949; ×5. 4, mostly testate pygidium, USNM 517492, USNM loc. 41942; ×10.

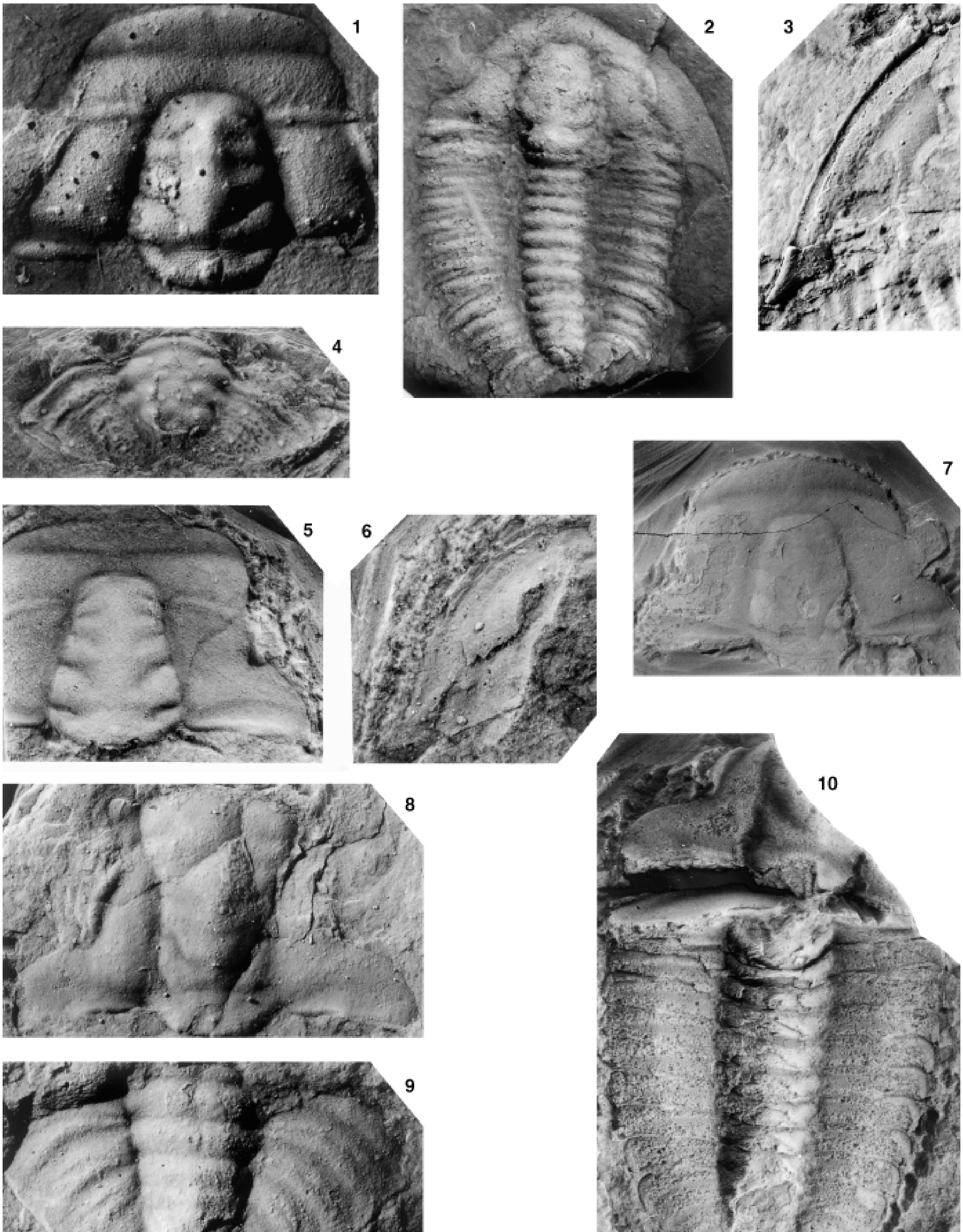
Figs 3, 7. *Eokochaspis delamarensis*? Sundberg and McCollum, 2000. 3, librigena showing the short, deflected genal spine, USNM 517489; ×5. 7, large, exfoliated cranidium, USNM 517488; ×3. Both from USNM loc. 41940.

Figs 5–6. *Eokochaspis piochensis*? (Palmer, *in* Palmer and Halley 1979). 5, nearly complete cranidium, USNM 517494, USNM loc. 41951; ×5. 6, librigena, USNM 517495, USNM loc. 41952; ×7.

Figs 8–10. *Wenkchemnia walcotti* Rasetti, 1951. 8, large cranidium, USNM 517685, USNM loc. 41941; ×6·3. 7, latex cast of large pygidium, USNM 517686, USNM loc. 41941; ×7. 10, nearly complete, articulated specimen, USNM 517687, USNM loc. 41949; ×5.

All specimens are from the *Eokochaspis nodosa* Biozone (lowermost Middle Cambrian), Emigrant Formation, Split Mountain, Nevada.

PLATE 2



SUNDBERG and McCOLLUM, *Eokochaspis*, *Wenkchemnia* bands long (exsag.), posterolaterally to posteriorly directed with flat spines; and V1 to V2 spines decreasing in size and projecting posteriorly.

Description. Cranidium small to moderate size, length 2·7–5·6 mm (n = 8); subtrapezoidal, length 58 ± 3 per cent width; low convexity (sag. and trans.); anterior margin slightly curved, anterior border furrow angle 153 ± 5 degrees, width (J_2) 70 ± 2 per cent cranidial width (J_1); posterior margin, excluding occipital ring, straight. Facial suture with anterior branches slightly bowed, slightly convergent; posterior branch moderately strongly divergent. Glabellar length 94 ± 0·5 cranidial length; width 31 ± 3 per cent cranidial width; slightly tapered, width at anterior end 92 ± 5 per cent glabellar width (K_2), frontal lobe not expanded; low convexity (sag. and trans.); frontal lobe rounded, without medial sulcus. Axial furrows moderate and uniform depth, sinuous around glabellar pits; preglabellar furrow moderate depth, same depth as axial furrow; lateral glabellar furrows not extending to axial furrows, circular pits at S1 to S3 positions, one transglabellar furrow, longitudinal furrows extending from the posterior margin of the occipital ring to the S4, connecting all glabellar pits, shallow in larger specimens. Occipital ring length 14 ± 1 per cent glabellar length, not elevated above glabella, low convexity; no occipital spine or node; S0 straight and moderate depth between circular pits, curved to posterior margin laterally, not extending to axial furrow; posterior margin very slightly curved. Frontal area length 6 ± 0·5 per cent cranidial length. Preglabellar field absent. Anterior border slightly convex, slightly upturned, uniform length, slightly curved, evenly curved with no curvature towards frontal lobe. Anterior border furrow evenly curved, shallow, shallower than axial furrows. Fixigena width 71 ± 8 per cent glabellar width (K_2), low convexity, level; no elongated swelling adjacent to palpebral lobes. Palpebral lobe narrow, width 17 ± 4 per cent lobe length; moderate length, 37 ± 4 per cent glabellar length; anterior about opposite L3 or S3, 34 ± 4 per cent glabellar length behind glabellar anterior; moderate curvature; palpebral furrow shallow, narrow. Eye ridge strong, joining glabella at or below S4, cut by axial furrows, directed moderately to strongly posterolateral from glabella at 64 ± 4 degrees to axis. Posterior area of fixigena length 25 ± 2 per cent glabellar length; width 63 ± 5 per cent glabella length; sharply terminated with fixigenal spine. Posterior border with moderate convexity, expanding distally; border furrow moderately shallow, uniform depth and length, straight.

Librigenae, hypostoma, and rostral plate unknown.

At least 12 thoracic segments slightly decreasing in width posteriorly. Axial furrows well defined, deep to shallower next to anterior pleural band. Thoracic pleura wide, length 125–140 per cent of axial width; anterior pleural band expanding distally, distal end forming long, flat, posterolaterally-directed spine; posterior pleural band narrows distally, relatively low relief, terminating at lateral margin.

Pygidium small, length 0·7–1·7 mm (n = 5); suboval, length 53 ± 6 per cent width; anterior margin curved moderately posterolaterally. Two pairs of marginal spines, broad, flat, level; V1 to V2 spines decreasing in size and project posteriorly; posterior pair small to moderate length; anterior pair long. Axis moderately tapered, width at midlength 75 ± 8 per cent anterior width, anterior width 40 ± 4 per cent pygidial width; length 52 ± 6 per cent pygidial length, no postaxial ridge; two axial rings, moderately low convexity, no axial nodes; terminal axial piece posteriorly rounded; axial furrows shallow depth; axial ring furrows shallow and of uniform depth. Pleural regions well defined, sagittally elongate; low convexity; two deep pleural furrows, two moderate-depth interpleural furrows, directed posteriorly, extending to margin. Anterior pleural bands expanding distally into marginal spines. Posterior pleural bands short (exsag.). Border absent.

Exoskeleton thin?; smooth on all external and internal surfaces.

EXPLANATION OF PLATE 3

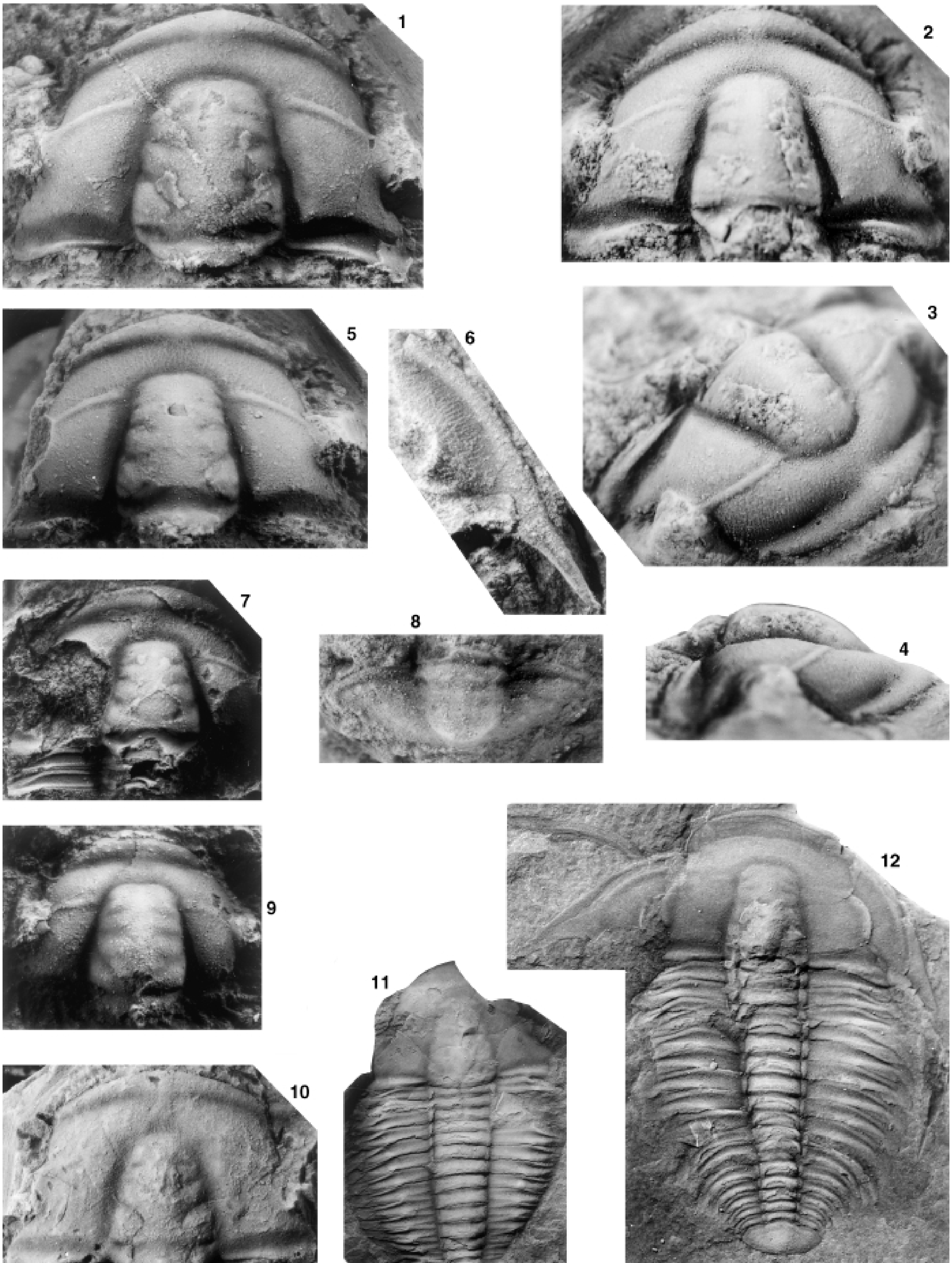
Figs 1–9. *Paraantagmus latus* Yuan and Li, 1999. 1, exfoliated, large cranidium, USNM 517596; ×5. 2–4, mostly exfoliated cranidium, USNM 517597; ×5.5. 5, mostly testate cranidium, USNM 517598; ×5. 6, exfoliated librigena, USNM 517601; ×7. 7, mostly exfoliated, small cranidium and articulated thoracic segments, USNM 517599; ×5. 8, testate pygidium, USNM 517602; ×10. 9, mostly testate, small cranidium, USNM 517600, with straighter anterior border; ×7. All specimens from USNM loc. 41953, Emigrant Formation, Split Mountain, Nevada.

Fig. 10. *Eokochaspis longspina*? Sundberg and McCollum, 2000. Exfoliated cranidium, USNM 517490, USNM loc. 41954, Emigrant Formation, Split Mountain, Nevada; ×5.

Fig. 11. *Mexicella robusta* Sundberg and McCollum, 2000. Latex cast of nearly complete shield, USNM 517497, USNM loc. 41992, Monola Formation, Saline Range, California; ×1.

Fig. 12. *Amecephalus arrojosensis* (Lochman, 1952). Complete, mostly articulated shield, USNM 517484, USNM loc. 41958, Emigrant Formation, Split Mountain, Nevada; ×5.

All specimens are from the *Amecephalus arrojosensis* Biozone (basal Middle Cambrian).



SUNDBERG and McCOLLUM, Cambrian trilobites

Remarks. *Oryctocephalus americanus* is similar to *Orytocephalus lancastrioides* (Shergold, 1969) in their near parallel-sided glabella, wide fixigena, single (S1) transglabellar furrow, sinuous axial furrow, circular S0 to S3 pits, flat and long pleural spines, and a pygidium with one or two axial rings and pleural spines. The Nevada specimens differ from the Australian specimens in their generally shorter palpebral lobes [37 ± 4 vs. 40 to 55 ($n = 2$) per cent glabellar length], intergenal spines, potentially fewer thoracic segments (a minimum of 12 thoracic segments vs. 17 segments) and shorter pleural spines. Smaller cranidia have a longitudinal furrow connecting the glabellar pits. This furrow is less pronounced or absent in larger specimens.

Although not known from thoracic or pygidial material, *Oryctocephalus* sp. 2 of Rasetti from the Mount Whyte Formation and *Oryctocephalus* sp. of Sundberg and McCollum (2003) have the cranidial characteristics of *O. americanus* and are here assigned to this species.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain and Goldfield Hills, western Nevada. *Poliella denticulata* Biozone, Susan Duster Limestone Member, Pioche Shale, Pioche District, eastern Nevada; Pyramid Shale Member, Carrara Formation, Groom Range, central Nevada (Sundberg and McCollum 2003). *Wenkchemnia-Stephenaspis* Biozone, Mount Whyte Formation, British Columbia, Canada (Rasetti 1951).

Oryctocephalus indicus (Reed, 1910)

Plate 8, figures 9, 12–13

1910 *Oryctocephalus* cf. *reynoldsi* Reed, pp. 12–13, pl. 1, figs 22–24.
1910 *Zacanthoides indicus* Reed, pp. 9–10, pl. 1, fig. 15.
1934 *Oryctocephalus kobayashii* Saito, pp. 231–232, pl. 25, figs 23–25.
1938 *Oryctocephalus indicus* (Reed); Resser, p. 38.
1967 *Oryctocephalus indicus* (Reed); Kobayashi, 1967, p. 486, fig. 11*a–b*.
1969 *Oryctocephalus* cf. *reynoldsi* Reed; Sastry and Mamgain, p. 17.
1969 *Zacanthoides indicus* Reed; Sastry and Mamgain, p. 11, pl. 3, fig. 4.
1974 *Oryctocephalus incurvus* Lu and Chien, *in* Lu *et al.*, p. 101, pl. 39, fig. 8.
1983 *Oryctocephalops incurvus* (Lu and Chien, *in* Lu *et al.*); Lu and Qian, pp. 26–27, pl. 3, figs 6–7.
1983 *Oryctocephalops tongrenensis* Lu and Qian, p. 27, pl. 3, figs 4–5.
1997 *Oryctocephalus indicus* (Reed); Jell and Hughes, pp. 34–35, pl. 5, figs 16–19.
1997 *Oryctocephalus indicus* (Reed); Sundberg and McCollum, pp. 1073–1077, figs 9.1–9.8, 9.10.

EXPLANATION OF PLATE 4

Figs 1–4, 7–8. *Oryctocephalus americanus* sp. nov. 1, large, partial paratype cranidium, USNM 517578, USNM loc. 41971; ×7. 2, damaged paratype cranidium, USNM 517577, USNM loc. 41964; ×7. 3, paratype cranidium, USNM 517587, USNM loc. 41984; ×10. 4, holotype cranidium, USNM 517583, USNM loc. 41978; ×12. 7, paratype, articulated thoracic segments and pygidium, USNM 517584, USNM loc. 41978, arrow marks boundary between thorax and pygidium; ×7. 8, paratype, articulated thoracic segments and pygidium, USNM 517580, USNM loc. 41976, arrow marks boundary between thorax and pygidium; ×7. All specimens from Emigrant Formation, Split Mountain, Nevada.

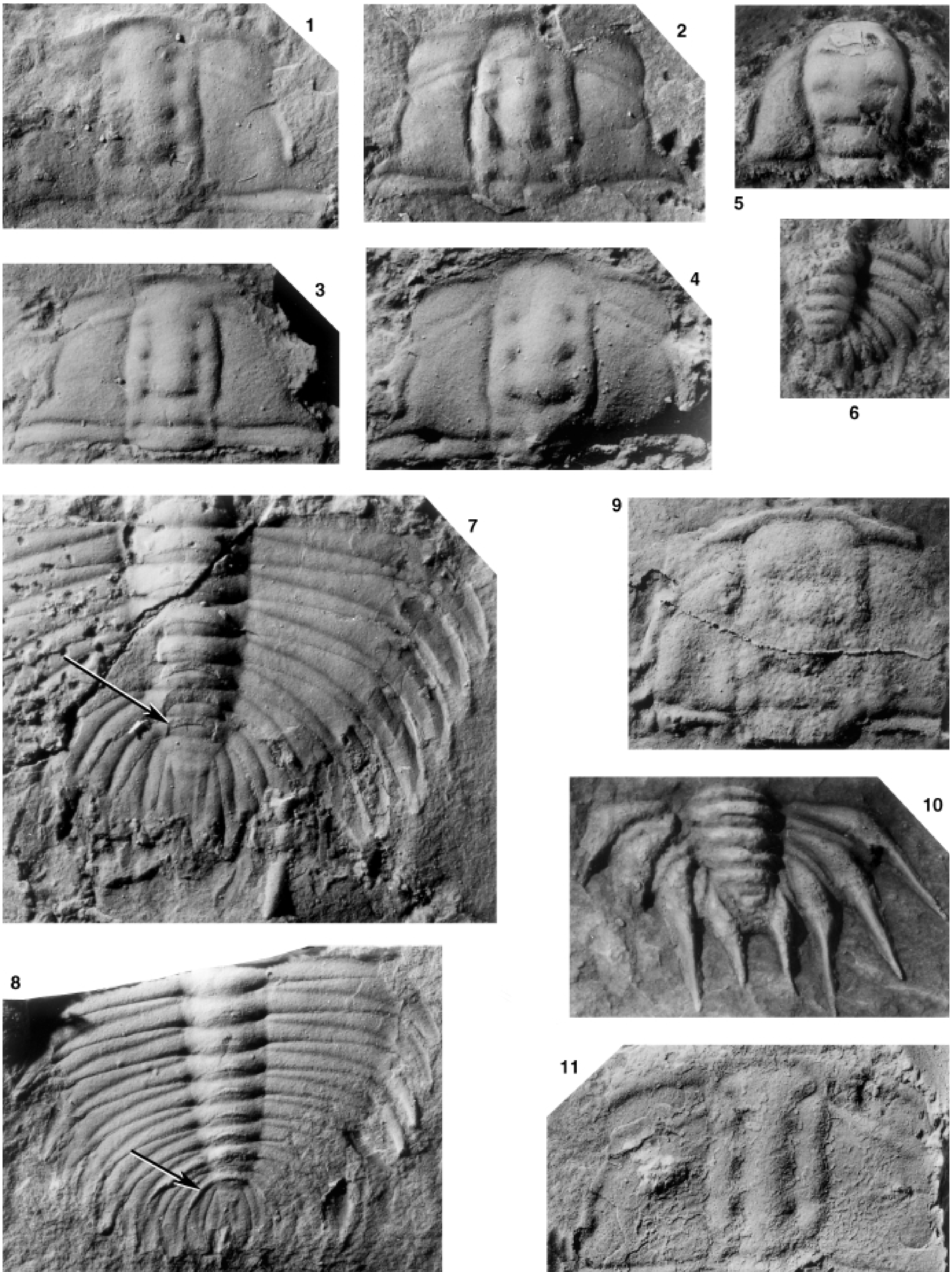
Figs 5–6. *Oryctocephalites runcinatus* Shergold, 1969. 5, small damaged, exfoliated cranidium, USNM 517574. 6, small partial pygidium, USNM 517575. Both from USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×10.

Figs 9–10. *Oryctocephalus orientalis* Saito, 1934. 9, latex cast of nearly complete cranidium, USNM 517593, USNM loc. 41976, Emigrant Formation, Split Mountain, Nevada. 10, latex cast of tectonically distorted pygidium, USNM 517594, USNM loc. 42019, Monola Formation, Saline Range, California. Both ×7.

Fig. 11. *Oryctocephalus* sp. A. Latex cast of partial cranidium, USNM 517591, USNM loc. 41969, Emigrant Formation, Split Mountain, Nevada; ×7.5.

All specimens are from the *Amecephalus arrojosensis* Biozone (basal Middle Cambrian).

PLATE 4



SUNDBERG and McCOLLUM, *Oryctocephalus*

1997 *Oryctocephalus indicus* (Reed); Yuan, Zhao, Wang, Zhou, and Chen, pl. 4, figs 1–6.
1997 *Oryctocephalops tongrenensis* Lu and Qian; Yuan, Zhao, Wang, Zhou, and Chen, pl. 4, figs 8–9.
1999 *Oryctocephalus indicus* (Reed); Yuan, Zhao, and Guo, pl. 1, fig. 6.
1999 *Oryctocephalus indicus* (Reed); Zhao, Yuan , Zhu, Yang, Guo, Qian, Huange, and Pan, pl. 4, fig. 4.
1999 *Oryctocephalus indicus* (Reed); Sundberg, Yuan, McCollum, and Zhao, pl. 1, fig. 3.

Material. Seventy-six cranidia from USNM localities 41986–41991, Emigrant Formation, Split Mountain. Several tens of specimens from USNM locality 41076, Emigrant Formation, Goldfield Hills. Several specimens from 41079, 42013?, and 42021, Monola Formation, Saline Range.

Remarks. A single specimen questionably assigned to *O. indicus* in Sundberg and McCollum (1997, fig. 9.9) has wide plural spines similar to *O. americanus* discussed above. This specimen may be related to *O. americanus*, but it contains at least three pairs of pygidial spines similar to *O. indicus*.

Distribution. Maozhuangian (= Maochuang Stage), Spiti, India (Reed 1910). Korea (Saito 1934; = Mansanri Formation?, Chang 1988). *Danzhaiaspis-Xingrenaspis* Biozone, Kaili Formation, south-west China (Chang 1988; Yuan *et al.* 1997, 1999). *Oryctocephalus indicus* Biozone, Emigrant and Monola formations, Split Mountain and Goldfield Hills, Nevada and Saline Range, Saline Valley, Inyo Mountains, California (Sundberg and McCollum 1997; this paper).

Oryctocephalus nyensis Palmer, *in* Palmer and Halley 1979

Plate 8, figure 11

1979 *Oryctocephalus nyensis* Palmer, *in* Palmer and Halley, pp. 84–85, pl. 6, figs 13–15.
1997 *Oryctocephalus nyensis* Palmer, *in* Palmer and Halley; Sundberg and McCollum, pp. 1077–1079, fig. 11.1, 3–8.

Material. Cranidium from USNM locality 42013, Monola Formation, Saline Range.

Remarks. The single specimen has only two transglabellar furrows at the S1 and S2 position and the expanding frontal lobe typical of the specimens from the Groom Range of central Nevada.

Distribution. *Oryctocephalus indicus* Biozone, Monola Formation, Saline Range, California. *Poliella denticulata* Biozone, Pyramid Shale Member, Carrara Formation, Groom Range, central Nevada (Palmer and Halley 1979; Sundberg and McCollum 1997, 2003).

Oryctocephalus orientalis Saito, 1934

Plate 4, figures 9–10

1934 *Oryctocephalus orientalis* Saito, pp. 230–231, pl. 25, figs 17–21.
1999 *Oryctocephalus* cf. *orientalis* Saito; Yuan, Zhao, and Guo, pl. 2, fig. 17.

Material. Cranidium from USNM locality 41976, Emigrant Formation, Split Mountain. Cranidium and pygidium from USNM locality 42019, Monola Formation, Saline Range.

Remarks. The two cranidia that are preserved in mudstone are identical to the specimens illustrated by Saito (1934) and Yuan *et al.* (1999). The pygidium is also similar to that illustrated by Saito (1934, pl. 25, fig. 21), which was incorrectly assigned to *O. indicus* by Sundberg and McCollum (1997). The material from the Kaili Formation is found in the *Olenoides jialaoensis* Biozone, which according to Yuan *et al.* (1999) is above *Oryctocephalus indicus*. However, *Olenoides jialaoensis* occurs with *Oryctocephalus indicus* (Yuan *et al.* 1997) and is presumably from the *Danzhaiaspis-Xingrenaspis* Biozone as well.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, western Nevada; Monola Formation, Saline Range, western Nevada. *Ptychoparia* beds, Mansanri Formation? (Chang 1988), Korea (Saito 1934). *Olenoides jialaoensis* Biozone, Kaili Formation, south-east China (Yuan *et al.* 1999).

Oryctocephalus sp. A

Plate 4, figure 11

Material. Cranidium from USNM locality 41969, Emigrant Formation, Split Mountain.

Remarks. Only the cranidia of this species is known. It is similar to *O. indicus* and *O. americanus*, but differs by having no transglabellar furrows at the S1 to S3 positions and nearly parallel-sided glabella. The slight expansion of the frontal lobe is similar to *O. nyensis*.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, western Nevada.

Genus ORYCTOCEPHALITES Resser, 1939

Type species. *Oryctocephalites typicalis* Resser, 1939.

Oryctocephalites resseri Rasetti, 1951

Plate 8, figure 10

1951 *Oryctocephalites resseri* Rasetti, p. 196, pl. 15, fig. 9.
1957 *Oryctocephalites resseri* Rasetti; Rasetti, p. 960, pl. 119, figs 1–2.

Material. Cranidium from USNM locality 41079, Monola Formation, Saline Range.

Remarks. This species is one of the few *Oryctocephalites* that have exsagittal furrows connecting the S1 to S3 rounded pits. The shale specimen from the Saline Range agrees well with the type material, given its compaction and slight tectonic distortion.

Distribution. *Oryctocephalus indicus* Biozone, Monola Formation, Saline Range, western Nevada. *Plagiura-Kochaspis* Zone, Mount Whyte Formation, British Columbia, Canada (Rasetti 1951, 1957).

Oryctocephalites runcinatus Shergold, 1969

Plate 4, figures 5–6; Plate 8, figure 8

1956 *Oryctocephalites* cf. *typicalis* Resser; Öpik, p. 43.
1969 *Oryctocephalites runcinatus* Shergold, pp. 29–32, pl. 6, figs 3–8; pl. 7, figs 1–4, text-fig. 10.

Material. Five cranidia, three partial shields, and three pygidia from USNM localities 41972–41973, 41975, 41978, 41981, 41983, 41984?, and 41985, Emigrant Formation, Split Mountain. Cranidium from USNM locality 42005, Emigrant Formation, Goldfield Hills.

Remarks. This species is one of the few *Oryctocephalites* that have lateral glabellar furrows that join the axial furrows and the S0 to S3 pits developed as slits. The shale specimens from Split Mountain agree well with the type material, given their compaction. The limestone specimens are small, but they display the original convexity of the species.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain and Goldfield Hills, western Nevada. *Ptychagnostus gibbus* Biozone, Arthur Creek Formation, Australia (Shergold 1969).

Subfamily ORYCTOCARINAE Hupé, 1953

Genus MICRORYCTOCARA Sundberg and McCollum, 1997

Type species. *Microryctocara nevadensis* Sundberg and McCollum, 1997.

Microryctocara nevadensis Sundberg and McCollum, 1997

Plate 8, figures 4–6

1997 *Microryctocara nevadensis* Sundberg and McCollum, pp. 1085–1086, fig. 15.1–10.
1997 *Euarthricocephalus* sp. 2 Yuan, Zhao, Wang, Zhou, and Chen, pl. 3, fig. 8.

Material. Eighty-one cranidia from USNM localities 41986–41991, Emigrant Formation, Split Mountain. Several specimens from USNM localities 41076 and 42005, Emigrant Formation, Goldfield Hills. Several specimens from USNM locality 41079, Monola Formation, Saline Range.

Remarks. The material from Split Mountain is poorly preserved due to their small size and the leaching of the sediments. However, a few complete specimens illustrate six bluntly terminated thoracic segments, not the five reported by Sundberg and McCollum (1997), and a narrow librigena with poorly defined border and border furrow and a very short genal spine. *Euarthricocephalus* sp. 1 of Yuan *et al.* [1997 = *Microryctocara* (Yuan *et al.* 1999)] also contains a similar librigena. The presence of a genal spine is not known for other members of Oryctocarinae (Whittington 1995).

Euarthricocephalus sp. 2 Yuan *et al.* (1997) is equivalent to *Microryctocara nevadensis*, differing only in having smaller intergenal spines. *Microryctocara nevadensis* differs from *Euarthricocephalus* sp. 1 Yuan *et al.* (1997) of the *Wuxunaspis* Biozone (Lower Cambrian) of the Kaili Formation (Yuan *et al.* 1999) by having longitudinal glabellar furrows, less pronounced interpleural furrows, and smooth pygidial surface.

A few specimens of *M. nevadensis* occur at USNM locality 42005 with typical elements of the *Amecephalus arrojosensis* Biozone at the top of the biozone. This is the oldest occurrence of the species in the United States.

Distribution. *Oryctocephalus indicus* Biozone, Emigrant Formation, Split Mountain and Goldfield Hills, western Nevada; Monola Formation, Saline Range, California. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Goldfield Hills, western Nevada. *Danzhaiaspis-Xingrenaspis* Biozone, Kaili Formation, south-east China (Yuan *et al.* 1997, 1999).

Genus OVATORYCTOCARA Chernysheva, 1962

Type species. *Oryctocara ovata* Chernysheva, 1960.

EXPLANATION OF PLATE 5

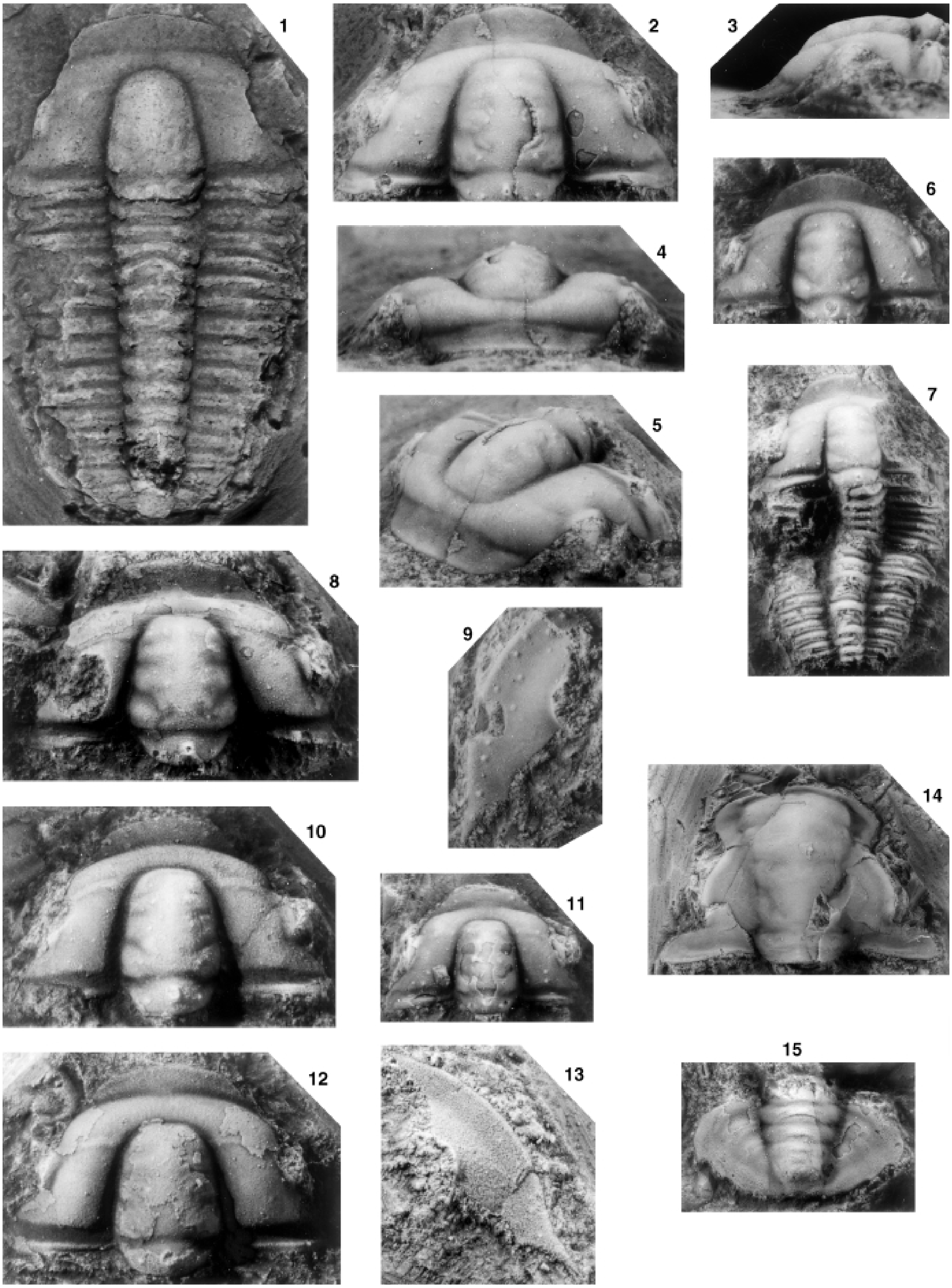
Figs 1–9. *Syspacephalus variosus* sp. nov., Form A. 1, nearly complete, articulated paratype specimen, USNM 517657, USNM loc. 42005, Emigrant Formation, Goldfield Hills, Nevada; ×7. 2–5, mostly testate holotype cranidium, USNM 517608, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7. 6, testate paratype cranidium, USNM 517634, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7. 7, articulated, testate paratype cranidium and thorax, USNM 517612, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7. 8, partially testate, paratype cranidium, USNM 517609, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7. 9, testate paratype librigena, USNM 517652, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×10.

Figs 10–13. *Syspacephalus variosus* sp. nov., Form B. 10, exfoliated paratype cranidium, USNM 517635; ×7. 11, mostly testate paratype cranidium, USNM 517611; ×7. 12, mostly exfoliated paratype cranidium, USNM 517644; ×7. 13, testate paratype librigena, USNM 517654; ×10. All specimens from USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada.

Figs 14–15. *Wenkchemnia sulcata* Rasetti, 1951. 14, testate cranidium, USNM 517683; ×3. 15, testate pygidium, USNM 517684; ×5. Both from USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada.

All specimens are from the *Amecephalus arrojosensis* Biozone (basal Middle Cambrian).

PLATE 5



SUNDBERG and McCOLLUM, *Syspacephalus*, *Wenkchemnia*

Ovatoryctocara? sp.

Plate 7, figure 10

Material. Four pygidia from USNM localities 41984 and 41985, Emigrant Formation, Split Mountain.

Remarks. The few small pygidia have the well-developed pleural and interpleural bands, complete margin, and an elongated, tapered axis matching the known species of *Ovatoryctocara*. No cranidia that can be assigned to this taxon were found.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, western Nevada.

Order PTYCHOPARIIDA Swinnerton, 1915
Suborder PTYCHOPARIINA Richter, 1932
Family unassigned

Genus AMECEPHALUS Walcott, 1924

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

Amecephalus arrojosensis (Lochman, 1952)

Plate 3, figure 12

1952 *Strotocephalus arrojosensis* Lochman, pp. 157–158, pl. 21, figs 29–34.
2000 *Amecephalus arrojosensis* (Lochman); Sundberg and McCollum, pp. 607–610, fig. 5.1–13.

Material. Twenty-five cranidia, seven librigenae, thorax, and complete shield from USNM localities 41953?, 41956–41958, 41974, 41978, and 41985, Emigrant Formation, Split Mountain. Thirty-one specimens from USNM locality 41992, Emigrant Formation, Goldfield Hills. Several specimens from USNM localities 42008–42011, 42014–42015, 42018, and 42020, Monola Formation, Saline Range.

Remarks. The shale specimens compare well to the specimens preserved in limestone from the 15-m level at Split Mountain and from the Pioche Shale and Arrojos Formation. Complete specimens have 17 thoracic segments that have moderately long, flat pleural spines and poorly developed fulcrum. Specimens of *Amecephalus arrojosensis* from the Saline Range compare well to specimens from other areas although they are tectonically distorted. Exceptions are those specimens from USNM localities 42015 at 8·75m and 42011 from approximately 8 m that are nearly effaced with little separation between the anterior border and preglabellar area and those from 42011 that have either flat or convex anterior borders instead of concave borders. These specimens from localities 42015 and 42011 may represent a new species, but given that they are tectonically distorted and that good specimens of *A. arrojosensis* are found both below and above, these effaced specimens may represent a local variation and are here placed in *A. arrojosensis*.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain and Goldfield Hills, western Nevada; Monola Formation, Saline Range, California; Comet Shale and Susan Duster Limestone members, Pioche Shale, eastern Nevada (Sundberg and McCollum 2000); Arrojos Formation, Caborca, Mexico (Lochman 1952).

Genus CRASSIFIMBRA Lochman, 1947

Type species. *Onchocephalus walcotti* Resser, 1937

Remarks. The type species is possibly conspecific to *Onchocephalus thia* Walcott, 1917*b*; see Palmer (1958).

Crassifimbra walcotti (Resser, 1937)

Plate 1, figures 9–10

1886 *Crepicephalus augusta* Walcott (part), p. 208, pl. 28, fig. 2*b* (only).
1890 *Crepicephalus augusta* Walcott; Walcott, p. 653, pl. 96, fig. 9 (only).
1916*a* *Crepicephalus augusta* Walcott; Walcott, p. 204, pl. 29, fig. 6 (only).
1937 *Onchocephalus walcotti* Resser, p. 21.
1947 *Crassifimbra walcotti* (Resser); Lochman, pp. 64, 71, text-figs 1–3.
1958 *Crassifimbra walcotti* (Resser); Palmer, pp. 157–161, pl. 25, figs 1–3 (only).
non 1958 *Crassifimbra walcotti* (Resser); Palmer, pp. 157–161, pl. 25, figs 4, 7–25; pl. 26, figs 1–24 (only) [= *Eokochaspis metalaspis* Sundberg and McCollum, 2000, pp. 618–619; also, see Fritz 1968, p. 224].
1962 *Antagmus* (*Antagmus*) *walcotti* (Resser); Shaw, pp. 334–335.
1968 *Crassifimbra walcotti*? (Resser); Fritz, pp. 223–224, pl. 37, figs 23–26.
2000 *Crassifimbra walcotti* (Resser); Sundberg and McCollum, pp. 618–619, fig. 11.1–8.

Material. Three cranidia and one librigena from USNM locality 41939, Emigrant Formation, Split Mountain.

Remarks. Two fragmented cranidia and one complete, but moderately preserved specimen illustrate the low relief glabella, effaced furrows, median inbend of the anterior border furrow, and profile and curvature of the anterior border typical of the species. The librigena of this species has not been illustrated previously. The single librigena possesses a wide anterior border, narrow genal area, shallow lateral border, and a short genal spine that continues the evenly curved lateral margin.

Distribution. *Olenellus* Biozone, Emigrant Formation, Split Mountain, western Nevada; Combined Metals Member, Pioche Shale, eastern Nevada (Palmer 1958; Sundberg and McCollum 2000).

Genus EOKOCHASPIS Sundberg and McCollum, 2000

Type species. *Eokochaspis nodosa* Sundberg and McCollum, 2000.

Eokochaspis nodosa Sundberg and McCollum, 2000

Plate 2, figures 1–2, 4

2000 *Eokochaspis nodosa* Sundberg and McCollum, pp. 611–614, fig. 7.1–20.

Material. One hundred and thirty-five cranidia, 23 librigenae, and 11 pygidia from USNM localities 41940?, 41941–41950, Emigrant Formation, Split Mountain.

Remarks. Specimens preserved in the basal mudstones of the Emigrant Formation show the original convexity and ornamentation that permits their comparison to the silicified specimens from the Pioche Shale. Specimens that are more compressed have a more subdued medial inbend and the granular surface is more difficult to determine. Some specimens also have a more equal subdivision of the frontal area with longer preglabellar fields, and thus start to resemble *Eokochaspis piochensis* (Palmer, *in* Palmer and Halley 1979); however, these specimens are still associated with the curved, non-deflected genal spine typical of *E. nodosa*. Articulated shields contain 13 thoracic segments.

Distribution. *Eokochaspis nodosa* Biozone, Emigrant Formation, Split Mountain, western Nevada; Comet Shale Member, Pioche Shale, eastern Nevada (Sundberg and McCollum 2000).

Eokochaspis delamarensis? Sundberg and McCollum, 2000

Plate 2, figures 3, 7

2000 *Eokochaspis delamarensis* Sundberg and McCollum, pp. 614–616, figs 8.1–15, 9.1–3.

Material. Eleven cranidia and one librigena from USNM locality 41940, Emigrant Formation, Split Mountain.

Remarks. A few flattened, shale specimens are tentatively assigned to this species based on their effaced nature, short genal spine, and overall cranidial, glabellar, and librigenal shape.

Distribution. *Eokochaspis nodosa* Biozone, Emigrant Formation, Split Mountain, western Nevada; Comet Shale Member, Pioche Shale, eastern Nevada (Sundberg and McCollum 2000).

Eokochaspis longspina? Sundberg and McCollum, 2000

Plate 3, figure 9

2000 *Eokochaspis longspina* Sundberg and McCollum, pp. 616–618, fig. 10.1–11.

Material. Twenty cranidia from USNM localities 41954 and 41956–41957, Emigrant Formation, Split Mountain.

Remarks. Several shale specimens are tentatively assigned to this species based on their wide and curved anterior border, glabellar outline, and palpebral lobes. The librigenae that are needed to verify the specific identification are lacking in the collections.

Distribution. *Eokochaspis nodosa* Biozone, Emigrant Formation, Split Mountain, western Nevada. Comet Shale Member, Pioche Shale, eastern Nevada (Sundberg and McCollum 2000).

Eokochaspis piochensis? (Palmer, *in* Palmer and Halley 1979)

Plate 2, figures 5–6

1979 *Eoptychoparia piochensis* Palmer, *in* Palmer and Halley, p. 105, pl. 7, figs 1–5.
2000 *Eokochaspis piochensis* (Palmer, *in* Palmer and Halley); Sundberg and McCollum, pp. 619–622, fig. 12.1–3.

Material. Fourteen cranidia from USNM localities 41951–41953, Emigrant Formation, Split Mountain.

Remarks. *Eokochaspis piochensis* in the basal Emigrant Formation is comparable to those found in the Pioche Shale with their relatively straight anterior border, long anterior branch of the facial suture, glabellar length, moderately defined glabellar furrows, construction of the posterior area of the fixigena, librigenal shape, and the length and posterolateral projection of the genal spine. These specimens differ in their relatively longer preglabellar area.

Distribution. *Eokochaspis nodosa* Biozone, Emigrant Formation, Split Mountain, western Nevada; Comet Shale Member, Pioche Shale, eastern Nevada (Sundberg and McCollum 2000).

MEXICELLA Lochman, 1948

Type species. *Mexicella mexicana* Lochman, 1948.

Mexicella robusta Sundberg and McCollum, 2000

Plate 3, figure 11

1979 cf. *Mexicella*? *stator* (Walcott); Palmer and Halley, pp. 109–110, pl. 8, fig. 23.
2000 *Mexicella robusta* Sundberg and McCollum, pp. 622–624, fig. 13.1–10.

Material examined. Cranidium and partial thorax from USNM locality 41992, Emigrant Formation, Goldfield Hills. Cranidium and partial thorax from USNM locality 42009, Monola Formation, Saline Range.

Remarks. Only two specimens have been found in the shales of the Emigrant and Monola formations in the study area.

Distribution. *Amecephalus arrojosensis* Biozone, Monola Formation, Saline Range, California; Emigrant Formation, Goldfield Hills, western Nevada; Comet Shale and Susan Duster Limestone members, Pioche Shale, eastern Nevada; Pyramid Shale Member, Carrara Formation, southern Nevada (Sundberg and McCollum 2000).

NYELLA Palmer, *in* Palmer and Halley 1979

Type species. *Poulsenia granosa* Resser, 1939.

Nyella? sp.

Plate 7, figure 9

Material examined. Eleven cranidia and two librigenae from USNM localities 42012 and 41079, Monola Formation, Saline Range.

Remarks. A few distorted specimens have been found in the limestones and shales of the Monola Formation. These are identical to a *Nyella*? species from the Pioche Shale that is presently under study. Because the Monola Formation material is tectonically distorted and the Pioche Shale material is well preserved, the nomenclature of this species is left open until the Pioche material can be described. A preliminary cladistic analysis suggests an affiliation of this species with *Nyella granosa* and *Kockaspis liliana* (Walcott, 1886). Thus, the generic placement of this species is questioned.

A single specimen was found preserved in shales at USNM locality 41079, which also contains the faunal elements of the *O. indicus* Biozone.

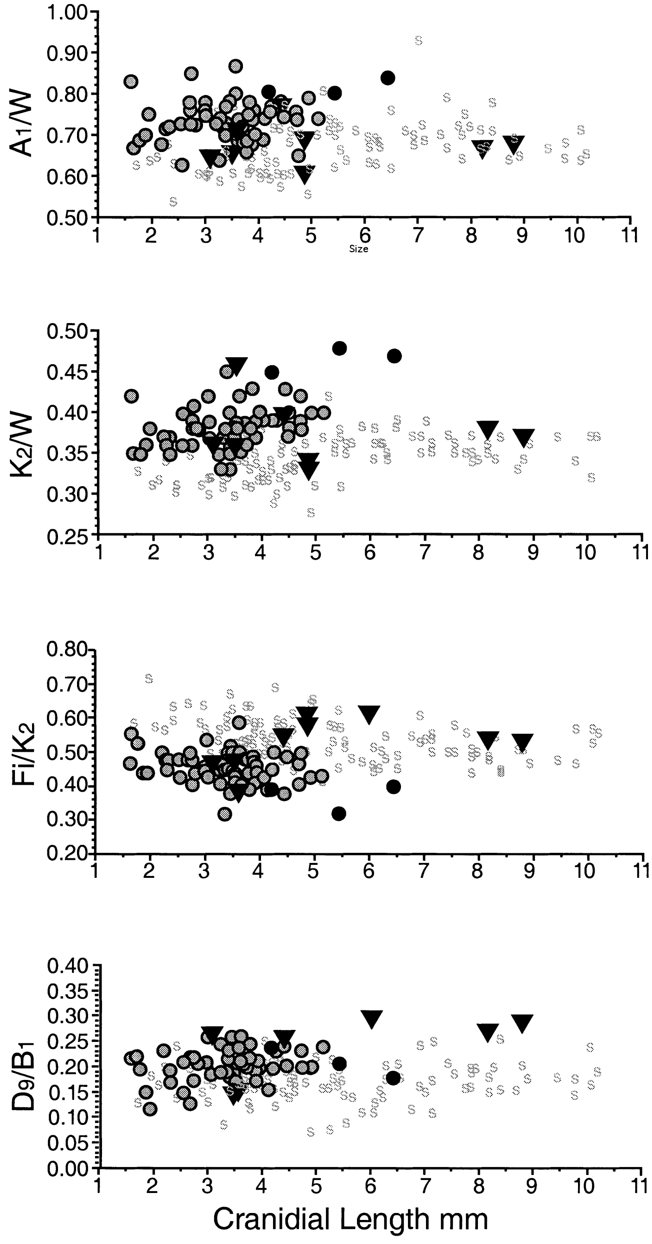
Distribution. *Amecephalus arrojosensis* Biozone, Monola Formation, Saline Range, western Nevada. *Oryctocephalus indicus* Biozone, Monola Formation, Saline Range, western Nevada; Susan Duster Limestone and Log Cabin members, Pioche Shale, eastern Nevada; Pyramid Shale Member, Carrara Formation, southern Nevada (unpublished data).

ONCHOCEPHALITES Rasetti, 1957

Type species. *Onchocephalites laevis* Rasetti, 1957.

Emended diagnosis. Cranidium subsquare with glabella wide and tapered; anterior border convex, moderately curved; anterior margin of palpebral lobes adjacent to S3 or L4; fixigena narrow, downsloping; anterior border furrow, lateral glabellar furrows, and axial furrows shallow to effaced; occipital furrow and posterior border furrow moderately deep. Anterior branches of facial suture moderately convergent; posterior branches moderately divergent. Librigena with small genal spine. Thorax with pleural terminations short and rounded. Pygidium micropygous, transversely elongated, axis nearly extending to posterior margin, anterolateral corners adjacent to anterior portion of axis.

Remarks. The emended diagnosis is based on the addition of a new species, *O. claytonensis*, which is known from articulated shields. Rasetti separated *Onchocephalites* from *Onchocephalus* Resser, 1937, in its effaced furrows, narrower fixigena, and angular turn of the anterior branches of the facial sutures. The angularity of the anterior branch is not as dramatic as illustrated by Rasetti (1957, text-fig. 2) and some of his photographs show much smoother curvature of the anterior branch from the anterior area of the fixigena to the anterior border. Based on the analysis of the three illustrated specimens of *O. laevis* and 60 specimens of *O. claytonensis*, *Onchocephalites* has a narrower fixigenal area and a higher length to width ratio than *Onchocephalus* (comparisons made to *O. maior* Rasetti, 1951; *O. depressus* Rasetti, 1951; and *O. fieldensis* Rasetti, 1951; Text-fig. 7). *Onchocephalites claytonensis* has a more pronounced anterior border furrow, axial furrows, and lateral glabellar furrow than *O. laevis*, but still not as much as *Onchocephalus*.



TEXT-FIG. 7. Bivariate plots of *Onchocephalites laevis* Rasetti, 1957 (solid circles), *Onchocephalites claytonensis* sp. nov. (grey circles), *Syspacephalus* species (S), *Onchocephalus* species (triangles) illustrating differences in the ratios of cranidial length to cranidial width (A_1/W), basal glabellar width to cranidial width (K_2/W), fixigena width to basal glabellar width (Fi/K_2), and the sagittal distance of the anterior margin of the palpebral lobe from the anterior margin of the frontal lobe to glabellar length (D_9/B_1) versus cranidial length.

Rasetti (1957) also compared *Onchocephalites* with *Syspacephalus* and differentiated the two, with the former having a more posterior position and greater length of the palpebral lobes and the angular bend of the anterior branches of the facial sutures. *Onchocephalites* differs from *Syspacephalus* [comparisons made with *S. perola* (Walcott, 1917); *S. laticeps* Rasetti, 1951; *S. variosus* sp. nov.; and *S. longus* Palmer (*in* Palmer and Halley, 1979)] in having a higher length to width ratio, generally more posteriorly placed palpebral lobes, narrower and shorter posterior area of the fixigena, narrower fixigena, and a wider glabella (Text-fig. 7). *Onchocephalites claytonensis* overlaps with *Syspacephalus* in the position of its palpebral lobes and length of the posterior area of the fixigena. *Onchocephalites* does not have longer palpebral lobes than *Syspacephalus*.

Onchocephalites laevis Rasetti, 1957

Plate 6, figure 16

1957 *Onchocephalites laevis* Rasetti, p. 962, pl. 121, figs 5–9, text-fig. 2.

Material. Eighty-four cranidia from USNM localities 42010–41012 and 42015–42017, Monola Formation, Saline Range.

Remarks. Several cranidia have the general outline and effacement typical of *Onchocephalites laevis*.

Distribution. *Amecephalus arrojosensis* Biozone, Monola Formation, Saline Range, western Nevada. *Plagiura-Kochaspis* Zone, Mount Whyte Formation, British Columbia, Canada (Rasetti 1957).

Onchocephalites claytonensis sp. nov.

Plate 6, figures 1–15

Derivation of name. Named for its common occurrence at the Split Mountain section in Clayton Ridge.

Holotype. Cranidium USNM 517520 (Pl. 6, figs 4–6) from USNM locality 41985, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, Nevada.

Paratypes. USNM 517503 (Pl. 6, fig. 3), 517504 (Pl. 6, figs 8–11), 517505–517506, 517507 (Pl. 6, fig. 7), 517508, 517509 (Pl. 6, fig. 12), 517510 (Pl. 6, fig. 14), 517511–517519, 517521–517558, 517559 (Pl. 6, fig. 15), 517560–517563, 517564 (Pl. 6, fig. 13), and 517565 from USNM locality 41985, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, Nevada. USNM 517566, 517567 (Pl. 6, fig. 2), 517568, and 517569 (Pl. 6, fig. 1) from USNM locality 41992, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Goldfield Hills, Nevada.

Additional material. A couple of hundred specimens from USNM localities 41961, 41966, 41968, 41970, 41972, 41974, 41976, 41978, 41982–41983, and 41985, Emigrant Formation, Split Mountain. Approximately 100 specimens from USNM localities 41992, 41994, 41997?, and 41998–42007, Emigrant Formation, Goldfield Hills. A hundred specimens from USNM localities 41079, 42010, 42013, 42015 and 42020–42021, Monola Formation, Saline Range.

Diagnosis. Cranidium has shallow lateral glabellar furrows, axial furrows, anterior border furrow, median inbend of the anterior border, and wide palpebral lobes.

Description. Cranidium small, length 1·6–5·4 mm ($n = 60$); subrectangular, length 74 ± 5 per cent width; moderate convexity (sag. and trans.); anterior margin evenly curved to nearly straight, width (J_2) 61 ± 5 per cent cranidial width (J_1); posterior margin, excluding occipital ring, project slightly posterolaterally. Anterior branches of facial sutures slightly to moderately convergent to anterior border, strongly convergent to anterior margin; posterior branches moderately divergent. Glabella moderately long, moderately tapered, width at anterior end 78 ± 4 per cent glabellar width (K_2); moderately convex (sag. and trans.); frontal lobe bluntly rounded; length 73 ± 2 per cent cranidial length; width 38 ± 2 per cent cranidial width. Axial furrow deep, deeper posteriorly, straight to slightly convex in outline; preglabellar furrow moderately deep, uniform depth, narrow, slightly curved to straight. Lateral glabellar furrows moderate depth to shallow; S1 bifurcated and directed slightly posteriorly, S2 directed slightly posteriorly, S3 directed laterally, and S4 directed slightly anteriorly. Occipital ring slightly elevated above glabella, moderately convex, length 24 ± 3 per cent glabellar length; occipital node; posterior margin convex posteriorly. S0 slightly flexed anteriorly and deep, shallowest medially. Frontal area subequally divided; length 27 ± 2 per cent cranidial length. Preglabellar field slightly convex, slightly downsloping, length 47 ± 5 per cent frontal area length. Anterior border moderately convex, level, strongly tapering laterally, strongly curved to nearly straight, length 14 ± 2 per cent cranidial length; slight inbend towards frontal lobe, more prominent in smaller specimens. Anterior border furrow strongly curved to nearly straight, narrow, moderate depth, shallower than axial furrows, shallowest medially. Fixigena slightly convex, level to slightly downsloping, anterior area moderately downsloping, width 46 ± 5 per cent glabellar width (K_2). Palpebral lobes slightly upturned, moderately wide and moderately short, width 37 ± 6 per cent lobe length, length 30 ± 4 per cent glabellar length; anterior margin located about opposite of S3 or L4, 21 ± 3 per cent glabellar length behind glabellar anterior margin; palpebral furrow moderately deep to shallow. Ocular ridge weak, slightly arched, directed moderately posterolateral from glabella at 69 ± 3 degrees to axis. Posterior area of fixigena triangular shaped, moderately downsloping, rounded termination; length 36 ± 5 per cent glabellar length; width 55 ± 5 per cent glabella length. Posterior border moderately convex, expanding and flattening distally; border furrow deep, straight, curving anterior distally, not expanding.

Hypostoma and rostral plate unknown.

Librigena small, length 2·7–3·4 mm (n = 4); moderately wide, width 25–45 per cent length without spine; lateral margin moderately curved. Genal field slightly convex, width 45–65 per cent librigenal width. Border moderately convex, uniform width, width 20–25 per cent librigenal width; lateral border furrow shallow, uniform depth, wide; posterior border furrow short and shallow. Genal spine moderate length, 10–25 per cent librigenal length, deflected laterally.

Twelve to 13 thoracic segments, pleura projecting laterally, decreasing in width posteriorly. Axial furrows well defined, moderate and uniform depth. Thoracic pleura wide, 116 ± 12 per cent of axial width, projected horizontally to fulcrum then downward and very slightly posterolaterally to distal end; anterior and posterior pleural bands uniform length, narrowing laterally from fulcrum; posterior pleural band wider than anterior pleural band; pleural tips short, flat, rounded; facets well developed; pleural furrow deep, expanding laterally after fulcrum, projecting into pleural tip.

Pygidium very small, length 0·30–0·35 mm (n = 3); suboval, length 30–35 per cent width; margin smooth, anterior margin curved slightly posterolaterally, anterolateral corners angled, adjacent to anterior end of axis; lateral margins slightly curved; median notch absent; low convexity (sag. and trans.). Axis slightly or not tapered, width at midlength 85–100 per cent anterior width, anterior width 35–45 per cent pygidial width; length 100 per cent pygidial length, no postaxial ridge; two axial rings, slightly convex; small terminal axial piece, posteriorly rounded; axial furrow shallow, uniform depth; axial ring furrows shallow and of 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 slightly posterolaterally; other furrows barely visible; first anterior pleural band weakly developed, other bands faint or not visible. Border narrow, wider at anterolateral corners, slightly downsloping; border furrow absent.

All parts appear to be smooth.

Remarks. *Onchocephalites claytonensis* is a variable species, displaying a range in the tapering of the

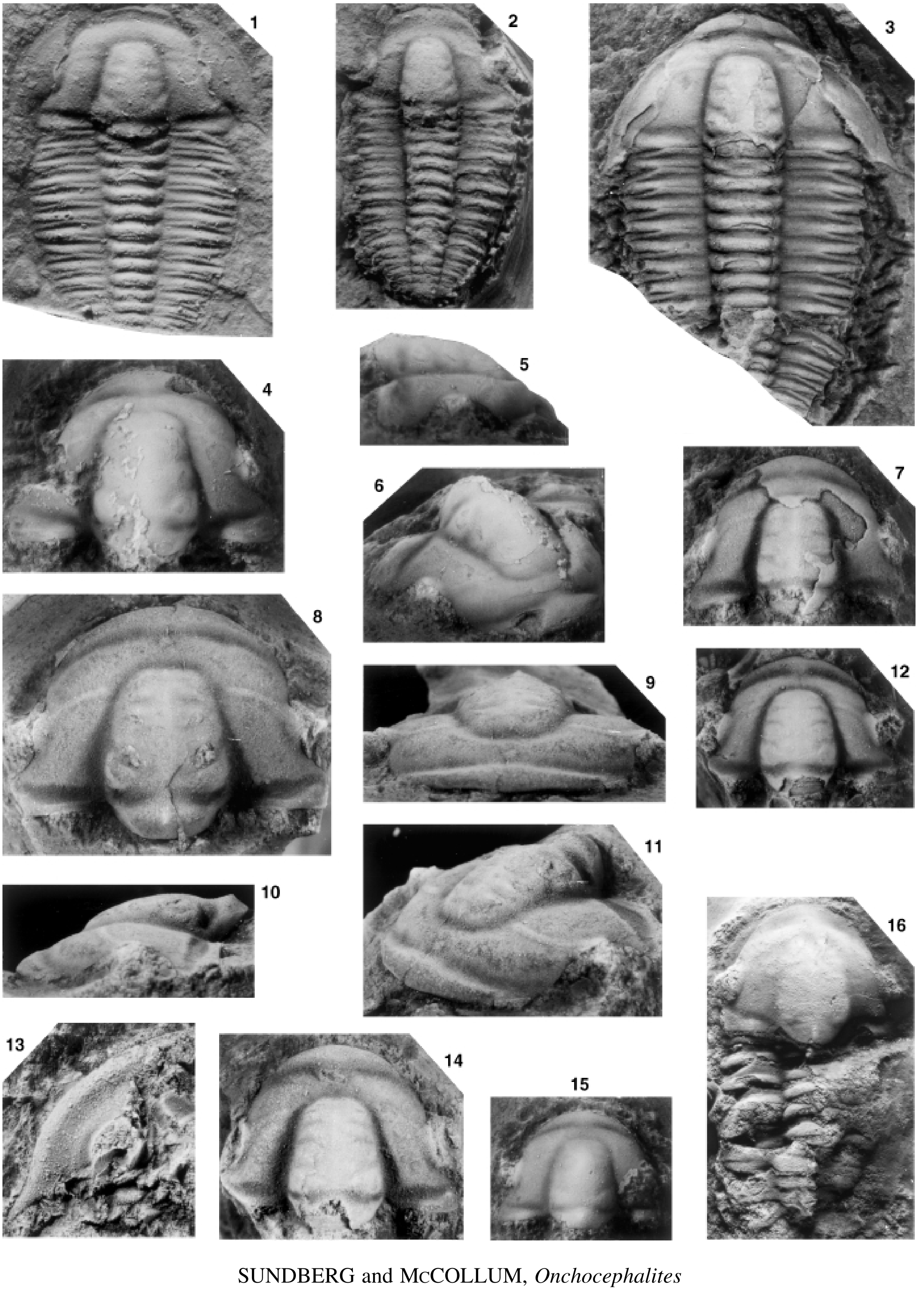
---

EXPLANATION OF PLATE 6

Figs 1–15. *Onchocephalites claytonensis* sp. nov. 1, latex cast of nearly complete, articulated paratype specimen, USNM 517569, USNM loc. 41992, Emigrant Formation, Goldfield Hills, Nevada; ×7. 2, nearly complete, articulated paratype specimen, USNM 517567, USNM loc. 41992, Emigrant Formation, Goldfield Hills, Nevada; ×7. 3, nearly complete, articulated paratype specimen, USNM 517503, USNM loc. 41969, Emigrant Formation, Split Mountain, Nevada; ×7. 4–6, mostly testate holotype cranidium, USNM 517520, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7. 7, mostly exfoliated paratype cranidium, USNM 517507, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7. 8–11, exfoliated paratype cranidium, USNM 517504, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7. 12, exfoliated paratype cranidium, USNM 517509, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7. 13, testate paratype librigena, USNM 517564, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×10. 14, exfoliated paratype cranidium, USNM 517510, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7. 15, testate paratype cranidium, USNM 517559, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7.

Fig. 16. *Onchocephalus laevis* Rasetti, 1957. Exfoliated partially articulated cranidium and thorax, USNM 517570, USNM loc. 42012, Monola Formation, Saline Range, Nevada; ×5.

All specimens are from the *Amecephalus arrojosensis* Biozone (basal Middle Cambrian).



SUNDBERG and McCOLLUM, *Onchocephalites* glabella, rounding of the frontal lobe, and the curvature of the anterior border. It differs from the type species in its more pronounced lateral glabellar furrows, axial furrows, anterior border furrow, median inbend of the anterior border, and wider palpebral lobes. It is also similar to *Syspacephalus perola* (Walcott, 1917) in its tapering glabella and anterior border, but differs in that most forms have a more curved anterior border, convex anterior border, and a librigenal spine. This species was originally reported as *Syspacephalus perola* or *S*. sp. by Sundberg and McCollum (1997).

Onchocephalites claytonensis is common in the 15-m limestone concretion layers and in the shales 3–4 m below. The cranidial description is derived from the specimens preserved in limestone, most of which exfoliate upon preparation. The remaining portion of the description is based on shale specimens. Comparison of 15 cranidia preserved in both shales and limestones illustrate only significant differences in length-width ratio (limestone average 70 per cent vs. 66 per cent average in shale), glabellar width-cranidial width (39 vs. 38 per cent), glabellar tapering (76 vs. 72 per cent), palpebral lobe length-glabellar length (29 vs. 32 per cent), and position of anterior margin of palpebral lobe-glabellar length (20 vs. 16 per cent). All of these differences can be explained through the compaction of specimens in shale.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain and Goldfield Hills, western Nevada; Monola Formation, Saline Range, California. *Oryctocephalus indicus* Biozone, Emigrant Formation, Horse Thief Canyon, western Nevada; Monola Formation, Saline Range and Saline Valley, California (Sundberg and McCollum 1997).

Genus 'ONCHOCEPHALUS' Walcott, 1917

Type species. *Onchocephalus thia* Walcott, 1917.

Remarks. A preliminary phylogenetic analysis indicated that the Middle Cambrian *Onchocephalus* are probably polyphyletic. In addition, the type species may be conspecific with *Crassifimbra walcotti* (see Palmer 1958), which is considerably different from the Middle Cambrian *Onchocephalus* in the effacement of the glabellar furrows, inbending of the anterior border, and its more triangular outline. Thus, the species discussed here is referred to '*Onchocephalus*' until it can be taxonomically placed.

'*Onchocephalus*' cf. *maior* Rasetti, 1951

Plate 7, figure 8

1951 *Onchocephalus maior* Rasetti, p. 234, pl. 14, figs 19–23.
1957 *Onchocephalus maior* Rasetti; Rasetti, pp. 962–963, pl. 120, fig. 11.

EXPLANATION OF PLATE 7

Figs 1–6. *Tonopahella goldfieldensis* gen. and sp. nov. 1, 3, partially, articulated holotype specimen, USNM 517665, USNM loc. 41992, Emigrant Formation, Goldfield Hills, Nevada; 1, ×2; 3, ×7. 2, paratype cranidium, USNM 517658, USNM loc. 41961, Emigrant Formation, Split Mountain, Nevada. 4, nearly complete, articulated paratype specimen, USNM 517671, USNM loc. 41992, Emigrant Formation, Goldfield Hills, Nevada; ×2. 5, latex cast of nearly complete, articulated paratype specimen, USNM 517664, USNM loc. 41992, Emigrant Formation, Goldfield Hills, Nevada; ×2. 6, latex cast of nearly complete, articulated paratype specimen, USNM 517676, USNM loc. 41992, Emigrant Formation, Goldfield Hills, Nevada; ×2.

Fig. 7. *Tonopahella walcotti* (Sundberg and McCollum, 2000). Exfoliated partial cranidium, USNM 517681, USNM loc. 42008, Monola Formation, Saline Range, Nevada; ×5.

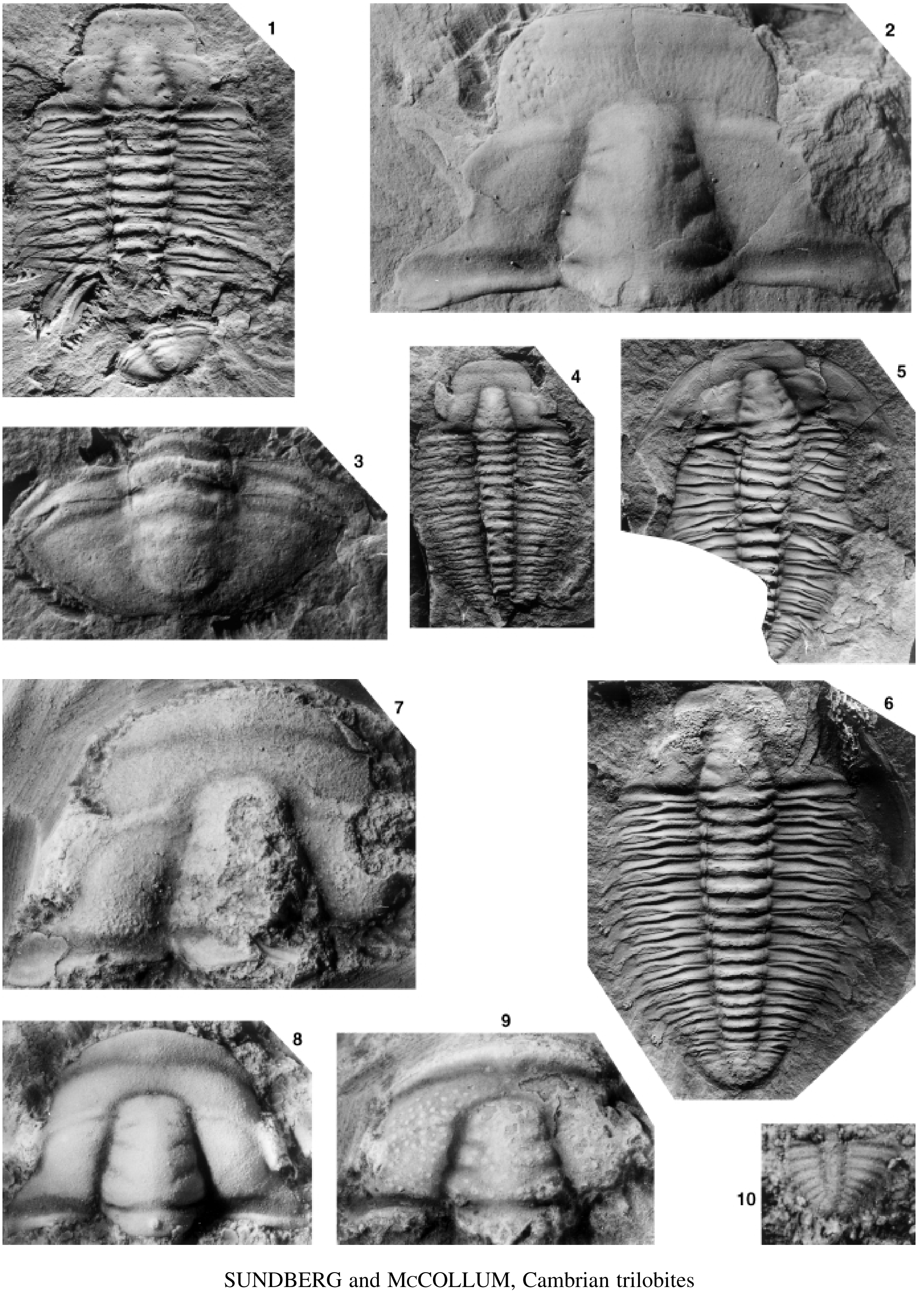
Fig. 8. '*Onchocephalus*' cf. *maior* Rasetti, 1951. Testate cranidium, USNM 517571, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7.

Fig. 9. *Nyella*? sp. Tectonically shortened, testate cranidium, USNM 517499, USNM loc. 42012, Monola Formation, Saline Range, Nevada; ×5.

Fig. 10. *Ovatoryctocara*? sp. Partial pygidium, USNM 517595, USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×15.

All specimens are from the *Amecephalus arrojosensis* Biozone (basal Middle Cambrian).

PLATE 7



SUNDBERG and McCOLLUM, Cambrian trilobites

Material. Three cranidia from USNM localities 41966 and 41985, Emigrant Formation, Split Mountain.

Remarks. '*Onchocephalus*' cf. *maior* from the Split Mountain lacks fine granulation and has the relatively shorter posterior area of the fixigena seen in the type specimens from British Columbia. The taxon is left in open nomenclature owing to the lack of adequate material.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, western Nevada.

Genus PARAANTAGMUS Qiu, 1980

Type species. *Paraantagmus angustalus* Qiu, 1980.

Paraantagmus latus Yuan and Li, 1999

Plate 3, figures 1–9

1999 *Paraantagmus latus* Yuan and Li, p. 418, pl. 1, figs 8–10.

Material. Thirty-six cranidia, three librigenae, and two pygidia from USNM locality 41953, Emigrant Formation, Split Mountain. Cranidium from USNM locality 42008, Monola Formation, Goldfield Hills.

Remarks. The Split Mountain specimens possess the median inbend of the anterior border, granular surface with two sizes of granules, convergent anterior branches of the facial sutures, truncated frontal lobe, tapered glabella, and short palpebral lobes typical of the Chinese specimens. These specimens differ only in having a stronger curved anterior border in the larger specimens. However, the maximum cranidial length illustrated by Yuan and Li is 4 mm; the Split Mountain material has lengths close to 10 mm. The librigena and pygidium of this species have not been illustrated previously. The librigena (Pl. 3, fig. 6) has a relatively narrow lateral border, wide genal area, and a relatively long, narrow-based, and flat genal spine. The pygidium (Pl. 3, fig. 8) is small and transversely ovate with a relatively long, slightly tapering axis with two or three axial rings separated by shallow axial ring furrows. The pleural field has well-defined

---

EXPLANATION OF PLATE 8

Figs 1–3. *Syspacephalus* cf. *laticeps* Rasetti, 1951. 1, partially testate cranidium, USNM 517605. 2, partial exfoliated cranidium, USNM 517606. 3, partial, exfoliated cranidium, USNM 517607. All specimens from USNM loc. 41985, Emigrant Formation, Split Mountain, Nevada; ×7.

Figs 4–6. *Microryctocara nevadensis* Sundberg and McCollum, 1997. 4, latex cast of holotype cranidium, USNM 488938, USNM loc. 41078, Emigrant Formation, Goldfield Hills, Nevada; ×17. 5, latex cast of pygidium, USNM 488947, USNM loc. 41078, Emigrant Formation, Goldfield Hills, Nevada; ×17. 6, latex cast of complete shield, USNM 517498, showing librigenal spines, USNM loc. 41987, Emigrant Formation, Split Mountain, Nevada; ×7

Fig. 7. *Wenkchemnia spinicollus*? Rasetti, 1951. Tectonically distorted cranidium, USNM 517682, USNM loc. 42012, Monola Formation, Saline Range, California; ×5.

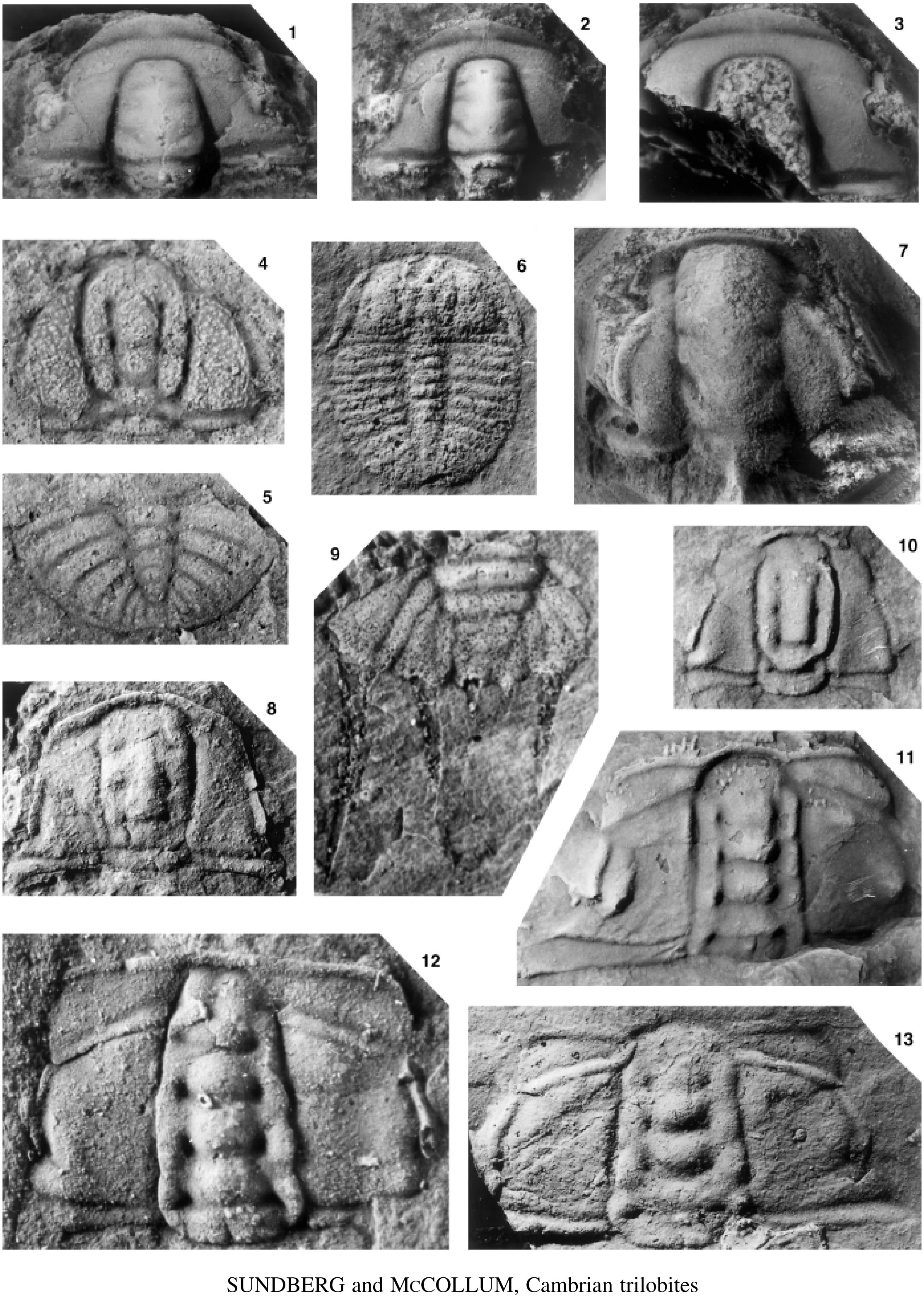
Fig. 8. *Oryctocephalites runcinatus* Shergold, 1969. Testate cranidium, USNM 517573, USNM loc. 41972, Emigrant Formation, Split Mountain, Nevada; ×7.

Figs 9, 12–13. *Oryctocephalus indicus* (Reed, 1910). 9, partial pygidium, USNM 488951, USNM loc. 41079, Monola Formation, Saline Range, California; ×7.5. 12, latex cast of cranidium, USNM 488953, USNM loc. 41080, Saline Valley, California; ×7.5. 13, latex cast of cranidium, USNM 517590, USNM loc. 41987, Emigrant Formation, Split Mountain, Nevada; ×5.

Fig. 10. *Oryctocephalites resseri* Rasetti, 1951. Cranidium, USNM 517572, USNM loc. 417079, Monola Formation, Saline Range, California; ×7.

Fig. 11. *Oryctocephalus nyensis* Palmer (*in* Palmer and Halley 1979). Latex cast of partial cranidium, USNM 517592, USNM loc. 42013, Monola Formation, Saline Range, California; ×5.

All specimens are from the *Amecephalus arrojosensis* or *Oryctocephalus indicus* biozones (basal Middle Cambrian).



SUNDBERG and McCOLLUM, Cambrian trilobites

first anterior pleural bands and pleural furrows, with more posterior bands and furrows poorly defined. The anterolateral corners are sharply rounded and adjacent to the anterior portion of the axis.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, western Nevada; Monola Formation, Saline Range, California. *Paragraulos* Zone, Laoyingshan Formation, Huainan, Anhui, China (Yuan and Li 1999).

Genus SYSPACEPHALUS Resser, 1936

Type species. *Agraulos charops* Walcott, 1917.

Remarks. Revision of *Syspacephalus* and related taxa is needed. Robison (1976) and Babcock (1994) have suggested that *Syspacephalus* and *Elrathina* Resser, 1937, are synonymous. Blaker and Peel (1997) synonymized *Elrathina*, *Syspacephalus*, and *Eoptychoparia* Rasetti, 1955, with *Ptychoparella* Poulsen, 1927, based on the morphological variation seen in *Ptychoparella* sp. A. However, *Ptychoparella* sp. A was not compared to the type species, *P. brevicauda* Poulsen, 1927, which has more posteriorly placed palpebral lobes. A phylogenetic analysis of these four genera needs to be done before they are synonymized. Such an analysis is beyond the scope of this paper.

Syspacephalus cf. *laticeps* Rasetti, 1951

Plate 8, figures 1–3

1951 *Syspacephalus laticeps* Rasetti, pp. 243–244, pl. 9, figs 1–6.

Material. Eleven cranidia from USNM locality 41985, Emigrant Formation, Split Mountain.

Remarks. A few cranidia have the slightly convex, short, tapering anterior border, slightly tapering glabella, wide fixigena, and trapezoidal cranidium typical of *Syspacephalus laticeps*. These specimens differ from the type material in having more posteriorly placed palpebral lobes and shorter posterior area of the fixigena. The nomenclature is left open because of the few specimens present.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, western Nevada.

Syspacephalus variosus sp. nov.

Plate 5, figures 1–13

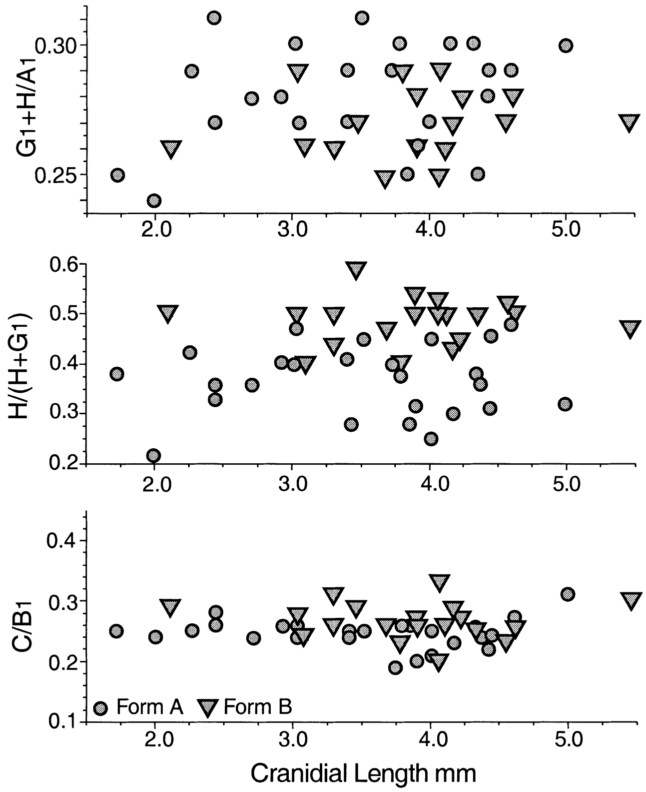
Derivation of name. Named for the variation in the frontal area.

Holotype. Cranidium USNM 517608 (Pl. 5, figs 2–5) from 41985, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, Nevada.

Paratypes. USNM 517609 (Pl. 5, fig. 8), 517610–517611, 517612 (Pl. 5, fig. 11), 517613 (Pl. 5, fig. 7), 517614–517633, 517634 (Pl. 5, fig. 6), 517635 (Pl. 5, fig. 10), 517636–517643, 517644 (Plate 5, fig. 12), 517645–517651, 517652 (Pl. 5, fig. 9), 517653, 517654 (Pl. 5, fig. 13), 517655, and 517656 from USNM locality 41985, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, Nevada. USNM 517657 (Pl. 5, fig. 1) from USNM locality 42005, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Goldfield Hills, Nevada.

Additional material. Numerous specimens from USNM localities 41966, 41968, 41970, 41972, 41974, 41982, and 41985, Emigrant Formation, Split Mountain. Thirty-eight cranidia from USNM localities 42005 and 42007?, Emigrant Formation, Goldfield Hills. Seven cranidia questionably assigned from USNM localities 42011–42012, 42015–42016, and 42020, Monola Formation, Saline Range.

Diagnosis. Cranidium with glabella narrow and slightly tapered; anterior margin of palpebral lobes adjacent to L3 or S3; fixigena moderately wide; anterior of fixigena strongly downsloping; granular surface. Librigena with genal spine.



TEXT-FIG. 8. Bivariate plots of Form A (circles) and Form B (triangles) of *Syspacephalus variosus* sp. nov. illustrating their differences in the ratios of frontal area length to cranidial length [$(G_1 + H)/A_1$], preglabellar area to frontal area length [$H/(H + G_1)$], and palpebral lobe length to glabellar length (C/B_1) versus cranidial length.

Description. Cranidium small, length 1·7–5·5 mm (n = 44, ratios are derived from specimens larger than 3 mm, Form A: n =18; Form B: n = 18); trapezoidal, length 63 ± 3 per cent width; moderate convexity (sag. and trans.); anterior margin evenly curved, width (J_2) 54 ± 7 per cent cranidial width (J_1); posterior margin, excluding occipital ring, project slightly posterolaterally. Anterior branches of facial sutures moderately to strongly convergent to anterior margin; posterior branches moderately divergent. Glabella moderately elongate, moderately tapered, width at anterior end 78 ± 4 per cent glabellar width (K_2); moderately convex (sag. and trans.); frontal lobe bluntly rounded to flattened; length 72 ± 2 per cent cranidial length; width 32 ± 2 per cent cranidial width. Axial furrow deep, deeper posteriorly, straight to slightly convex in outline; preglabellar furrow moderately deep, uniform depth, narrow, slightly curved to straight. Lateral glabellar furrows moderate depth to shallow; S1 bifurcated and directed laterally, S2 directed laterally, S3 and S4 directed slightly anteriorly. Occipital ring slightly elevated above glabella, moderately convex, length 22 ± 2 per cent glabellar length; small occipital node; posterior margin convex to nearly straight. S0 slightly flexed anteriorly and of moderate depth, shallowest medially. Frontal area unequally divided; length 28 ± 2 per cent (Form A) or 27 ± 1 per cent (Form B) cranidial length. Preglabellar field slightly convex, strongly downsloping, length 37 ± 7 per cent (Form A) or 49 ± 5 per cent (Form B) frontal area length. Anterior border flat to concave (Form A) to slightly convex (Form B), downsloping to level, slightly (Form A) to strongly (Form B) tapering laterally, slightly curved to nearly straight, length 18 ± 2 per cent (Form A) or 14 ± 2 per cent (Form B) cranidial length; no inbend towards frontal lobe. Anterior border furrow slightly curved to nearly straight, narrow, shallow depth, shallower than axial furrows, shallowest medially. Fixigena slightly convex, level, anterior area strongly downsloping, width 57 ± 5 per cent glabellar width (K_2). Palpebral lobes slightly upturned, moderately narrow and moderately short, width 30 ± 5 per cent lobe length, length 29 ± 3 per cent (Form A) or 32 ± 3 per cent (Form B) glabellar length; anterior margin located about opposite L3 or S3, 19 ± 3 per cent glabellar length behind glabellar anterior margin; palpebral furrow shallow. Ocular ridge weak, straight, directed moderately to slightly posterolateral from glabella at 75 ± 5 degrees to axis. Posterior area of fixigena triangular shaped, moderately downsloping, rounded termination; length 39 ± 3 per cent glabellar length; width 72 ± 6 per cent glabella length. Posterior border moderately convex, expanding and flattening distally; border furrow deep, straight, curving anteriorly distally, not expanding.

Hypostoma and rostral plate unknown.

Librigena small, length 3·9 ± 0·4 mm (n = 5); moderate width, width 40 ± 2 per cent length without spine; lateral margin moderately curved. Genal field slightly convex, width 38 ± 5 per cent librigenal width. Border flat (Form A) to slightly convex (Form B), uniform width, width 35 ± 7 per cent librigenal width; lateral border furrow very shallow; posterior border furrow short and shallow. Genal spine short, 29 ± 8 per cent librigenal length, slightly deflected laterally.

Thorax with 14 segments, pleura projecting laterally, decreasing in width posteriorly. Axial furrows well defined, moderate and uniform depth. Thoracic pleura wide, 100–120 per cent of axial width, projected horizontally to fulcrum then downward and very slightly posterolaterally to distal end; anterior and posterior pleural bands of uniform length; posterior pleural band wider than anterior pleural band; pleural tips short, flat, pointed; pleural furrow deep, expanding laterally after fulcrum into pleural tip.

Pygidium poorly known. Transversely elongate, non-tapering axis nearly extending to margin. Anterior lateral corners adjacent to anterior portion of axis.

Occipital ring, fixigena, glabella, librigena and thoracic pleura with coarse and fine granules.

Remarks. *Syspacephalus variosus* is represented by numerous cranidia and partial shields preserved in limestone and shale. It has granular ornamentation, unlike other species in the genus. This species is dimorphic, with the forms differing in the frontal area construction and the length of the palpebral lobes (Text-fig. 8). Form A (Pl. 5, figs 1–9) has a concave to flat, long, non-tapering anterior border, shorter preglabellar area, and slightly shorter palpebral lobes. Form B (Pl. 5, figs 10–13) has slightly convex, short, strongly tapering anterior border, longer preglabellar area, and with slightly longer palpebral lobes. The differences between the two forms are significant (length of the anterior border, $P < 0{\cdot}0001$; length of preglabellar area, $P < 0{\cdot}0001$; length of palpebral lobe, $P < 0{\cdot}0144$). However, there is considerable overlap between the two populations (Text-fig. 8). Given this overlap and the similarity in the area behind the frontal area and the coarse and fine granulation, these two forms are considered to be the same species.

Syspacephalus variosus is most similar to *S. laticeps* Rasetti, 1951, in its glabellar outline, fixigenal width, and trapezoidal outline. This species differs by having granular ornamentation, a concave to flat anterior border, wider anterior border, stronger downsloping of the anterior area of the fixigena, and more posteriorly placed palpebral lobes.

The granular surface of shale specimens is not well expressed. Specimens from the Monola Formation in the Saline Range are questionably assigned to the species. The presence of granules cannot be established in these specimens because of their tectonic distortion and the poor condition of the exoskeleton.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Shale, Split Mountain and Goldfield Hills, western Nevada; Monola Formation?, Saline Range, California.

TONOPAHELLA gen. nov.

Type species. *Tonopahella goldfieldensis* sp. nov.

Derivation of name. Named for the nearby town of Tonopah, Nevada.

Diagnosis. Cranidia with glabella with deep axial furrows that bow inwards in outline, and S1 and S2 lateral glabellar furrows moderately deep. Palpebral lobes slightly upturned and moderately long (averages 40–45 per cent glabellar length). Ocular ridge directed slightly posterolaterally (averages 75–80 degrees). Anterior border level; border furrow shallow to moderately shallow; weakly curved, and interborder furrow absent. Anterior branches of facial suture slightly bowed. Fixigena with anterior area slightly downsloping; posterior area of moderate width (with averages 75–90 per cent glabellar length), moderately short (averages 35–40 of basal glabellar length); lateral extension of posterior branches not parallel. Librigenae with border area having triangular cross-section, genal spine moderately long, straight, and with moderately wide base. Thoracic segments with well-developed fulcurm, short pleural spines. Pygidia with pleural furrows weakly developed; anterolateral corners rounded, no pygidial spines or lobes. Pustules absent.

Remarks. A preliminary cladogram for the kochaspids (*sensu* Palmer *in* Palmer and Halley 1979) placed *Kochina*? *walcotti* Sundberg and McCollum, 2000, and *K*.? cf. *walcotti* (= *Tonopahella goldfieldensis*) as two branches after *Eokochaspis piochensis* and before the *Amecephalus* and related taxa. *Kochina* Resser, 1935, occurs within an amecephalid clade. Thus, these species need to be removed from *Kochina* and placed in a new genus, here named *Tonopahella*. The diagnosis above consists of character states that can be used to separate it from the other kochaspids.

Tonopahella is most similar to *Amecephalus* in having a moderately shallow anterior border furrow, shorter posterior length of fixigena, posterior branches that are not parallel at thin lateral extent, long palpebral lobes, and a librigenal border area with a triangular cross-section. It differs in having axial furrows that have an inward-curved outline, deeper S1 and S2 lateral glabellar furrows, no interborder furrow, a narrow genal spine base, short thoracic pleural terminations, and a well-developed fulcrum. It can be differentiated from *Eokochaspis* in having longer palpebral lobes, fixigena of shorter posterior length, the lateral extent of the posterior branches not being parallel, and a triangular cross-section to the librigenal border area.

Tonopahella goldfieldensis sp. nov.

Plate 7, figures 1–6

Derivation of name. Named for the type locality in the Goldfield Hills.

Holotype. Partially articulated, nearly complete shield USNM 517665 (Pl. 7, figs 1, 3) from USNM locality 41992, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Goldfield Hills, Nevada.

Paratypes. USNM 517658 (Pl. 7, fig. 2), 517659, and 517660 from USNM locality 41961; USNM 517661 from USNM locality 41972, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Split Mountain, Nevada. USNM 517662–517663, 517664 (Pl. 7, fig. 5), 517666–517670, 517671 (Pl. 7, fig. 4), 517672–517675, 517676 (Pl. 7, fig. 6), 517677, and 517678 from USNM locality 41992; USNM 517679 and 517680 from USNM locality 41993, *Amecephalus arrojosensis* Biozone, Emigrant Formation, Goldfield Hills, Nevada.

Additional material. Thirty-five cranidia, ten librigenae, and six pygidia from USNM localities 41961–41963, 41966–41967, 41969–41970, 41972, and 41980?, Emigrant Formation, Split Mountain. Forty-two specimens from USNM localities 41992–41993, 41995–41997, and 41999, Emigrant Formation, Goldfield Hills. Sixty-two specimens from USNM localities 42009 and 42019, Monola Formation, Saline Range.

Diagnosis. Cranidium with a nearly straight, slightly convex anterior border with shallow anterior border furrow.

Description. Cranidium moderate size, length 3·5–9·3 mm (n = 19); subrectangular, length 55 ± 4 per cent width; low convexity (sag. and trans.); anterior margin nearly straight, width (J_2) 50 ± 5 per cent cranidial width (J_1); posterior margin, excluding occipital ring, projects laterally. Anterior branches of facial sutures slightly divergent to midlength (exsag.) of preglabellar area, then slightly convergent to anterior border, moderately convergent to anterior margin; posterior branches strongly divergent. Glabella moderately elongated, strongly to very strongly tapered, width at anterior end 63 ± 5 per cent glabellar width (K_2); moderately convex (sag. and trans.); frontal lobe bluntly rounded; length 71 ± 2 per cent cranidial length; width 32 ± 2 per cent 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. Lateral glabellar furrows moderate depth; S1 bifurcated and directed posteriorly, S2 directed slightly posteriorly, S3 and S4 directed slightly to moderately anteriorly. Occipital ring slightly elevated above glabella, moderately convex, length 21 ± 2 per cent glabellar length; small occipital node; posterior margin convex posteriorly. S0 slightly flexed anteriorly and moderate depth, shallowest medially. Frontal area equally divided; length 29 ± 3 per cent cranidial length. Preglabellar field slightly convex, slightly downsloping, length 50 ± 5 per cent frontal area length. Anterior border slightly convex, level, slightly tapering laterally, nearly straight, length 15 ± 2 per cent cranidial length. Anterior border furrow nearly straight, narrow, shallow, shallower than axial furrows. No medial boss. Fixigena slightly convex, level, anterior area slightly downsloping, width 55 ± 6 per cent glabellar width (K_2). Palpebral lobes slightly upturned, narrow and long, width 24 ± 5 per cent lobe length, length 43 ± 4 per cent glabellar length; anterior margin located about opposite frontal lobe, 15 ± 5 per cent glabellar length behind glabellar anterior margin; palpebral furrow moderate depth. Ocular ridge moderate strength, slightly arched, directed slightly posterolateral from glabella at 83 ± 1 degrees to axis. Posterior area of fixigena strap-like, slightly downsloping, sharply terminated; length 38 ± 4 per cent glabellar length; width 87 ± 7 per cent glabella length. Posterior border moderately convex, expanding and flattening distally; border furrow moderate depth, straight, not expanding.

Hypostoma and rostral plate unknown.

Librigena moderate size, length 7·3 ± 2·8 mm (n = 5); moderately wide, width 45 ± 5 per cent length without spine; anterior portion of lateral margin moderately curved, posterior portion straight to slightly curved. Anterior part of dorsal surface developed as short projection. Genal field slightly convex, width 50 ± 4 per cent librigenal width. Border slightly convex, uniform width, width 19 ± 2 per cent librigenal width; lateral border furrow moderately shallow, uniform depth; posterior border furrow short and moderately shallow. Genal spine moderate length, 41 ± 6 per cent librigenal length. Doublure as wide as lateral border, with triangular cross-section extending into the spine.

Sixteen thoracic segments, pleura projecting laterally, decreasing in width posteriorly. Axial furrows well defined, moderate and uniform depth. Thoracic pleura wide, 130–150 per cent of axial width anteriorly and 170–200 per cent posteriorly, projected horizontally to fulcrum then downward and very slightly posterolaterally to distal end; anterior and posterior pleural bands uniform length, narrowing laterally from fulcrum; posterior pleural band wider than anterior pleural band; pleural tips posterolaterally directed, short, flat, pointed; facets well developed; pleural furrow deep, narrow, narrowing laterally after fulcrum, not projecting into pleural tip.

Pygidium small, length 1·7–3·5 mm (n = 7); suboval, length 41 ± 8 per cent width; margin smooth, anterior margin curved posterolaterally, anterolateral corners angled to rounded, adjacent to axial midlength; lateral margins moderately curved; median notch unknown; moderate convexity (sag. and trans.). Axis slightly tapered, width at midlength 85 ± 4 per cent anterior width, anterior width 34 ± 3 per cent pygidial width; length 91 ± 4 per cent pygidial length, no postaxial ridge; three axial rings, moderately convex; moderate terminal axial piece, posteriorly rounded; axial furrow shallow, uniform depth; axial ring furrows 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 posterolaterally; other furrows barely visible; first anterior pleural band weakly developed, other bands faint or not visible. Border narrow, wider at anterolateral corners, slightly downsloping; border furrow absent.

Genal caeca are present on the frontal area and fixigena. Possible fine granules on axial rings. Other parts appear to be smooth.

Remarks. *Tonopahella goldfieldensis* is known only from shale specimens; thus, the convexity information in the description probably does not accurately reflect the true convexity due to compaction. This species differs from *Tonopahella walcotti* in having a straighter, less tapered, less convex anterior border and a shallower anterior border furrow.

Distribution. *Amecephalus arrojosensis* Biozone, Emigrant Shale, Split Mountain and Goldfield Hills, western Nevada. Monola Formation, Saline Range, California.

Tonopahella walcotti (Sundberg and McCollum, 2000)

Plate 7, figure 7

2000 *Kochina*? *walcotti* Sundberg and McCollum, pp. 626–628, fig. 15.1–6.

Material. Two cranidia from USNM localities 42008 and 42014, Monola Formation, Saline Range.

Remarks. The two cranidia preserved in limestone are comparable to that from the limestone beds in the upper Comet Shale Member, Pioche Shale (Sundberg and McCollum 2000, fig. 15.1), in its curved anterior border.

Distribution. *Amecephalus arrojosensis* Biozone, Monola Formation, Saline Range, California; Comet Shale Member, Pioche Shale, eastern Nevada (Sundberg and McCollum 2000).

Ptychopariid sp. A

Plate 1, figure 8

Material. Four cranidia from USNM localities 41938 and 41939, Emigrant Formation, Split Mountain.

Remarks. Small cranidia that possess anteriorly placed, short palpebral lobes; a long, slightly tapered glabella; a truncated frontal lobe; and a relatively straight anterior margin are left unassigned. They are similar to *Illtydaspis* Fritz, 1991, from the Lower Cambrian of Canada, but differ in having shorter palpebral lobes and a well-defined frontal lobe.

Distribution. *Olenellus* Biozone, Emigrant Formation, Split Mountain, western Nevada.

Ptychopariid sp. B

Plate 1, figure 7

Material. Two cranidia from USNM localities 41936 and 41937, Mule Spring Limestone, Split Mountain.

Remarks. This species is similar to ptychopariid sp. A, but has a broader anterior border furrow and more convex anterior border.

Distribution. *Olenellus* Biozone, Mule Spring Limestone, Split Mountain, western Nevada.

Kochaspid? sp.

Plate 1, figure 11

Material. Cranidium from USNM locality 41938, Emigrant Formation, Split Mountain.

Remarks. A large, nearly complete cranidium has the posteriorly placed, small palpebral lobes, nearly parallel anterior branches of the facial sutures, tapering glabella, granular ornamentation, and interborder furrow typical of the kochaspids, specifically *Kochiella* Poulsen, 1927. The differences are the squared-off distal ends of the posterior portions of the fixigena and the strongly convex, wide anterior border. If this is truly *Kochiella* or a closely related taxon, then it is similar in age to the purported Lower Cambrian *Kochiella* from Greenland (Poulsen 1927; see also Sundberg and McCollum 2002) and is the oldest *Kochiella* in western North America.

Distribution. *Olenellus* Biozone, Emigrant Formation, Split Mountain, western Nevada.

Acknowledgments. We thank M. B. McCollum and the students at Eastern Washington University for their assistance in collecting the trilobites from the Emigrant and Monola formations. Collection activities were funded by NSF RUI grant EAR-9218892 and EAR-9973180 and the Eastern Washington University, Northwest Institute for Advanced Studies to L. B. McCollum. P. Jell provided valuable comments on the similarity of taxa between Chinese and North American faunas. J. Shergold provided an informative review of this paper.

REFERENCES

ALBERS, J. P. and STEWART, J. H. 1972. Geology and mineral deposits of Esmeralda County, Nevada. *Bulletin of the Nevada Bureau of Mines and Geology*, **78**, 80 pp., 2 pls.

BABCOCK, L. E. 1994. Systematics and phylogenetics of polymeroid trilobites from the Henson Gletscher and Kap Stanton formations (Middle Cambrian), North Greenland. *Bulletin, Grønlands Geologiske Undersøgelse*, **169**, 79–127.

BEECHER, C. E. 1897. Outline of a natural classification of the trilobites. *American Journal of Science*, *Series 4*, **3** (13), 89–106; 181–207.

BLAKER, M. R. and PEEL, J. S. 1997. Lower Cambrian trilobites from North Greenland. *Meddelelser om Grønland, Geoscience*, **35**, 145 pp.

CHANG WEN-TANG 1988. The Cambrian System in eastern Asia. Correlation chart and explanatory notes. *International Union of Geological Sciences*, **24**, 81 pp., 4 charts.

CHERNYSHEVA, N. E. 1960. *Principles of paleontology–arthropods, trilobites and crustaceans*. Gosudar, Moscow, 515 pp. [In Russian].

—— 1962. Kembriiske trilobity Semeistva Oryctocephalidae. *In* Problemy Neftegazonosnosti Sovetskoi Arktiki Paleontologiya i Biostratigrafiya 3. *Trudy Nauchno-Issledovatel'skii Geologo-Razvedochnyi Neftianoi Institut Arktiki* **127**, 3–52, 6 pls. [In Russian].

FRITZ, W. H. 1968. Lower and early Middle Cambrian trilobites from the Pioche Shale, east-central Nevada, U.S.A. *Palaeontology*, **11**, 183–235, pls 36–43.

—— 1972. Lower Cambrian trilobites from the Sekwi Formation type section, Mackenzie Mountains, north-western Canada. *Bulletin of the Geological Survey of Canada*, **212**, 90 pp., 20 pls.

—— 1991. Lower Cambrian trilobites from the Illtyd Formation, Wernecke Mountains, Yukon Territory. *Bulletin of the Geological Survey of Canada*, **409**, 77 pp., 17 pls.

HALL, J. 1859. Trilobites of the shales of the Hudson River Group. 59–62. *In: 12th Annual Report of the New York State Cabinet of Natural History*. Albany, New York, 111 pp.

—— 1861. Supplementary note to the thirteenth report of the Regents of the State Cabinet. 113–119. *In: 15th Annual Report of the New York State Cabinet of Natural History*. Albany, New York, 198 pp.

HUPÉ, P. 1953. Classe des Trilobites. 44–246. *In* PIVETEAU, J. (ed.). *Traité de Paléontologie, III*. Masson, Paris, 1063 pp.

KAESLER, R. L. (ed.). 1997. Volume 1: Introduction, Order Agnostida, Order Redlichiida. *Treatise on invertebrate paleontology, Part O, Arthropoda 1, Trilobita, Revised*. Geological Society of America, Boulder, and University of Kansas Press, Lawrence, 530 pp.

KOBAYASHI, T. 1935. The Cambro-Ordovician formations and faunas of South Chosen. Paleontology, pt III. Cambrian faunas of South Chosen with special study on the Cambrian trilobite genera and families. *Journal of the Faculty of Science, Imperial University of Tokyo*, **4** (2), 49–344, 24 pls.

—— 1967. Stratigraphy of the Chosen Group in Korea and southern Manchuria and its relation to the Cambro-Ordovician formations of other areas. Section C. The Cambrian of eastern Asia and other parts of the Continent. *Journal of the Faculty of Science, Imperial University of Tokyo*, **16**, 381–535.

JELL, P. A. and HUGHES, N. C. 1997. Himalayan Cambrian trilobites. *Special Papers in Palaeontology*, **58**, 113 pp., 32 pls.

LOCHMAN, C. 1947. Analysis and revision of eleven Lower Cambrian trilobite genera. *Journal of Paleontology*, **21**, 59–71.

—— 1948. New Cambrian trilobite genera from northwest Sonora, Mexico. *Journal of Paleontology*, **22**, 451–467, pls 69–70.

—— 1952. Trilobites. 60–162. *In* COOPER, G. A., ARELLANO, A. R. V., JOHNSON, J. H., OKULITCH, V. J., STAYANOW, A. and LOCHMAN C. Cambrian stratigraphy and paleontology near Caborca, northwestern Sonora, Mexico. *Smithsonian Miscellaneous Collections*, **119** (1), 184 pp., 31 pls.

LU YEN-HAO, CHANG WEN-TANG, CHIEN YI-YUAN, ZHU ZHAO-LING, LIN HUAN-LING, ZHOU SHIYI, SHANG SENGUI and YUAN JIN-LIANG 1974. Cambrian Trilobites. 82–107, pls 31–42. *In: A handbook of the stratigraphy and paleontology in southwest China*. Science Press, Beijing, 527 pp. [In Chinese].

—— and QIAN YI-YUAN 1983. Cambro-Ordovician trilobites from eastern Guizhou. *Palaeontologica Cathayana*, **1**, 1–105, 12 pls.

MCCOLLUM, L. B. and SUNDBERG, F. A. 1999. Stop 9. Biostratigraphy of the traditional Lower-Middle Cambrian boundary interval in the outer shelf Emigrant Formation, Split Mountain East section, Esmeralda County, Nevada. 29–34. *In* PALMER, A. R. (ed.). *Laurentia 99, V Field Conference of the Cambrian Stage Subdivision Working Group*, Institute for Cambrian Studies, Boulder, Colorado, 65 pp.

ÖPIK, A. A. 1956. Cambrian geology of the Northern Territory. 25–54. *In: El Sistema Cambrico, su paleogeograia y el problema de su base*, **2**. International Geological Congress, 20th Session, Mexico, 762 pp.

PALMER, A. R. 1957. Ontogenetic development of two olenellid trilobites. *Journal of Paleontology*, **31**, 105–128, pl. 19.

—— 1958. Morphology and ontogeny of a Lower Cambrian ptychoparioid trilobite from Nevada. *Journal of Paleontology*, **32**, 154–170, pls 25–26.

—— 1998*a*. A proposed nomenclature for stages and series for the Cambrian of Laurentia. *Canadian Journal of Earth Sciences*, **35**, 323–328.

—— 1998*b*. Terminal Early Cambrian extinction of the Olenellina: documentation from the Pioche Formation, Nevada. *Journal of Paleontology*, **72**, 650–672.

—— and HALLEY, R. B. 1979. Physical stratigraphy and trilobite biostratigraphy of the Carrara Formation (Lower and Middle Cambrian) in the southern Great Basin. *Professional Paper of the United States Geological Survey*, **1047**, 131 pp., 18 pls.

—— and REPINA, L. N. 1993. Through a glass darkly: taxonomy, phylogeny, and biostratigraphy of the Olenellina. *Contributions of the University of Kansas, Paleontology*, *New Series*, **3**, 1–35.

PENG, S. and ROBISON, R. A. 2000. Agnostid biostratigraphy across the Middle-Upper Cambrian boundary in Hunan, China. *Journal of Paleontology, Memoir*, **53**, 104 pp.

—— YUAN JIN-LIANG and ZHAO YUAN-LONG 2000. Taijiangian Stage: a new chronostratigraphic unit for the traditional lower Middle Cambrian in South China. *Journal of Stratigraphy*, **24** (1), 53–54. [In Chinese, English abstract].

POULSEN, C. 1927. The Cambrian, Ozarkian and Canadian faunas of northwest Greenland. *Meddelelser om Grønland*, **70**, 233–343, 8 pls.

QIU HONG-AN 1980. Lower Cambrian trilobites of the Mantou Formation from Xuxhou-Suxian area, N. Jiangsu and Anhui. *Bulletin of the Chinese Academy of Geological Sciences, Series 7*, **1** (1), 34–64. [Not seen].

RASETTI, F. 1951. Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains. *Smithsonian Miscellaneous Collections*, **116** (5), 277 pp., 34 pls.

—— 1955. Lower Cambrian ptychopariid trilobites from the conglomerates of Quebec. *Smithsonian Miscellaneous Collections*, **128** (7), 35 pp., 6 pls.

—— 1957. Additional fossils from the Middle Cambrian Mt. Whyte Formation of the Canadian Rocky Mountains. *Journal of Paleontology*, **31**, 955–972, pls 118–122.

REED, F. R. C. 1910. The Cambrian fossils of Spiti. *Palaeontologia Indica*, *The Geological Survey of India*, *Series 15*, **7**, *Memoir* **1**, 70 pp., 6 pls.

RESSER, C. E. 1935. Nomenclature of some Cambrian trilobites. *Smithsonian Miscellaneous Collections*, **93** (5), 29 pp.

—— 1936. Second contribution to nomenclature on Cambrian trilobites. *Smithsonian Miscellaneous Collections*, **95** (4), 29 pp.

—— 1937. Third contribution to nomenclature on Cambrian trilobites. *Smithsonian Miscellaneous Collections*, **95** (22), 1–59.

—— 1938. Fourth contribution to nomenclature of Cambrian fossils. *Smithsonian Miscellaneous Collections*, **97** (10), 1–43.

—— 1939. The *Ptarmigania* Strata of the northern Wasatch Mountains. *Smithsonian Miscellaneous Collections*, **98**, 72 pp., pls 1–14.

RICHTER, R. 1932. Crustacea (Paläontologie). 840–864, figs A, 1–65. *In* DITTLER, R., JOOS, G., KORSCHELT, E., LINEK, G., OLTMANNS, F. and SCHAUM, K. (eds). *Handwörtenbuch der Naturwissenschaften*. Second edition. Gustav Fisher, Jena.

ROBISON, R. A. 1976. Middle Cambrian trilobite biostratigraphy of the Great Basin. 39–50. *In* ROBISON, R. A. and A. J. ROWELL (eds). *Paleontology and depositional environments: Cambrian of western North America*. Brigham Young University Geology Studies, **23** (2), 227 pp.

SAITO, K. 1934. Older Cambrian Trilobita and Conchostraca from north-western Korea. *Japanese Journal of Geology and Geography*, **11**, 211–237, pls 25–27.

SASTRY, M. V. A. and MAMGAIN, V. D. 1969. *Bibliography of Indian Geology. Part 4. Paleontological index. Revised and enlarged. Part 1. Trilobita*. Manager of Publications, Civil Wing, Delhi, 39 pp.

SHAW, A. B. 1957. Quantitative trilobite studies II. Measurement of the dorsal shell of non-agnostidean trilobites. *Journal of Paleontology*, **31**, 193–207.

—— 1962. Paleontology of northwestern Vermont, VIII. Fauna of the Hungerford Slate. *Journal of Paleontology*, **36**, 314–321, pls 49–50.

SHERGOLD, J. H. 1969. Oryctocephalidae (Trilobita: Middle Cambrian) of Australia. *Bulletin of the Bureau of Mineral Resources, Geology and Geophysics*, **104**, 1–66, pls 1–12.

SUNDBERG, F. A. and MCCOLLUM, L. B. 1997. Oryctocephalids (Corynexochida: Trilobita) of the Lower-Middle Cambrian boundary interval from California and Nevada. *Journal of Paleontology*, **71**, 1065–1090.

—— —— 2000. Ptychopariid trilobites of the Lower-Middle Cambrian boundary interval, Pioche Shale, southeastern Nevada. *Journal of Paleontology*, **74**, 604–630.

—— —— 2002. *Kochiella* Poulsen, 1927, and *Hadrocephalites* new genus (Trilobita: Ptychopariida) from the early Middle Cambrian of western North America. *Journal of Paleontology*, **76**, 76–94.

—— —— 2003. Trilobites of the lower Middle Cambrian *Poliella denticulata* Biozone (new) of southeastern Nevada. *Journal of Paleontology*, **77**, 331–359.

—— YUAN JIN-LIANG, MCCOLLUM, L. B. and ZHAO YUAN-LONG 1999. Correlation of the Lower-Middle Cambrian boundary of South China and western North America. *Acta Palaeontologica Sinica*, **38** (Supplement), 102–107.

SWINNERTON, H. H. 1915. Suggestions for a revised classification of trilobites. *Geological Magazine*, *New Series*, **2**, 407–496, 538–545.

WALCH, J. E. I. 1771. *Die Naturgeschichte der Versteinerungen, zur Erläuterung der Knorrischen Sammlung von Merkwürdigkeiten der Natur.* Volume **4**, Part 3. Paul Jonathan Felstecker, Nürnberg, 184 pp., 81 pls.

WALCOTT, C. D. 1886. Second contribution to the studies on the Cambrian faunas of North America. *Bulletin of the United States Geological Survey*, **30**, 1–369, pls 1–33.

—— 1890. The fauna of the Lower Cambrian or *Olenellus* Zone. *10th Annual Report of the United States Geological Survey*, **1**, 515–629.

—— 1910. *Olenellus* and other genera of the Mesonacidae. *Smithsonian Miscellaneous Collections*, **53** (6), 231–422, 95 pls.

—— 1916*a*. Cambrian geology and paleontology of Cambrian trilobites. *Smithsonian Miscellaneous Collections*, **64** (3), 157–258, pls 24–38.

—— 1916*b*. Cambrian geology and paleontology of Cambrian trilobites. *Smithsonian Miscellaneous Collections*, **64** (5), 303–456, 67 pls.

—— 1917. Cambrian geology and paleontology, 3, fauna of the Mount Whyte Formation. *Smithsonian Miscellaneous Collections*, **67** (3), 61–114.

—— 1924. Cambrian geology and paleontology, part 5, no. 2. Cambrian and lower Ozarkian trilobites. *Smithsonian Miscellaneous Collections*, **75**, 53–60.

WHITE, C. A. 1874. *Preliminary report upon invertebrate fossils, with descriptions of new species*. United States Geographical Exploration of the West 100th Meridian [Wheeler Survey], pamphlet, 27 pp.

WHITTINGTON, H. B. 1995. Oryctocephalid trilobites from the Cambrian of North America. *Palaeontology*, **38**, 543–562, 4 pls.

YUAN JIN-LIANG and LI YUE 1999. Lower Middle Cambrian boundary and trilobite fauna at Laoyingshan, Huainan, Anhui. *Acta Palaeontologica Sinica*, **38**, 413–430, 6 pls.

—— ZHAO YUAN-LONG, WANG ZONG-ZHE, ZHOU ZHEN and CHEN XIAO-YUAN 1997. A preliminary study on Lower-Middle Cambrian boundary and trilobite fauna at Balang, Taigjiang, Guizhou, South China. *Acta Palaeontologica Sinica*, **36**, 494–524, 6 pls. [In Chinese, English summary].

—— —— and GUO QING-JUN 1999. On the Kaili Formation. *Acta Palaeontologica Sinica*, **38** (Supplement), 15–27, 2 pls.

ZHAO YUAN-LONG, YUAN JIN-LIANG, ZHU MAO-YAN, YANG RUI-DONG, GOU QING-JUN, QIAN YI, HUANGE YOU-SHUANG and PAN YU 1999. A progress report on research on the early Middle Cambrian Kaili biota, Guizhou, PRC. *Acta Palaeontologica Sinica*, **38** (Supplement), 1–14, 4 pls.

FREDERICK A. SUNDBERG

LINDA B. MCCOLLUM

Department of Geology
Eastern Washington University
Cheney, WA 99004-2499, USA
e-mail lmccollum@mail.ewu.edu

Typescript received 5 October 2001
Revised typescript received 16 July 2002